Designing Biotopia: A Transmedia Experience for Natureculture Heritage and More-than-Human Entanglements

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Figure 1: The iterative phases of the research-through-design process of *Biotopia*. First, the exploratory phase led to diverse insights about the contexts and actors. These insight were summarized in three Design Constructs to inform the design of this experience and future HCI work. Finally these design constructs inspired and informed the design of the transmedia experience by being translated to design concepts and ideas.

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Abstract

In recent years, HCI research around post-anthropocene design has been gaining traction. Caring and inclusive stances towards more-than-humans, multispecies dialogues, and decentering the human in design are imbuing HCI and other disciplines. Similarly, critical heritage scholars have pointed to the need to re-frame

heritage in light of the challenges of the Anthropocene. As part of a heritage-focused EU-funded project, we extend these efforts, thinking through collaborative research-through-design to design "Biotopia" – a transmedia experience that aims to connect museum and nature walk visitors with entangled natureculture and more-than-human heritage. We propose three Design Constructs from our exploratory phase and detail how they have informed the design of the critical heritage experience, contributing with the transmedia experience design and proposing ways of applying emerging posthuman concepts in practice. By reflecting on our process, we discuss the opportunities and challenges of designing for more-than-human heritage in a posthuman world, working towards decentered practices in HCI.

CCS Concepts

• **Human-centered computing** → **Interaction design**; • **Interaction design** → *Theory, concepts and paradigms.*

Keywords

Critical Heritage; Natureculture; Storytelling; HCI; Posthuman; More-than-human; Research-through-design

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1 Introduction

The criteria for creating and selecting heritage have long been debated, particularly in the context of authorized heritage discourses (AHD) that reinforce Western elitist values and histories [46, 47, 78]. These processes often limit the potential scope of what heritage can represent. While natural heritage is frequently perceived as a static category, it is also socially and culturally constructed [70], making it an integral part of AHD. The interplay between culture and nature within heritage narratives is especially pertinent amidst global challenges such as climate change and biodiversity loss. We contribute to these discussions by presenting the design of a novel transmedia experience informed by proposed *design constructs* – guiding principles derived from posthuman proposals and our exploratory research that informed and shaped the development of the design ideas and prototypes.

The work presented in this paper is part of the broader context of the LoGa Culture EU project, focused on promoting accessible and ethical heritage practices by using collaborative digital tools that provide inclusive access to both tangible and intangible cultural heritage. The project addresses diverse challenges within heritage landscapes and cultural institutions by involving various technical, social, and artistic partners across three European sites. The work discussed here is part of a case study that takes a nature-inclusive approach to heritage, aiming to enhance local well-being and support sustainable development. Contextualised in the Madeira Islands, its heritage comprises natural sites with cultural aspects where nature is considered a central tenant of its cultural heritage. The assumption and challenges for this case study are twofold: i) relying on posthuman theories, nature is inseparable from culture, being both a man-defined construct that can be referred to as natureculture [34]; ii) the importance of feeling aware of and connected with nature is a key component of the local culture and should be highly valued by locals and visitors to the islands, who should be supported in preservation and conservation actions towards such heritage [27].

The prevailing heritage narratives often centre on human appreciation and value materiality over meaning [73], neglecting the entangled relationships between humans, more-than-humans, and their environments. This anthropocentric focus marginalizes alternative perspectives, particularly in regions where natural and cultural heritage are inseparable. With the Anthropocene urging critical reflection on human-nature relationships [21], it is vital to challenge established heritage frameworks and foster inclusive, diverse, and sustainable narratives. Posthuman theories, feminist posthumanism, and critical heritage studies offer frameworks to decenter humans and incorporate multispecies perspectives [13, 45]. This research aligns with these efforts by exploring how technology and design can contribute to diverse and pluriversal heritage narratives.

We respond to Braidotti's [14] call to materialize posthuman theory with a focus on "displacing anthropocentrism", also working towards consolidating "a wide array of posthumanist approaches to design and HCI under the overarching idea of the more-than-human" [41]. Combining exploratory research, stakeholder engagement, and Research-through-Design (RtD) [38, 88], this study aims to: i) develop design constructs that support nature-inclusive heritage practices, ii) create a transmedia experience that engages users with entangled cultural and natural narratives, and iii) demonstrate how posthuman theories can inform HCI practices. These aims led to the exploration of an emergent type of heritage: *more-than-human heritage*. This concept is explored through the design of a transmedia experience – a connected narrative experienced through different media, each one adding something different to the overall story [51, 52]. The experience is connected to popular natural hotspots and a natural history museum to generate digitally enriching and inspiring experiences of and in these naturally and culturally entangled landscapes. According to Sterling, the challenge lies in "how can critical thinking in the contact zone of heritage studies engage with the urgent challenges of the present in a way that is analytically insightful and socio-politically transformative" [79]. We use our design practice to detail considerations around posthuman HCI and critical heritage, contributing to ongoing discussions around these pressing design challenges and illustrating pathways of formalizing posthuman ideas into design practice.

After the positionality and reflexivity subsection, the remainder of the paper is organized as follows: Section 2 presents the theoretical background and related work; Section 3 details the exploratory research that informed the design; Section 4 describes the three design constructs and how they were used in the design of *Biotopia*; Section 5 discusses the research-through-design process, reflects on more-than-human representation and critical heritage design, and closes with future directions.

1.1 Research Context, Positionality and Reflexivity

Madeira islands are an outermost region of Europe recognized by Article 349 TFEU. These regions are special because of their remoteness, rich biodiversity and natural resources. They are also very dependent on limited economic activities, in particular tourism. This case study attempts to promote a deeper understanding of natural and cultural heritage as an integrated system and a basis for holistic management in touristic destinations that are simultaneously biodiversity preservation spots and highly dependent on tourism as an economic activity.

The areas of expertise of the authors mainly focus on communication design, HCI, architecture, neuroscience, psychology and computer science. Within the LoGa Culture project and our particular work package, our primary responsibility was to mindfully reflect with the social, cultural, and technical partners to finally design a posthuman intervention related to Madeira's heritage formalized as a transmedia experience. All project partners were actively invested in using the project tools to increase inclusion, respect, and conservation of nature, enhance multispecies dialogues, and highlight the local communities' values and stories. To this end, the project explicitly stated to nurture actions that contribute to, rather than undermine, practices of recognizing differences by giving individuals a voice to promote cultural diversity.

The authors of this publication have all lived and worked in Lisbon and/or Funchal. We saw ourselves as "HCI and design experts" and "friendly outsiders" of the local community committed to learning from and standing with the participants. We acknowledge to partially understand the larger systems in natural and cultural heritage contexts, and acknowledge the bias that our expertise and experiences bring to this research.

Posthuman theory is something designers actively create through their own research and practice in more-than-human design [57]. In such a complex context as designing in the Anthropocene with posthuman considerations, the "correct" path (if it even exists) is not a linear one. On the contrary, it can be a very controversial endeavour molded by the researchers' experiences. We have not set out to define a methodology for posthuman HCI practices for critical heritage, but illustrate the complexity of such a process and discuss the design considerations that can assist in a sustainable and inclusive path forward.

2 Background and Related Work

First, we propose an overview of the posthuman HCI theories we build on to inform our critical heritage views and the heritage approach chosen. We then focus on a branch of critical heritage – more-than-human heritage – the approach explored in the transmedia experience design. We close by analyzing related works in HCI and transmedia interventions for more-than-human heritage.

2.1 Critical Heritage and Posthuman HCI

Design researchers have been debating the role and responsibilities of design in the current Anthropocene. Interest in moving beyond human exceptionalism and human-centric design is rising, with scholars advocating for broader ethical considerations beyond humans [31, 32, 58]. Braidotti [15] argues that we are witnessing a convergence of *posthumanism*, which rejects the humanist ideal of the human as the universal measure, and *post-anthropocentrism*, which rejects species hierarchy and human exceptionalism. This shift prompts a transition from user-centered design to inclusive posthumanistic perspectives [5, 84] that need to support equality and justice for humans and nonhumans simultaneously [32]. The current *entanglement HCI* age is greatly influenced by posthuman theories such as posthumanism, feminism, and post-phenomenology applied to science and technological innovation [33]. This wave understands relations between humans, more-than-humans and objects as producing realities through their interactions [49]. Knowledge is shown to be socially constructed, and technologies become entangled in and with our bodies and lives. As Ulmer puts it, "the importance of posthumanism may not be in knowing, but in exploring how we are entangled with other organisms around us" [83]. This call greatly inspired us to explore our (humans') entanglements with the diverse environments and actors around us and how these relations influence our view of heritage.

These approaches advocate for a broadening of design participation to include more-than-human interactions [1] to ground design in more-than-human perspectives [41], fostering wider understanding and collaboration [6, 22]. Diverse theoretical views and applied experimentation have been developed recently, attempting to redefine what design could and should be in the post-Anthropocene. Wakkary has proposed 'designing-with' as an approach where humans share the stage with nonhumans and are "materially, ethically, and existentially" connected [84]. Fuchsberger and Frauenberger [35] propose that 'doing responsibilities' should be carried out within hybrid assemblages of both humans and nonhumans, grounded in fluid relationships. Concepts such as co-performance and co-creation with more-than humans [55, 69], entanglements [33], fluid assemblages [74], or methods like noticing with more-than-humans [9, 60, 71], sketching in nature [29], material speculations [10, 65, 85], or photographic observations [11], have been proposed and explored to assist in orienting HCI posthumanistic way forward. These strategies help the researcher to think "differently and re-envisioning research" in the "uncertain messiness of knowledge production as an ongoing opportunity in a politics of hope, creativity, and imagination" [83]. We have applied several of these methods in our explorations into posthumanistic heritage design to broaden our perspectives.

In line with these posthuman approaches in HCI, modern approaches to heritage have begun to include diverse voices and perspectives in their discourse, favouring a polyvocal, critical, and future-oriented view of heritage [42, 44]. Posthumanism in heritage studies challenges the idea that humans are the sole producers of knowledge, instead acknowledging the potential for other beings, objects and phenomena [83]. Critical heritage has emerged as a sub-field in heritage studies that asks "uncomfortable questions of traditional ways of thinking about and doing heritage" [19] working towards democratisation, decolonisation, inclusion of marginalised perspectives, and a shift towards non-human centered approaches. Critical heritage sees heritage as a political, cultural, and social *phenomenon* [40] that should consider dynamics such as

power, identity or conflicts; a *phenomenon* that crosses human and non-human worlds [34].

Posthumanism and critical heritage call for "thinking and doing heritage otherwise", through an "alliance of critical heritage praxis and critical posthumanist thinking" [79] as possible pathways for an expansion of the field. The various 'components' that form *heritage*, including museology, tourism, site management, or interpretation, should be addressed with a critical lens. Traditional museology often perpetuates colonial and exclusionary narratives, demanding that current heritage practices become more inclusive, reflective, and reparative by engaging communities and revising narratives. Museums, in particular, can be places of dialogue and transformation [80]. Through this work, we resonate with previous research [46, 68, 79] by expanding on traditional views of heritage to include more critical posthuman views explored through posthuman HCI. In particular, we focused on exploring ways of diversifying heritage voices and perspectives, going beyond the normative authorized heritage discourses (AHD) [46, 78]. Critical-creative heritage practice can assist in tackling important societal challenges, such as climate change, the loss of biodiversity, and environmental justice [79], and HCI can propel these endeavours. These complex issues are formed by multiple and situated entanglements of humans, more-than-humans and their different temporalities, and critical heritage can harness the liveliness of the posthuman debate to engage with these complex topics. Considering these aspects, we decided to explore *more-than-human heritage* that articulates the diversity, relationality, and pluriversality of posthuman critical heritage. Moving away from the limited view of the 'privileged human' [13], with research-through-design we work towards post-anthropocentric and decentered perspectives of heritage [79] that thrive to include non-human voices and their role in heritage conceptualization and creation.

2.2 Heritage as Interconnectivity: More-than-human Heritage

Heritage has recently started embracing the "nonhuman turn" [43]. The promotion of human dominance over nature and ignoring multi-species interdependencies has been critiqued by Tsing [82], aligning with Haraway's [45] view that this mindset is conceited and shortsighted. Such perspectives risk undervaluing sustainable inter-species relationships by excluding many actors. It is important to consider human perception of heritage, but allowing this 'cultural filter' to appropriate all notions of 'nature' furthers human-centered and purely human-meaning-making perspectives [34]. Braidotti [13] suggests viewing subject positions as figurations rather than identities, seeing humans as 'more-than-humans', embedded in complex natureculture relationships. This posthuman shift is propelled by posthuman feminism's responses to contemporary narrow anthropocentric views [16]. Naturecultures need to be acknowledged as crucial in heritage practices.

The complex interconnections between human and non-human beings, the realities outside our human perception, and self-knowledge of our responsibilities are crucial aspects to consider [63]. The idea of 'intercorporeality', attempting to become 'more than ourselves' through, for example, deep observation of natural processes, is one example of working towards broadening our perception and relations to *others* [48]. Human experience is inseparable from our local ecologies [83], and our way of perceiving and representing nonhuman perspectives is always relational and situated, demanding a critical assessment of one's biases [41]. More-than-human contributions need to be considered in heritage creation as they change the way landscapes are 'created'. Furthermore, "heritage sites and monuments can be understood as assemblages that gather the world around them in situated ways" [34], representing important contexts of use that help shape ideals that could inspire alternative sustainable practices. Importantly, these heritage experiences can work purposefully to restore positive and hopeful visions in diverse multi-species communities. Haraway [44], for instance, proposes a focus on care between different species over time as an alternative to catastrophe-focused histories. These strategies that consider more-than-human agencies work towards inspiring de-colonizing practices through heritage [34].

Nicenboim et al. ask "what is decentered and what is instead accounted for" when designing for *decentering* in HCI [66]. In the case of this research, we work towards more-than-human heritage by recognising and deeply considering the complex systems we humans inhabit, interacting with non-human entities such as technology, animals and the environment [41]. In critically engaging with the different contexts that form the experience's entangled environment, we strive to decenter the human-focused and user-focused directions in the design process. These considerations challenged us to move away from human exceptionalism by confronting different scales to the natural heritage context and the entanglements of these complex environments, aiming to bring an alternative and more inclusive narrative to the museology we were intervening in. Throughout the design process, we aimed to explore new ways of bringing more-than-human voices and narratives to the heritage experience.

2.3 Transmedia and HCI for More-than-human Heritage

The growing disconnection between humans and nature has been mentioned as one contributor to the environmental crisis [67, 89]. Therefore, exploring ways of enhancing this connection is of crucial importance.

2.3.1 HCI for More-than-human Heritage.

A critical shift in Human-Computer Interaction (HCI) involves reconceptualising participation to include more-than-human stakeholders [31, 32]. In this direction, various strategies have emerged that challenge anthropocentric design paradigms. For instance, frameworks such as phenology probes [75] and Natureculture probes [8, 36] explore human-nature relationships through sensory and temporal mappings, advancing sustainable and participatory design practices. Similarly, the Umwelt-sketch methodology seeks to decenter the human by visualising overlapping "Umwelts" of non-human actors, thereby fostering more inclusive design interventions [24]. These approaches align with broader calls for ethical participatory practices that integrate plants, animals, and spirits into the design process [1].

Digital tools further extend these participatory efforts by leveraging mobile and place-based learning to uncover the relational affordances of nature, cultivating curiosity and deeper connection

[4, 77]. Immersive technologies such as Tree Box promote mindfulness in natural settings through embodied interaction [61], while augmented and virtual reality applications expand the possibilities for environmental learning and engagement [18, 64].

Interactive storytelling also plays a significant role in fostering more-than-human connections. Workshops and artefacts, such as *Finding Arcadia*, use narrative and positive framing to facilitate emotional engagement with complex climate data, encouraging empathy between humans and more-than-human entities [30]. Similarly, initiatives like Hackeanos embrace co-creative and speculative design to cultivate relationality with the ocean as a dynamic and interconnected being [25].

Integrating more-than-human perspectives into education, however, presents distinct challenges. For example, designing digital experiences in natural history museums that resonate with teenagers requires an understanding of personality traits and behavioural dynamics [20]. Concurrently, workshops such as *Digital Technologies in Nature* surface ethical tensions and design complexities when deploying technology in ecological contexts, advocating for the inclusion of local communities and non-human stakeholders alike [87].

Artistic practices offer yet another dimension for exploring these interactions. The use of point cloud datasets in art reveals the expressive potential of remote sensing to engage with theories of new materialism and entanglement [50]. Projects like *EdenX* exemplify the blending of artistic and technological approaches to articulate more-than-human dialogues that address both environmental and social justice concerns [72].

2.3.2 *Transmedia for More-than-human Heritage.*

Expanding on the possibilities of exploring different media and contexts, transmedia storytelling bridges cultural and natural heritage through narrative and interaction. As proposed by Jenkins [52], each individual intervention, exploring different media, is a possible entry-point to the journey and should contribute with a different facet of the overall narrative. This structure allows for the engagement of users with different interests and media literacies, and the exploration of various aspects of the narrative without over-complexifying each one. Especially for projects using digital technologies for diverse audiences (e.g. for schools, museums and other public spaces), there is great potential for using a mix of different media for inclusive experiences. However, within HCI research venues – namely the ACM Digital Library, IEEE, Springer LNCS, Convergence Journal, and DIGRA, from 2000 to 2024 – we found very few results related to transmedia for natural heritage that actually explore more than one medium.

The potential of geostorytelling in transmedia has been explored [12] by using mobile devices and georeferenced multimedia content to create emotional and participatory narratives that enhance the experience of small heritage sites, promoting slow and conscious tourism. The 3D-Pitoti project uses technologies like augmented reality, 3D cinema, and virtual exhibitions to showcase Valcamonica rock engravings, transforming scientific data into engaging, interactive cultural experiences for the public [53]. *Bear 71* explores the intersection of the human and animal worlds through a multimedia web documentary that maps wildlife encounters [62]. *Fragments of Laura* integrates mobile virtual reality and location-aware storytelling to uncover challenges and opportunities for immersive public experiences [26]. Mixed-reality projects like *Bitter and Sweet* explore postcolonial narratives of slavery, employing digital sketching to reveal hidden layers of cultural heritage [28].

Work on technology for nature engagement should integrate direct and indirect nature experiences, respect cultural diversity, and foster environmental identity [86]. Despite the growing body of work exploring more-than-human heritage in HCI, existing studies often focus on specific applications or theoretical frameworks. This paper proposes an underutilized transmedia experience as an actionable strategy for bridging posthuman heritage theory with design practice derived from a detailed, exploratory design process. Our aim is to propose and illustrate novel approaches to applying posthuman principles in critical heritage experience design that represent and consider more-than-human entities and systems.

3 Exploratory Phase: Understanding the Context and Actors

In this section, we outline the different phases of the design process, leading to our proposal for designing a more-than-human focused transmedia experience detailed in section 4. The design of *Biotopia* is a culmination of multiple steps meant to better understand different components of the project and how they could inform the design of a decentered natureculture experience. Arguably, "posthuman research is as much about what knowledge is as it is how knowledge comes to be" [83], and so we contribute to these explorations and debate by carefully presenting and reflecting on each phase of the work and how they informed the proposed design constructs.

3.1 Initial Field Research: Probing More-than-human Considerations

The first phase of the LoGa Culture project focused on *exploring* different facets of the implementation context and theoretical frameworks (Fig. 2). We started by engaging with visitors of the sites through self-reports [37] and creative probes [8] designed specifically for these natureculture contexts. The probes were developed as research tools to gather in-depth, subjective data about participants' sensory and emotional experiences while visiting the sites. Drawing on feminist posthuman approaches, these tools captured natural heritage's relational and more-than-human aspects, emphasizing a multi-sensory and embodied engagement [36].

This research identified four main design directions to address the challenge of balancing over-tourism with conservation efforts at natural heritage sites [36]. These directions are: 1) Cultivating Empathetic Connections and Holistic Education, which aims to deepen visitors' understanding of nature through immersive, multisensory experiences; 2) Encouraging Collective Stewardship and Community Resilience, fostering community-driven conservation efforts by promoting collaborative caretaking and shared stewardship through gamified experiences and participatory projects; 3) Reflecting and Respecting Diverse Narratives and Agencies, highlighting the diverse cultural and ecological narratives of the region; and 4) Fostering Inclusivity and Adaptability in Interconnected

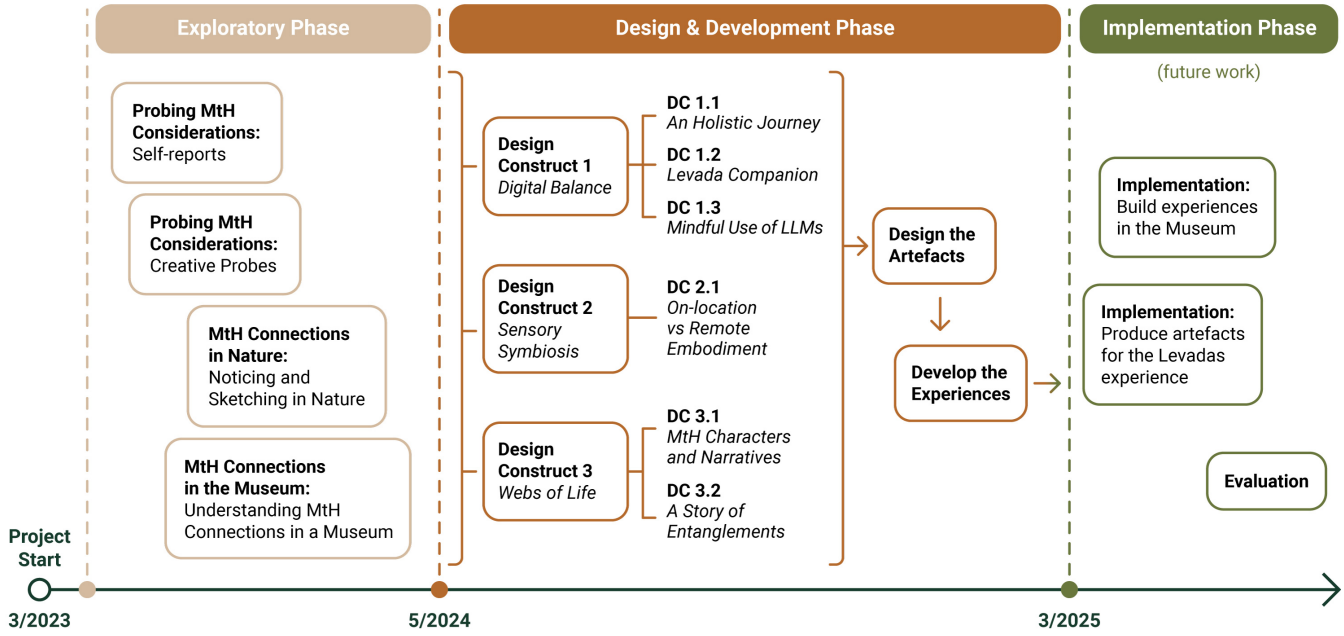

Figure 2: Overview of the project's phases and outputs of each phase: *Exploratory Phase:* four moments of exploration to better understand the context and actors involved; *Design and Development Phase:* Three Design Constructs (DC) were derived from the exploratory phase to inform future work. These were interpreted through six design ideas for *Biotopia*; and the *Implementation Phase:* with three stages of future work.

Ecosystems, emphasizing resilient, adaptable designs that accommodate diverse visitor needs and dynamic environmental conditions.

The data collected from these tools offered a nuanced understanding of visitors' experiences and the challenges in designing for these sites.

3.2 Exploratory Field Research: Fostering More-than-human Connections in Nature and in a Museum Space

The results from the initial field research inspired further explorations, now more focused on design considerations – first, for the researchers to explore their connection with the natural environment in a more immersive manner; second, to better understand the needs and challenges of the museum implementation context.

3.2.1 Exploratory Noticing and Sketching in Nature.

We felt it was crucial for us as individuals and researchers to better understand the different actors and their relationships in a closer and embodied way. Emphasizing the value of situated practices in nature-related technology design [2, 3], we used noticing and sketching in nature as an embodied exploratory practice [11, 29, 56, 76, 81] that would help us see beyond our usual experiences of the Madeira's natural environment and hopefully guide a more decentered design approach [59, 60] with a deeper consideration for more-than-human entanglements. With this purpose, two authors (R1 and R2) performed two nature walks in Madeira's Levadas – water canals first built in the 15th century to take fresh water from rainy parts of the island to others, now used as nature walk paths.

During the walks, two researchers (the first and second authors – R1 and R2 respectively) collected field notes and sketches performed on-location to notice human/nonhuman tensions, their feelings in different moments of the journey, and their connection or disconnection to more-than-humans. These methods were chosen for their ease and versatility – R1 is a designer and has an affinity for sketching, while R2, a neuroscientist, prefers the written word. Still, both researchers engaged with this mixed-method approach so that each could adapt and explore it freely while following the same methodology.

By analysing their sketches and reflections, R1 noticed a preference for solitude and quiet and an appreciation for simple, introspective moments. These reflective moments allowed R1 to engage with the natural surroundings fully and facilitated an embodied understanding of the space. R2, despite finding sketching challenging, observed that drawing the Levadas made him more aware of the spatial relationships and specific elements within the landscape. R2's suggestion to promote mindfulness and awareness without overwhelming the senses aligns with R1's reflections. Both highlighted the impact of tourism on the natural setting, acknowledging its role in transforming the Levadas from serene nature escapes to busy, human-modified spaces.

Both researchers emphasized various more-than-human elements that contributed to their experiences. R1 noted interactions with birds, lizards, water, and flora, emphasizing how the presence of living organisms shaped her sense of connection to the

Levadas. For R2, elements like moss, rocks, and water canals were vital, indicating a blend of natural and man-made features that felt alive and integral to the experience. These observations suggest that more-than-human entities play a crucial role in shaping how people perceive and interact with the Levadas, highlighting the interconnectedness between human and non-human elements.

3.2.2 Understanding More-than-human Connections in a Museum Space.

Another important layer to informing the design was to understand visitors' experience in the museum related to the representation of more-than-humans and how to improve and foster these connections. We also interviewed four experts from two natural history museums. By understanding the needs and expectations of museum visitors, alongside the museum's internal objectives, we aim to identify opportunities to integrate more-than-human considerations into the museum's design and interactions.

Museum Visitors

The purpose of the interviews conducted at the Funchal Natural History Museum was to gain insights into visitors' expectations, experiences, and suggestions for enhancing the museum's representation of the natural heritage of Madeira. One researcher (the fifth author) casually approached visitors at the museum entrance and asked them to reply to an anonymous questionnaire composed of three demographic questions and seven open questions (Annex 1.1). We engaged 19 participants: 13 females and 6 males, ranging in age from 16 to 69 years old, and an educational background that varied from basic education (n=4, up to High School level n=4) to those holding advanced degrees (n=9, Bachelor to PhD n=2). The respondents were predominantly tourists (n=16), with only a few residents of Madeira Island (n=3). This demographic information suggests that the museum attracts a wide range of visitors, both in age and educational background, most of whom are not residents. However, the walk-in affluence is low, with the museum relying on organised visits, mainly from schools.

Responses were thematically analysed [17] and discussed among the authors. Several visitors mentioned a desire for more detailed information about the species on display, including aspects like their habitat, diet, and conservation status, as well as suggestions for integrating modern technologies, such as interactive exhibits and multimedia presentations, to create a more engaging experience. Many visitors expressed satisfaction with the museum's current offerings, particularly the audio elements in the forest-themed room (the only audio element in the main exhibition space). However, they also highlighted the need for expanded content, such as additional species and interactive elements that could appeal to younger audiences. The interviews reveal a strong interest in interactive and immersive technologies, particularly related to the museum's representation of Madeira's biodiversity. There was a consensus on the value of these experiences, such as moving models or digital projections, and providing guided tours or audio guides to offer deeper insights into the exhibits.

Cultural Partners

In addition to gathering visitors' perspectives, we interviewed four experts from two natural history museums (Project Cultural Partners) – from Portugal (CP1, CP2) and Germany (CP3, CP4). The questionnaire was composed of six open questions (Annex 1.2) and results were also thematically analysed and discussed among the authors. We aimed to gain insights into the institution's role in preserving and communicating more-than-human heritage. Their insights are particularly valuable as they provide a professional perspective on the museums' mission, challenges and potential areas for improvement.

CP1 emphasized the institution's core mission to document and disseminate knowledge about Madeira's natural heritage through its extensive scientific collections. They advocated using modern technologies to enhance visitor engagement and suggested expanding educational resources to foster a deeper connection between visitors and the exhibits. CP2 also highlighted the museum's role in local education, stressing its long-standing integration into school curricula. They identified areas for improvement, including the need for more immersive and interactive displays, particularly for underrepresented species like plants and terrestrial invertebrates. To bridge this gap, CP2 recommended leveraging digital tools to provide more engaging and informative experiences for a diverse audience.

CP3 focused on the institution's role in preserving and interpreting natural heritage through its vast collection of specimens. They emphasized the museum's efforts to balance regional and international biodiversity representation while highlighting the importance of emotional storytelling and contextual information to enhance visitor engagement. CP3's insights suggested that museums could improve visitor experiences by incorporating narratives that provide historical and cultural context to the exhibits, thus fostering a deeper connection between visitors and nature. CP4 highlighted the value of digital interactive options, such as augmented reality (AR) and small games, to engage younger visitors and enhance interaction with exhibits. They suggest incorporating questions in media guides and worksheets to promote visitor reflection and engagement. Additionally, CP4 emphasized the importance of personalized guided tours and the use of AR to improve accessibility, particularly for younger visitors and those with visual impairments. Incorporating touch and other sensory experiences like smell and hearing would create a multi-sensory, immersive experience.

Connecting these perspectives, it becomes evident that while museums have strong foundations in education and conservation, and are appreciated for their collections and thematic focus, they could benefit from incorporating more interactive and emotionally engaging elements. By using technology-driven strategies and compelling narratives, museums can enhance their educational impact, promote environmental awareness, and create more dynamic presentations of natural heritage.

4 *Biotopia*: Designing a More-than-Human Transmedia Experience

Biotopia, a transmedia experience which strives to connect visitors with more-than-human perspectives, was inspired by a vision of thriving coexistence between humans and the more-than-human

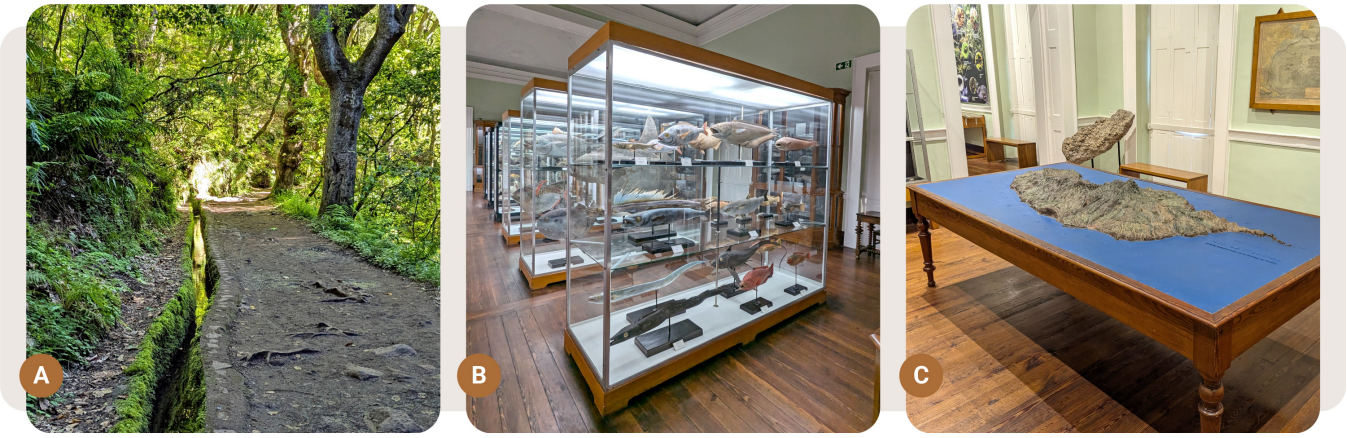

Figure 3: The implementation contexts of the transmedia experience *Biotopia*: A) Madeira's *Levadas* (nature walks along the water canals); B) Museum's permanent exhibition space; C) Museum's Map room adjacent to the room installation.

world. This multi-context and transmedia experience proposes connecting with and representing various local nonhuman actors and their complex interconnections, fostering links between different locations and their natural heritage. This work illustrates ways of "thinking and doing heritage otherwise" [79].

Research-through-design naturally allows for learning and creating theory through continuous exploration. In line with the idea of *emergence* in design practice, what we learned from each stage led to a better understanding of the context in which we were operating (*design in settings*) and adaptation to *technical affordances* [39]. We also "drifted by intention" [54] as some design explorations demanded a shift of initial ideas to reply to the needs of the contexts or audiences.

Through this process, we "illuminate the evolving nature of designing within the more-than-human paradigm" [41], and work towards effective engagement with natureculture and non-human others through HCI. To accomplish this, we translated the various theoretical frameworks and results from the exploratory phases into three inspirational Design Constructs to inform future work: DC1) *Digital Balance*; DC2) *Sensory Symbiosis*; DC3) *Webs of Life*.

We performed four brainstorming workshops with the research team to ideate how to transform these constructs into practice—two sessions for the transmedia journey and two sessions focused on ideating the storytelling component. The first author (R1) further developed the ideas between each session. We also shared the ideas with the museum partners at various stages of development to get their feedback and approval.

We illustrate how these Design Constructs can inspire and inform future natureculture work by interpreting them in the design of *Biotopia*. After each of the three design constructs we illustrate how we applied them in our designs: DC1.1) *An Holistic Journey*; DC1.2)*The Levada Companion*; DC1.3) *Mindful Use of LLMs*; DC2.1) *On-location vs Remote Embodiment*; DC3.1) *MtH Characters and Narratives*; and DC3.2) *A Story of Entanglements*. We envision that this process will contribute to their application by other HCI researchers.

4.1 Design Construct 1 – *Digital Balance*: Mindful Integration of Technology in Reflective Visitor Journeys

Inspired by the probes and self-reports, our own noticing activities, and previous research (e.g. [33, 86]), this design construct proposes highlighting the mindful use of technology – essential when implementing digital experiences in natural contexts.

When working in natural settings, one should prioritize non-intrusive technologies that harmonize with and respect the surrounding environment. The design needs to iteratively adapt sustainability practices to ensure that technology integration is context-specific and environmentally mindful.

Furthermore, previous work on transmedia [26] indicates the need to explore structured, meaningful journeys that include different moments, balancing action, and reflection. Each moment adds meaning to the overall experience and can cater to different media literacies and knowledge levels, ensuring accessibility for various abilities and backgrounds. Carefully considering the experience journey can include more or less attention-demanding technologies depending on the moment's communication needs and the context's considerations.

The overarching aim of this design construct is to respect visitors' need for stillness, contemplation, and reflection, especially in natural settings, by minimizing distractions and ensuring technology enhances rather than detracts from the immersive experience of each context. At the same time, a well-conceptualised user journey with different interaction moments can still reply to the project's information and interaction needs without detracting from the environment. It also avoids fragmented or overwhelming visitor experiences by balancing actively engaging moments with spaces for personal observation and meaning-making.

4.1.1 *Digital Balance in Biotopia (DC1.1):* ***An Holistic Journey***.

Considering the possibility of exploring multiple implementation locations with very different characteristics and demands, we decided to create a transmedia experience with a well-defined, albeit flexible, journey composed of several moments – each bringing a

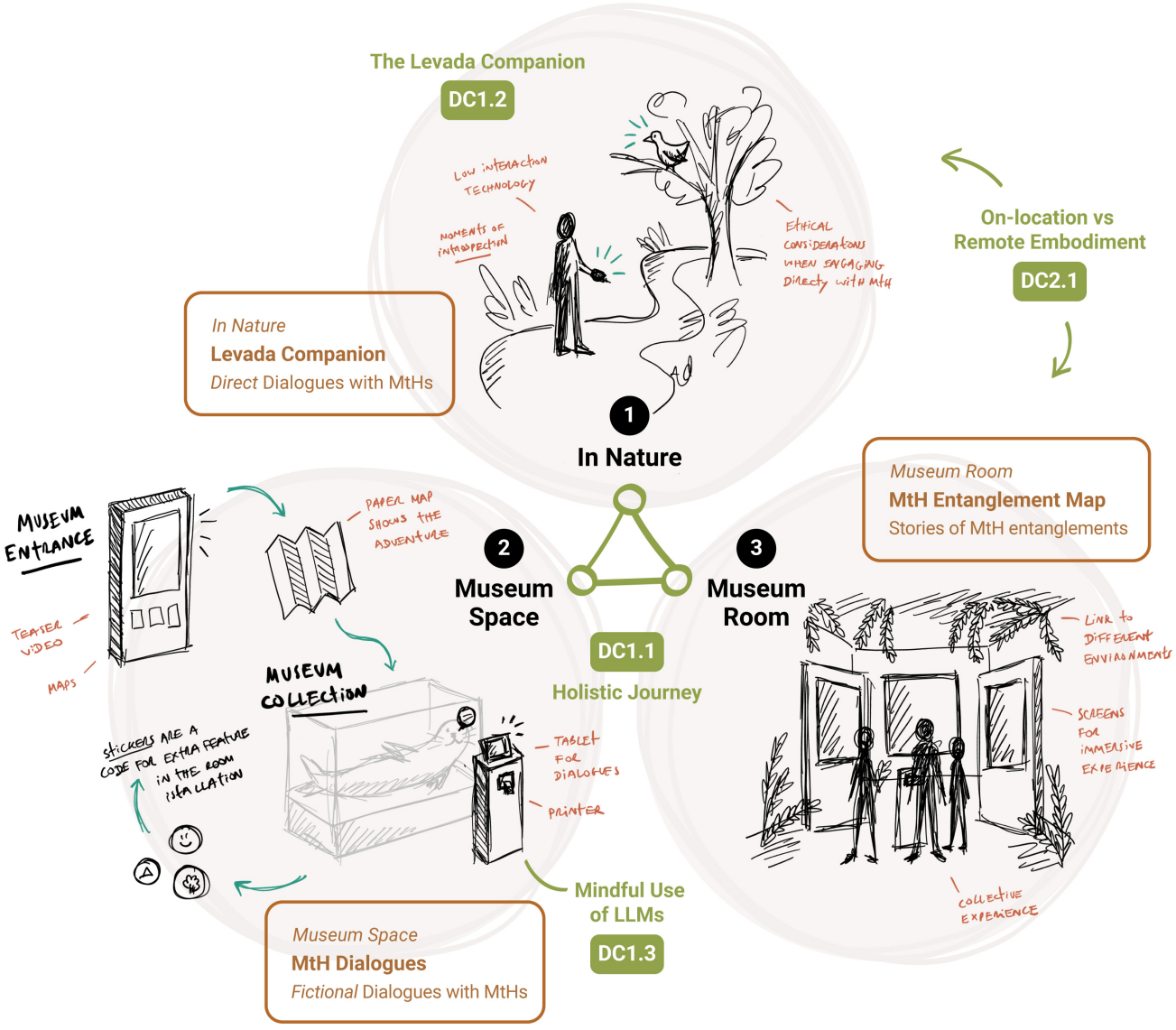

Figure 4: *Biotopia* trasmedia journey design: The three contexts of implementation of the transmedia experience: 1) In Nature (Levadas), 2) Museum Space (the permanent exhibition), and 3) Museum Room (a room exclusively dedicated to the interactive experience). Each of the three moments are accompanied by some of the conceptual aspects considered while designing the experience and, in green, the Design Constructs (DC) applied.

different layer of meaning to the experience.The overarching narrative becomes more complete and engaging with each moment. The various artefacts can be experienced independently and in any order, allowing for a flexible transition between sites. The very different nature of each context and the physical distance between the museum and the Levadas help avoid possible dissonance when transitioning between the various experiences.

The transmedia experience is, therefore, divided into three artefacts (Fig. 4). The first is the *Levada Companion* [42] that focuses on "experiencing" – engagement with the MtHs through an embodied and sensorial interaction. *In nature*, we propose a technological solution that requires little interaction with the device. This mode of interaction was devised to not detract from nature. The experience facilitates a "direct dialogue" with more-than-humans in a subtle, non-intrusive manner (details in 4.1.2). On the other hand, with the second artefact in the *museum space* – the *MtH Dialogues* – we propose an alternative approach to dialoguing with the MtHs. Using a large-language model (LLM), we facilitate "fictional dialogues" with four of the collections' more-than-human entities. Inspired by Benford et al.'s [7] work that proposed an emotional journey through a museum's collection to add layers of emotional content to the

exhibits and a physical postcard for further reflection, we invite visitors to take a map that guides them through the museum collection to learn about the MtHs and collect tokens to open an extra feature in the room installation. The visitors impersonate characters depending on the adventure they choose (e.g. an explorer, an animal, a time-traveller). We saw the museum exhibition as a context that permitted the exploration of more attention-demanding technology solutions with a more ludic experience with the species when compared to the natural environment. These interactive solutions also add new layers of experience and meaning to the traditional exhibition format of the taxidermy animals (Fig. 3-B) characterized by high scientific value but low engagement for visitors. This artefact is focused on "learning" – enhancing visitors' knowledge and ecological literacy through MtH empathy. Finally, the third artefact – the *MtH Entanglement Map* – aims to "change perspectives" by decentering the heritage narrative and show the complexity of MtH entanglements. For the *museum room*, we designed a multisensory experience with screens, a controlling console, and decoration that represents different natural environments through light and sound. This artefact revolves around two interactive entanglement stories (4.3.2) with the MtHs as protagonists (4.3.1). The story is explored through multiple moments of interactive exploration that dive into the entity's perspectives and connections. We strive to incentivize reflection through playful interactions.

Each implementation space affords different ethical considerations and modes of technological exploration in or about nature, guiding very different forms of representing and connecting with MtHs – some more experiential, some more informative, and all working together as a cohesive experience.

4.1.2 Digital Balance in Biotopia (DC1.2): ***The Levada Companion****.*

To respect visitors' contemplative experiences in nature, we decided to use minimal and non-intrusive technological solutions in this implementation context. Interestingly, this decision contradicts our initial ideas, as we hypothesized implementing more complex games and mechanics during the nature walks. Still, we revised this approach based on the exploratory research results. In the case of the *Levadas*, people tend to want to be immersed in nature. They are not keen to have more digital "interference". Therefore, building on R7's previous experiments, we propose a device that allows visitors to the natural site to "dialogue" with some species in a less intrusive manner.

The Levada companion is a compact arm wearable designed to minimise its impact on visitors' walks and their experience of nature. Its waterproof materials, discreet green colour, and simplicity of use, with only two buttons, ensure wearability in any weather and environment. The device's design moves away from traditional technological cues (such as screens and vibrations), fully immersing the wearer in the Levadas' environment. Connected through GPS to a static database of species geolocation based on scientists' and volunteers' observations, the device will leverage diverse sensory stimuli (touch and vision) to let the wearer know they've entered another being's area or 'contact zone'. Tactile stimuli are tailored to each species to deepen the visitors' connection with that specific animal. Once in a contact zone, a speaker activates, allowing the wearer to play the species call by pressing a button to engage in multispecies dialogues. The device's emphasis on sensory-rich multispecies interactions (through sound, touch, and vision) allows visitors to experience nature from different perspectives, fostering a deeper connection with a specific ecosystem. The mechanics of this interaction can foster stillness and reflection by inviting users to observe more closely.

4.1.3 Digital Balance in Biotopia (DC1.3): ***Mindful Use of LLMs****.*

In recent years, LLMs have developed as a crucial AI technology supporting intelligent chatbots in various application settings. However, integrating LLMs introduces unpredictability and uncontrollability into current dialogue-based interactions. The generated content from LLMs includes aspects like outdated recommendations, which are limited by the static training dataset, knowledge from non-authoritative sources, and information that could be inaccurate and fabricated. These points become unacceptable in rigorous scientific and educational contexts, such as Natural History Museums—our implementation context.

With this in mind, we designed our dialogue system leveraging RAG (Retrieval-Augmented Generation). This technique does not require costly resources to retrain the LLMs, achieving preferential information retrieval from authoritative sources of knowledge prepared by the researchers. Together with the LLMs' paraphrasing ability, our dialogue system realized the goal of giving users playful feedback, digestible (e.g., by rephrasing a dry scientific presentation colloquial) and, most importantly, rigorously traceable. Furthermore, we believe this greater transparency in the source of generated information will improve the public's trustworthiness of AI-based dialogue systems (Fig. 6–2). We also used an open-source LLM running locally to reduce the technology's environmental impact.

4.2 Design Construct 2 – *Sensory Symbiosis*: Multisensory and Embodied Storytelling

From the feedback of nature and museum visitors and previous work on more-than-human HCI [49, 83], we point to the potential of developing immersive, multisensory experiences that engage visitors emotionally and empathetically with more-than-human heritage. These experiences can explore embodied approaches, such as interactive sensory elements, to deepen understanding of ecological systems. When applied to museum spaces, this construct also addresses the cultural partners' need for interactive, engaging and informative experiences.

Designers should strive to meaningfully use the media choices to represent more-than-human perspectives – for example, through participatory and sensory methods that allow visitors to "step into the world" of more-than-human entities (e.g., feeling temperature changes, hearing species' sounds, or experiencing simulated interdependencies). Ultimately, these strategies strive to overcome emotional disconnection between visitors and natural heritage by fostering embodied, multisensory interactions based on compelling narratives. These lead to inclusive and innovative engagement methods that invite diverse visitor participation. Immersive storytelling can make more-than-human entities tangible and relatable,

enabling visitors to empathize with them and enhance their understanding of ecological relationships.

4.2.1 *Sensory Symbiosis in Biotopia (DC2.1):* ***On-location vs Remote Embodiment***.

We explored two embodied approaches: on-location, in the Levadas, and remote, in the museum room. Being physically in nature differs from being in a room inspired by nature. Adapted to the implementation contexts, we developed different strategies to enhance the sense of embodiment and bring about alternative forms of MtH connection.

The Levada companion highlights the embodied experience of being in nature by aligning the visitor's presence with that of a MtH. By pointing to this possible proximity and facilitating the means for connection, the artefact opens up the opportunity for pause and reflection, making the human closer and more conscious of their environment. It uses the already immersive natural surroundings to add a layer of experiential meaning.

In the museum room, we wanted to link to the embodied experience of being in nature to enhance the engagement with the interactive story. We did this by designing a space inspired by natural environments (ocean and forest) that is visually very different from the remaining museum and gives a sense of entering a different world (Fig. 6). The intention was not to "replace" natural encounters inside the room walls, as warned by [87], but to use a sensorial and tangible experience to bring out a sense of wonder that would give meaning to the more-than-human heritage information being shown. The immersive environment is composed of nature sounds, digital visuals, and exhibition design inspired by plants and algae that change their look through different coloured lights – e.g. blue for ocean ecosystems, green for forests, red for volcanic environments.

4.3 Design Construct 3 – *Webs of Life*: Ecological Interconnectedness and More-Than-Human Narratives

Inspired by HCI previous work that advocates for inclusive approaches (e.g. [55, 66]), and our exploratory research in nature, this design construct focuses on developing empathic more-than-human narratives by drawing attention to the relationships and interdependencies within ecosystems, such as the connection between water, flora, humans and fauna. These proposals encourage collective stewardship by involving visitors in diverse and inclusive narratives – a need derived from the probes and self-reports.

Encouraging people to feel connected to natural systems – a part of them but also responsible for them – can be accomplished through participatory narratives and gamified interactions that promote empathy for more-than-human entities and highlight the entanglements between humans and the environment, inviting visitors to explore and question relationships. Expanding on this argument, the aim is to work towards eliminating these divisions (natureculture) and guiding visitors to see themselves as part of nature.

Design directions should work towards encouraging visitors to engage with inclusive narratives through subtle cues and open-ended exploration, allowing for personal meaning-making while respecting the dynamic character and complexity of nature. These explorations expand the scope of AHD by deeply considering and representing more-than-human narratives in traditional heritage experiences. It also explores the need to engage non-expert audiences with scientific topics through storytelling [23]. This design construct addresses the museum partners' needs for alternative, more engaging and detailed stories about species and ecosystems, fostering collective engagement by putting the audience as a part of a complex and interdependent ecosystem.

4.3.1 *Webs of Life in Biotopia (DC3.1):* ***MtH Characters and Narratives***.

Informed by the museum's collection, we selected five MtH entities representing different aspects of Madeira's natural heritage and allowing for exploring human/more-than-human entanglements (Fig. 5).

We started by selecting two "emblematic" species of the island: the Mediterranean monk seal and the Zino's petrel. The first inhabits a coastal marine ecosystem. The second is a seabird that lives in the central mountainous areas of the island and travels to the open sea (high mountain and deep-sea ecosystems). To complement these species, we selected two others that inhabit mid-altitude forest ecosystems and are typically regarded as "less popular". The Trocaz pigeon is endemic to Madeira and lives in the laurel forests. Interestingly, it is not well-loved by some humans as it sometimes feeds off farmers' crops, but it is fundamental for its ecosystem as it disperses the seeds of the laurel forest trees. On the other hand, the Iberian green frog was introduced to Madeira by humans, bringing up the question of human interference in natural habitats. This, allied with inhabiting the human-made water canals, illustrates the complexities of natureculture. Both these species brought interesting tensions to the more-than-human heritage discourse. Finally, as a non-living entity, the volcanic rock introduced a distinct nuance to the experience. For example, we saw exciting temporal opportunities, allowing to link visitors with the concept of deeptime and make them question their place in these more-than-human temporalities.

We explore two very different approaches to representing the MtHs in the transmedia experience (Fig. 5-3). In the *Levada Companion*, there is no character development and the interaction with a wild animal in their own language and habitat are the main aspects of the interaction. In contrast, in the museum artefacts, we create anthropomorphic characters to make use of narrative conventions and structures to convey specific information but also draw on empathy and narrative transportation – the feeling of being completely immersed in the world of a narrative. The biological and behavioural characteristics of each entity are used to inform the traits of their fictional characters. This selection of MtHs brought diversity and versatility to the transmedia narrative, making the information flow entertaining but based on accurate scientific information. Furthermore, the different MtH representations afforded by the transmedia experience allow us to explore contrasting strategies.

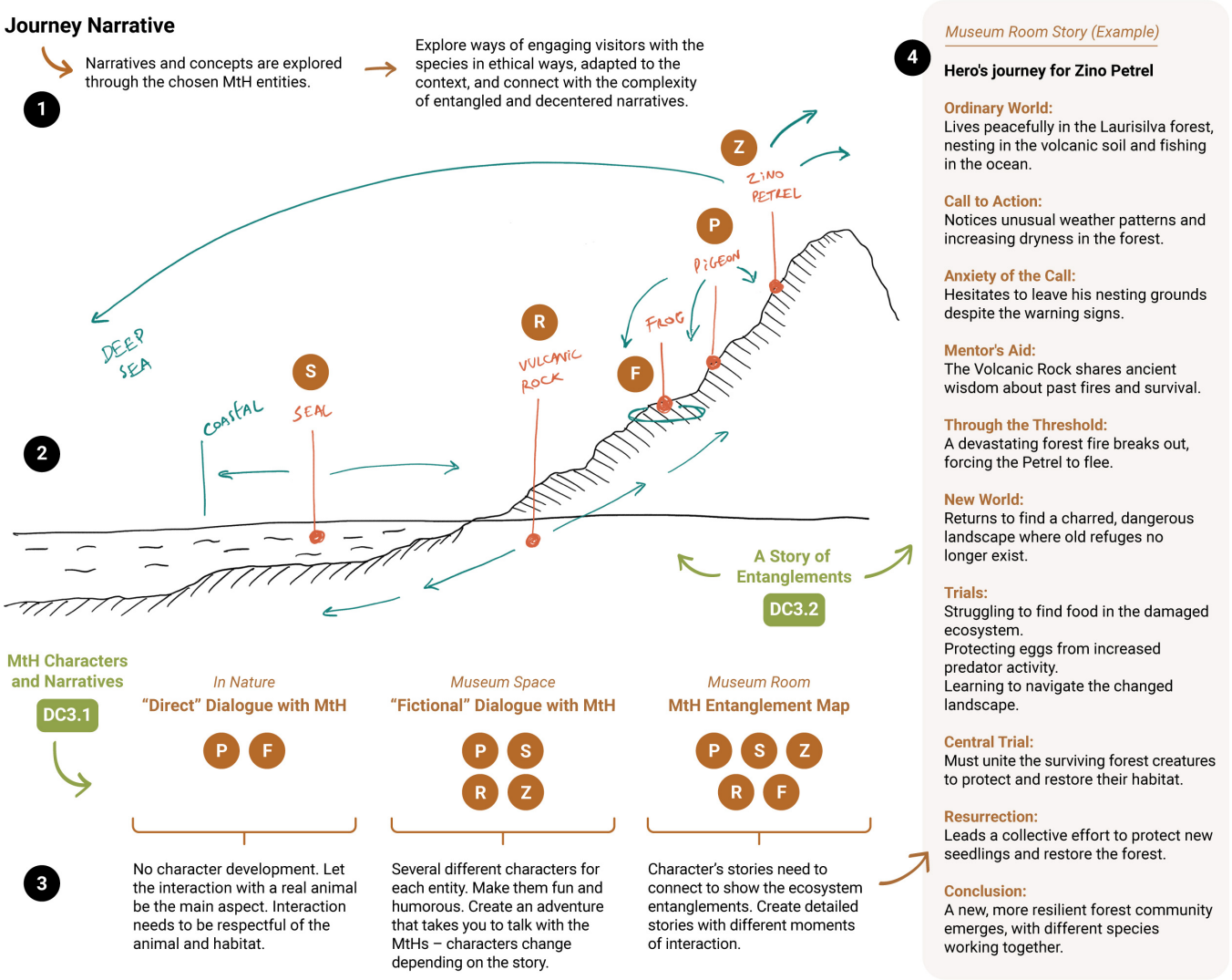

Figure 5: *Biotopia* trasmedia narrative design: This figure visually summarizes the different elements considered in developing the narrative journey and storytelling. 1) First, we settled on the main aim of the narrative. 2) Then, we selected the more-than-human characters considering their habitats and usual movements (diversity and connections/entanglements to explore): Pigeon (P), Monk Seal (S), Zino's Petrel (Z), Vulcanic Rock (R) and Frog (F). 3) We settled on which characters to explore in each of the experience's artefacts and some considerations taken for each particular story section/context. 4) Finally, we created two stories each with several of the characters, based on planned hero's journeys for the protagonists. The Design Constructs (DC) are marked in green to illustrate where they were considered.

The characters are presented through two narrative mechanics mediated by digital technologies. In the museum space, the open-ended nature of the stories created with the LLM dialogue feature is adaptable to the visitor's own interests while also being ludic and informative. With a different narrative strategy, the immersive room installation uses two stories with a MtH as the protagonist and others as characters. These stories follow the hero's journey structure to give an emotional base to the natural heritage information (Fig. 5-4) – about the species, ecosystems and conservation efforts – which the visitor can explore in key interactive moments.

These interactive narratives expand the museum's offerings with empathetic and informative experiences about the species on display.

4.3.2 *Webs of Life in Biotopia (DC3.2):* ***A Story of Entanglements.***

Expanding the museum's natural heritage discourses led to the conceptualization of a story of entanglements with the five MtHs as the main vectors. By exploring the complexity of Madeira's

ecosystems, we intend to foster decentered thinking through a deeper sense of our interconnectedness and interdependencies with more than humans.

Our inspirational starting point was a wooden, table-sized map of Madeira, a centerpiece of the museum's permanent exhibition (Fig. 3-C). We interpreted this map as an Anthropocentric and reductive point-of-view regarding the island's complex and dynamic natural heritage. Considering the potential that the museum's diverse collection presents, and intending to bring posthuman narratives to the heritage discourse, we decided to design a complexity-embracing point-of-view of natureculture. This MtH Entanglement map is designed to explore the connections between human and more-than-human actors. We changed the viewpoint to a lateral cut of the island (Fig. 5-2) to also show the massive underwater area that is part of Madeira but usually ignored. In this representation, land and ocean are intrinsically connected.

As mentioned in the previous section, the five MtHs were selected for their diversity in terms of physical characteristics and, importantly, usual habitat and opportunities for connections with the other entities. The two stories have been written to highlight entanglements through fictional journeys that also link to recent environmental events—for example, last summer's forest fires, how they affect humans and more-than-humans, and how humans and more-than-humans are crucial for the forest's regeneration (example in Fig. 5-4).

5 Discussion

By detailing our RtD approach, we contribute to ongoing research linking more-than-human heritage and HCI practice-based work. Our process illustrates how posthuman theory and exploratory research can inform the design of interactive natureculture experiences in real-world implementations. The three design constructs proposed and how they inspired and informed the design of *Biotopia* demonstrate the value of each step of the design process for critical HCI research. In this section, we reflect on our design journey to discuss how the work sits within current critical heritage and posthuman HCI explorations. We also incorporate considerations discussed with the Portuguese and German cultural partners while presenting the final designs.

5.1 Reflections on Posthuman Research-through-Design

Calls to move design processes beyond human exceptionalism and human-centric approaches are not new in HCI [31, 32]. However, how to apply these proposals in real-world design is continuously being explored. We align with Nicenboim et al's argument that decentering practices must "be entangled with the activities, tools, and daily challenges of design processes" [66]. How to "decenter through design" and think beyond user-centred methods towards more inclusive ones has been one of the main challenges of this research. An example of how we materialized these ideas is the Levada companion artefact. Our design decisions considered the animal's needs and the "functionality" of the device. In our concept, the interaction does not need to "work" in a traditional usability sense. A no-resolution (not having a reply from the contacted species) is part of the interaction design, not a flaw. This exercise is meant to create a connection between the human and the animal, but it is also meant to educate the user that we do not control these interactions, nor should we attempt to. In line with our intention, one of the partners suggested that the tool could be an educational tool to teach people about nature conservation. Also, for ethical reasons, it should not be used excessively so as not to disturb the animals. We build on previous work exploring cohabitation in practice [22] through the design of forms of interaction that unite contained and serendipitous interactivity with respect towards the multiple actors involved (human and more-than-human).

Another crucial aspect in our process has been questioning how to explore HCI to go beyond restrictive human-meaning-making perspectives [34]. We built on evolving methodologies that connect theoretical ideas with lived experiences [1] and help designers connect with and interpret natural spaces and more-than-human relations [9, 29, 60, 71] to guide us in understanding the particularities of the context in which we are intervening. R2, despite finding sketching challenging, observed that drawing the Levadas made him more aware of the spatial relationships and specific elements within the landscape, which traditional cultural probes hadn't captured as effectively. This act of sketching, despite its difficulty, encouraged him to engage with the physicality of the trail in a more exploratory manner, suggesting that such activities can help break conventional modes of interaction and foster new ways of perceiving space and build situated knowledges [83].

The designs we create are inevitably moulded by our biases, and, as we pointed out regularly throughout our process, our perspectives are always relational and situated [41]. There are no universal methods for posthuman design, and that is why it is crucial to present and debate the rationale that guides these design experiments.

5.2 Tensions in More-than-human Interactions and Representation

When designing an intervention that connects visitors with wild animals, we tried to base our approach on "humility and cohabitation", being acutely aware of the dangers of "exploitation of nonhuman species" [84] in our design. Initially, we thought of building the dialogue with the Zino's Petrel, a more emblematic bird on the island. However, this endangered species lives in secluded habitats high in the mountains. We decided to work with more approachable species for the animal's protection and the visitor's safety in a, hopefully, non-invasive deployment. Here, we considered Webber et al.'s [87] ethical tensions when designing in natural spaces. Still, our team has continuously discussed these considerations, and we intend to build on them as the work progresses. In alignment with our ethical debates, both the German and Portuguese partners emphasized the importance of respecting the animals and their environment – on the one hand, discussing the importance of considering the potential impact of the animal call on other species, and on the other, the need to respect spatial distances.

Contrary to our expectations, none of the partners expressed concerns about using LLMs, anthropomorphized characters or fictional stories to present the MtHs, affirming that the audience understands the nature of these communication strategies and that it all depends

Figure 6: Proposals for the design of the artefacts: 1) The MtH Entanglement Map room installation (3D render of the room and floor plan); 2) The MtH Dialogues experience in the museum permanent exhibition and tablet with the first version of the UI design; 3) The first version of Levada Companion [42] for the nature walks.

on the purpose of each artefact. One partner highlighted the importance of scientific accuracy in the LLM responses and biological accuracy when developing character traits for species representations – aspects that we have already carefully addressed. Together with the Levada Companion, we worked towards using the different artefacts of the transmedia experience to explore diverse strategies to represent and engage with more-than-humans.

Through continuous iterations and improvements of the artefacts, we are considering "the long-term environmental or social consequences of the products and systems" [41] we are developing but with the open realization that our approach is inherently limited. The debate on these issues within the HCI community is crucial for the collective evolution of sustainable and ethical design processes and we hope this research contributes to it. The importance of multidisciplinarity and multiple worldviews in building more inclusive and sustainable design processes is also key [1]. Our close collaboration with the culture partners' team, which includes biologists, science museum curators and communicators, allowed us to integrate insights from different disciplines to account for the welfare and needs of wildlife [87]. Still, being based on the global north, we

see the need to include other perspectives apart from our own. Our work acknowledges the roles and interdependencies of humans and nonhumans in shaping worlds and futures [1]. However, R1 recognizes the discomfort of how some pluriversal worldviews push against hard-set biases of her Western-based ways of thinking and user-centred design methodologies. This paper illustrates how she and the team replied to these crucial challenges and incrementally reflected them in their design practices. We humbly acknowledge that we have a long way to go and that each experiment is a step in the right direction.

5.3 Critical Heritage Discourses as a Posthuman Endeavor

The narratives we propose for more-than-human heritage extend on previous HCI explorations on MtH connections [25, 30]. Our design concepts replied to the challenge of converging *posthumanism* and *post-anthropocentrism* ideals [15] to expand Madeira's heritage discourses in a decentered direction. By focusing the narrative on MtHs and building the heritage narrative around them, we are attempting to contradict human exceptionalism in heritage discourses. However, this approach needs to build interest in the heritage information. We addressed this balance by focusing on the entanglements of humans and non-humans – how we are not at the centre of any natural hierarchy and MtH's are crucial for our and the environment's well-being.

As proposed by Sterling [79], our detailed process demonstrates the diverse and critical considerations discussed for the various 'components' that form *heritage*. Each of these design decisions influences the heritage narrative and we strived to build discourses that are inclusive and reparative. As the construct of natureculture proposes [34], landscapes, archaeological sites, and ecosystems are interconnected and should not be treated as separate fields. This proposal became the cornerstone of our design concept. In *Biotopia*, we worked towards merging 'nature' (MtHs) and 'culture' (the man-made canals) for critical heritage where both constructs are equally defining of Madeira's heritage. We interpreted the sites as assemblages of multiple actors [34].

The Levadas are an example of *"a landscape constructed through the human gaze"* that *"colonizes nature and materiality by depriving materiality and a range of naturalized others of an active role in the co-creation of events"* [34]. These tensions demand a critical analysis and consideration when creating interventions for these natureculture contexts. Our designs reply to critical heritage's purpose of questioning traditional ways of doing heritage [19] while, at the same time, testing how open to these strategies a heritage institution – a natural history museum – would be. Madeira's natural heritage is intrinsically linked to Portuguese colonization. Despite the island not being inhabited by humans prior to the Portuguese arrival, the subsequent human presence shaped the natural environment. The choice of species is meant to explore these tensions. When discussing the species chosen, one of the museum's partners questioned the choice of the frog, mentioning it is not an endemic species. But after we explained that it was precisely for that reason that it was selected, they agreed on the interesting points it raised. In their view, the five species naturally couldn't represent the whole diversity of the island, but the selection was appropriate to give a broad view of the complex ecosystems. Furthermore, they highlighted the importance of these modern technological solutions to make Madeira's natural heritage more accessible and appealing to a 21st-century audience and to inform the museum's curatorial future.

5.4 Limitations and Future Work

This research is intrinsically moulded by the researchers' experiences, worldviews and areas of practice. We see great value in expanding this work by involving researchers with varying and contrasting perspectives.

This paper contributes to the HCI community with the design process of the natureculture artefacts and the crucial reasoning behind theoretical, conceptual and interaction decisions. Our research highlights the need for continuous discussions on the work and ethical considerations implemented in the design. Next, the project will enter the crucial phase of testing in the various contexts and with diverse user groups. This next phase will further inform these design directions.

6 Conclusion

This research explores the intersection of critical heritage and posthuman HCI, demonstrating how theoretical proposals and exploratory research inspire and inform the design of an HCI-based transmedia experience for more-than-human heritage.

The design process underwent various phases, each based on the previous one. First, through exploratory research, we worked towards understanding the multiple facets and actors in the spaces we were intervening in. This phase led to several insights that were compiled in three Design Constructs for natureculture heritage design: 1) *Digital Balance* – Mindful Integration of Technology in Reflective Visitor Journeys; 2) *Sensory Symbiosis*: Multisensory and Embodied Storytelling; and 3) *Webs of Life*: Ecological Interconnectedness and More-Than-Human Narratives. We then describe how these design constructs were translated in the design of *Biotopia*, a transmedia experience for more-than-human heritage. The transmedia journey connects three sites – nature walks, the museum collection and a museum room installation – through a narrative centered on human/non-human entanglements.

We contribute to the HCI community by discussing the design decisions for three interactive artefacts combined into a cohesive transmedia journey that embody posthuman theories, more-than-human considerations and decentering practices. This research-through-design highlights the challenges and opportunities in translating these propositions in real-world applications, balancing the evolution of more inclusive ways of thinking and doing design away from user-centred paradigms, with the needs and constraints of cultural institutions and diverse audience groups. We hope our work contributes to crucial discussions on decentering HCI design practices and posthuman ways of thinking.

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