Vital Biodiversity Systems: A Companion Paper

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Executive Summary

Regenerative and diverse ecosystems are essential to living futures. Healthy ecosystems are more resilient to climate change and are better able to absorb and store carbon. Communities and corporations worldwide are currently establishing how environmental data can best support these processes. This *Companion Paper* provides the rationale for the *Design Brief* and synthesizes findings from four years of research across academia, corporate sustainability teams, and community stakeholders. It argues that biodiversity data systems are not neutral repositories but designed artefacts that embed assumptions and values. To redirect innovation, the paper supports the *Brief* by expanding on its key design principles, criteria, constraints, and propositions that together chart a pathway for '**vital biodiversity systems**': platforms that embed the aliveness of the ecosystems they mediate.

Key Insights:

- **Problem of misalignment**: new technologies such as remote sensing, digital archives, and corporate reporting tools have expanded the capacity to gather and process environmental data. However, today's biodiversity data systems remain misaligned with ecological realities. They fragment living systems into computable units, producing information rather than pathways to regenerative ecosystems. This reinforces ineffective data production that fails to support the Kunming-Montreal Global Biodiversity Framework's vision.
- **Stakeholder perspectives**:
    - **Ecosystem entities** are the most direct participants in constituting data systems, but they are rarely acknowledged as stakeholders. Ecologically-attuned design methods can enable more innovative proposals that enrich the livingness of data technologies.
    - **Corporations** need data systems that inform biodiversity pathways. The issue for this stakeholder group often appears to be a lack of data while the actual problem is that available approaches do not support decision-making, lack incentives, or are insufficiently meaningful to result in transformation. There is a need for more effective data practices.
    - **Data producers and users** contribute critical ecosystem expertise, yet they often lack real decision-making power in development processes. This leads to missed opportunities in integrating more unique and specialized knowledge of living worlds.
- **Innovation opportunity**: True innovation lies not in more automation or larger datasets but in creating systems that connect complex ecological data to comprehensible decision contexts. Existing tools are dominated by technological features that are far removed from the living ecosystems they represent, and need closer integration of ecosystem sciences to embed more relational, unpredictable, complex, and other – more vital – ecosystem dimensions.

Strategic Implications

- This document calls for biodiversity data system decision-makers including funders, corporate sustainability leads, platform product owners, and designers to shift investment and design priorities away from mere data accumulation. It outlines new innovation characteristics to establish more effective ecosystem data practices.
- Existing systems are often designed through less intentional processes. For example, their features and interfaces are often driven by biodiversity data itself or only formalized at the end of a development process. The recommendations outlined in the *Design Brief* and *Companion Paper* instead provide more structured consultation for the development of new proposals.
- Biodiversity tools must evolve from merely producing more data towards making data actionable and meaningful. By embedding vitality into design, new biodiversity systems can help transition corporate, community, and ecological stakeholders toward regenerative futures.

1. Introduction: A New Ecosystem Data Landscape

Over the last few decades, environmental data systems have greatly increased our understanding of ecosystems and changing planetary phenomena. More recently, automated species identification technologies, high-resolution satellite data, growing digital archives, environmental reporting regulations, and many other new developments have created a rapidly expanding market for biodiversity data tools and platforms. Repositories like the TNFD Tools Catalogue (2026) or the Observatory by NatureTECH Collective (2025) each list hundreds of new tools for organizations to monitor, model, assess, or report their biodiversity impacts. Yet, these systems also cause data fragmentation, information overload, and misaligned incentives for users. Available technologies often fall short in connecting emerging data to meaningful insights, incentives, or decision-making. For many users, the datasets and assumptions that construct these tools remain unclear, making it challenging to discern which tools to use.

This paper outlines possibilities towards overcoming these challenges, drawing on established literature and sharing findings from four years of research. The work presented here is grounded in design research and recognizes how biodiversity systems do not just appear as neutral data platforms but are actively designed according to certain principles while bypassing other possible approaches. They embed assumptions, values, and worldviews that shape how biodiversity becomes addressed, which ecosystem processes are recognized as data, and what futures are rendered possible.

Building on the foundational role of design research to produce generative and future-oriented knowledge, new recommendations are translated into a practical *Design Brief* with the aim to redirect tool development towards more innovative systems. In turn, this *Companion Paper* serves as the backdrop for the *Design Brief* by connecting its statements to more detailed research and providing the ecological, technological, and socio-political contexts from which its propositions emerge.

This work is important because current approaches to designing biodiversity data technologies fall short of being useful for stakeholders when they lack the long-term vision that climate challenges demand. The reason is structural: most biodiversity technologies are overshadowed by the logics of computation and data and thereby risk ignoring the more vital phenomena of ecosystem processes, despite being built to model these dynamics. Only by deliberately designing biodiversity systems that center the responsiveness, alive-ness, and connectedness of ecosystems can digital technologies produce actionable and relevant insights that reflect how ecosystems actually live and change.

2. Problem Statement: Data Systems Are Out of Sync with Ecological Realities

> *"The vision of the Kunming-Montreal Global Biodiversity Framework is* ***a world of living in harmony with nature*** *where by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people."* (*Kunming-Montreal Global Biodiversity Framework*, 2022).

The Kunming-Montreal Global Biodiversity Framework (KMGBF) is a landmark agreement signed by 196 nations that outlines a global strategy in response to the Global Assessment Report (IPBES, 2019) and other ecosystem science publications (IPCC, 2021, 2022a, 2022b). These documents evidence how biodiversity deterioration worldwide is predominantly caused by land and sea use, exploitation of organisms, climate change, pollution, and invasive species. This research has demonstrated that current emission reduction pathways alone are insufficient to maintain earth system stability or operate within planetary boundaries that ensure a habitable planet (Rockström et al., 2009). Biodiversity and balanced ecosystems are crucial components in addressing climate change (Montràs-Janer et al., 2024). The KMGBF also illustrates the importance of attending to the socio-political dimensions of ecosystem challenges as people are differently affected by and involved in anthropogenic environmental issues (KMGBF, 2022). The KMGBF emphasizes the important role of science, technology, and innovation to monitor ecosystems and reach targets. This paper examines the rapid growth of technological innovation efforts that, despite their scale, remain largely misaligned with the vision and strategies outlined in the KMGBF.

Decades ago, researchers in Science and Technology Studies already wrote about the mismatch between data technologies and the complex ecosystems they seek to depict. The assertion that biodiversity should be conceived of as an issue of information raises important questions about how scientific and computational infrastructures turn living organisms into fragmented data units that can simply be counted to create ecosystem insights (Bowker, 2000, 2007). Researchers argue that these systems fail to address environmental challenges because they foreground anthropocentric ways of understanding far more complex processes by digitally transforming ecosystems through economic, positivistic, and computational logics (Büscher et al., 2012; Ellis et al., 2010; Turnhout et al., 2013; Westerlaken, 2024; Yusoff, 2010). Additionally, Indigenous scholarship has also noted that dominant environmental approaches exclude elements of reciprocity and other relational orientations to ecosystems, rendering living beings as extractable data rather than crucial life-sustaining entities (Kimmerer, 2013).These technological infrastructures have also been critiqued because they use considerable energy resources to perform analysis and store data, they risk reinforcing existing global inequalities, and they tend to produce or confirm one-sided data (Gabrys et al., 2022; Nadim, 2021; Nost & Goldstein, 2022; Pritchard et al., 2022; Thayyil, 2018). These systems often fail to connect data to other environmental or social issues, making it unclear how they can become helpful in decision-making processes for their users (Westerlaken, 2025).

Current processes and infrastructures to monitor ecosystems are designed around the principle that data itself is the most valuable outcome (Westerlaken, 2024). A recent landscape report by NatureTech Collective also shows that this field is dominated by data-driven digital tools such as for automating species identification or database analysis primarily with data from remote sensing, species collections, or landscape classifications (NatureTech Collective, 2025). For the users of these systems, the most crucial value emerges from connecting trustworthy ecological insights to relevant decision-making. For instance, corporate sustainability teams try to use these data platforms to identify the biodiversity impacts of their company activities, ideally with the objective to not only report changes but to transition into becoming nature positive. Or, biodiversity restoration communities seek to engage in environmental monitoring to document ecosystems in order to obtain indicators that can better support affected ecosystems. Instead of data-gathering, target-setting, and reporting, only these final goals of becoming nature-positive and supporting ecosystems are aligned with the KMGBF vision towards ‘living in harmony with nature’. In other words, current data systems risk treating data production itself as the end goal, and might thereby fail to integrate the KMGBF vision.

Besides prioritizing information production as an end-goal, these environmental data technologies are structurally driven by their technical features rather than their relations to ecosystems. These tools are inspired by the availability of new algorithmic tools, environmental sensors, or high-resolution recording equipment. Interviews with the developers of these environmental systems showed that selecting which species are monitored and determining how ecosystems are digitalized is dictated by technological capacity rather than ecological need (Westerlaken, 2024). In other words, new tools are driven by what can be measured and modeled, rather than what can best address ecosystem challenges.

The computational, positivistic, and economic logics that guide the design of biodiversity systems risk becoming increasingly disconnected from the living ecosystems that they seek to represent. In fact, there is no real reason for ecosystem processes to follow these human-installed data principles. Ecological processes stem from much older dynamics that have shaped this planet for millions of years and do not necessarily conform to human data initiatives (Mihoub et al., 2017). Just because mathematical patterns are found in nature does not automatically mean that there is an ecological reason for these patterns, or that modeling these patterns will tell us anything new about how to support these processes. Species diversity also changes suddenly, randomly, chaotically, or haphazardly, and may not follow the logics of models and data systems (Benincà et al., 2015; Clark & Luis, 2020; Rogers et al., 2022). The value of the natural world is furthermore not always quantifiable, such as in nature's capacity for beauty, its place-based uniqueness and land histories, evolution's adaptive potential, and ecosystems' mutually sustaining species relations.

While environmental data can teach us lots of new and important things about ecosystem changes, their organic unpredictability is at the very essence of being alive. A wildfire or flood may occur suddenly. A single virus can spur global transformations. A local ecosystem can adapt through random composition changes. The ecosystem sciences that produce biodiversity knowledge are complex, evolving, and include many uncertainties, biases, and shortfalls (Bowler et al., 2025; Hortal et al., 2015). The wondrous, haphazard, opportunistic, and often random evolutionary processes that make our planet alive do not conform to anthropocentric data systems. While these systems can produce important new insights, digital platforms simultaneously narrow our knowledge and can precisely filter out the unpredictability, instability, and relationality that are often at the heart of the environmental crises they seek to address.

True innovation, in a time of ecological decline, is not about merely applying new technological features and automation to generate more biodiversity data as an end-goal. Instead, how can biodiversity data systems be designed with the goal of supporting 'a world of living in harmony with nature'? Rather than being driven by data production, this premise leads to entirely different proposals.

Designers and other creative future-makers are uniquely positioned to take up this challenge. This is because they are trained to navigate between the technical expertise and imaginative practice that can help to question entrenched assumptions and reconfigure how technology interfaces with the living world. Designers have the methodological flexibility to probe, rethink, and disrupt conventional data systems. Here, creative practitioners are not tasked with solving biodiversity loss through more effective automation tools or more data, but by proposing entirely different – **more vital** – ways of relating to ecosystems altogether. Instead of flattening ecological realities into data points, they can make space for the unruly, fragile, and living nature of the world that we seek to live in more harmony with.

3. Objective: Create a Response-able, Organic, and Relational Biodiversity Data Platform

To develop *vital* biodiversity systems that are aligned with the KMGBF vision, the *Design Brief* outlines three foundational design principles. These theoretical principles unpack 'vitality' to inspire new design:

Response-able Design

Ecosystem theorists have long moved on from a nonetheless still prevailing Cartesian logic that understands the natural world as a passive, fixed, external object that is knowable through dissection. Instead, ecosystems are not machines but dynamic and often unpredictable entities consisting of innumerable interdependencies. Humans, like other living entities, are themselves constituted through the ecosystems of which they are a part. We cannot observe or intervene in these ecosystems from the outside, but we exist and are formed within them.

Embodying this principle in design practices requires us to consider how data systems do not merely depict ecosystems objectively but instead are ongoing and active modes of responding within them. In critical ecological thought, scholars including Donna Haraway, Vinciane Despret, and others have used the notion of response-ability to argue for modes of noticing and thinking-with living entities that recognize how humans both shape and are shaped by ecosystem processes, technologies, and living entities (Despret, 2016; Haraway, 2008). This also helps to understand how data is never fully neutral but is always shaped by measurement methods and limited to the observations that humans and/or computers pay attention to.

By designing with this principle in mind, it becomes possible to create data practices that more deliberately engage in meaningful response, make careful ecosystem adaptation decisions, or shape transformative human-environment relations. The call for designing for the 'ability to respond' signals that interacting with biodiversity systems goes beyond just looking at data, by actively responding to environmental processes. Bringing data systems to life requires designing for these interactions by connecting environmental data points to ecological dynamics via features that encourage users to interpret, challenge, contextualize, or act upon them. Computers should thereby not replace human decision-making but become an assistive tool that helps users better understand complex data and complex decisions. Such design can for instance include interfaces that display potential decision pathways, involve participatory features for users to make sense of data and prioritize issues, or embed feedback mechanisms in which data is not just observed but becomes a medium to respond to environmental processes.

Organic Design

The design of biodiversity data systems should be inspired by the ecosystem processes they seek to engage with, rather than only by their technical features. The aliveness of ecosystems and their intricate dynamics can offer an inexhaustible and exciting inspiration for design. Organic design is essentially as old as time but emerged more formally in architecture with a focus on promoting harmony between humans and the natural world, for instance through traditional Japanese architecture, or through the work of modern architects like Frank Lloyd Wright and Rudolf Steiner. This principle aligns well with the KMGBF vision and can creatively bring organic elements into data practices including life's textures, cycles, rhythms, spaces, scales, playfulness, poetics, and regrowth, but also its inevitable decay, compost, and its more uncomfortable elements.

But beyond the human capability to create things, this understanding of organic design should be expanded to better attend to the ways other living entities shape worlds. Since the 60s, foundational texts such as Rachel Carson's *Silent Spring* (1962) and Lynn Margulis' theory of symbiotic relations (1970) paved the way for more ecologically inclusive understandings of systems and interactions. These works demonstrate how living beings actively shape worlds and that humans are merely one element within these ecosystems.

Extending these understandings into design, the importance of incorporating the active role of ecosystem dynamics into design artefacts steadily rose to the forefront through concepts such as "multispecies design", "more-than-human design", "non-anthropocentric design", or "planet-centric design (Clarke et al., 2019; DiSalvo & Lukens, 2011; Forlano, 2017; Giaccardi & Redström, 2020; Wakkary, 2021; Westerlaken & Sandelin, 2024). Biodiversity data systems can become more ecologically relevant when including these contemporary ecological studies into their design approaches. In this reading, the idea of 'organic design' aligns precisely with renewed ecosystem understandings and foregrounds both how living entities and ecosystem processes can become stakeholders and co-creators of these systems, and that ideas for design artefacts can emerge from the aliveness of the ecosystems that are turned into data.

Relational Design

Biodiversity is not made up of isolated entities but of relations: between species, between organisms and environments, and between knowledge systems and the social conditions under which they are produced. Yet many biodiversity monitoring tools treat data as discrete, decontextualized units such as species sightings, metadata columns, timestamps, or spatial indicators, without attending to the ecological or epistemological relations that make such data meaningful. This principle calls for systems that center these relationships from the outset.

Designing for relationality means recognizing that what matters in ecological observation is often how things are connected: how a particular insect depends on a flowering schedule, how a forest's health reflects land management practices, or how communities understand and respond to shifting species distributions. Such relations become increasingly difficult to understand using current data architectures or user interfaces, which tend to abstract and fragment ecological life into comparable and scalable datasets. Furthermore, failing to interconnect biodiversity with aspects such as water, food, health, and climate analysis risks creating incomplete and often contradicting strategies (IPBES, 2024).

Instead, relational design foregrounds connections and requires systems to be built in conversation with those who hold relational knowledge, including through lived experience or other ways of knowing. This means creating infrastructures that allow different stakeholders to interpret and navigate data together, rather than positioning one knowledge system as universal (Longdon et al., 2024). And it means that scientific insights must be braided together with other knowledge practices that recognize the reciprocal and kinship dynamics of ecosystem relations (Kimmerer, 2013). Here, relational design is also inspired by work in participatory design to emphasize that meaningful ecological data infrastructures must acknowledge wider stakeholder networks and should be situated within the relations they aim to mediate (Light et al., 2024; Westerlaken et al., 2023).

Relational design treats collaboration as an organizing principle from the onset of the innovation process, shaping what is collected, how it is structured, and how it is made visible. It resists the abstraction of ecosystem problems into decontextualized metrics and instead creates ongoing reflection on the relationships that are being tracked, transformed, or ignored.

Together, these three theoretical principles: response-able, organic, and relational design, constitute the components of vitality that spur the creation of biodiversity systems to achieve the KMGBF vision towards ‘a world of living in harmony with nature’. These principles can be applied at any scale, ranging from data systems focusing on the lives of individual species to systems that incorporate data about large planetary patterns. The next sections will align these principles with the key stakeholder groups involved and with the more practical design criteria that further redirects innovation in this field.

4. Key Stakeholders: Ecosystems, Corporate Actors, and Data Operators

This section reports key insights from four years of research with the three central stakeholder groups identified in the *Design Brief*. These perspectives were gathered through interviews, design workshops, and community-based fieldwork between 2022-2025.

Key Stakeholder 1:
Living ecosystems, humans, and multispecies entities who express data and need their processes to be engaged with in more meaningful ways.
In designing biodiversity data systems, it is easy to forget that the main participants in these technologies are the ecosystem entities recorded through data practices. These include species who are observed and identified through sensors, living systems that are affected by technologies, and humans who live in and around the ecosystems that are mediated through data. Rather than mere units of measurement, they are key stakeholders that have specific interests in how their data should be captured, stored, shared, and interpreted. Ecosystems consist of innumerable entities and relations that have a stake in maintaining or restoring ecosystem balance. Data systems can positively interfere in these dynamics by drawing attention to ecosystem destruction or by reshaping our understanding of environmental challenges. At the same time, these practices inevitably ensure that non-datafied ecosystem participants are ignored or otherwise compromised as these effects are complex and not completely knowable.

After a decade of research into how multispecies entities including animals, plants, and other organisms can participate as stakeholders in design processes the conclusion is that this is incredibly challenging, yet not inherently harder than collaborating with human stakeholders (Westerlaken, 2020; Westerlaken et al., 2023). While humans can answer interview questions and indicate their preferences in co-design workshops, designers are trained to use skills such as empathizing, imagining, noticing, observing, listening, attuning, and attending to power dynamics while translating these into design decisions. These skills can be adapted to methods that involve non-humans and can identify ecosystem stakeholder networks through multispecies ethnography and design activities deliberately adapted to include multispecies entities (see e.g. Akama et al., 2020; Botero et al., 2022; Clarke et al., 2019; Heitlinger et al., 2025; Meesters et al., 2023; Sheikh et al., 2021).

Images of multispecies design methods projects undertaken between 2015-2024. Attuning to how ecosystem entities express their preferences, configuring new human-nonhuman relations through creative methods, rethinking how living entities are collected, and observing how they escape datafication are all examples of multispecies design methods through which new biodiversity systems can be developed (images by author 1).

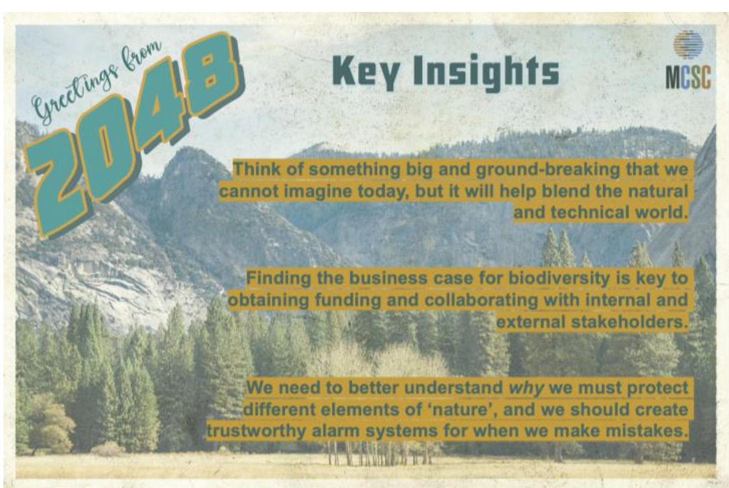
Emerging from this research are guiding questions and methods as starting points for designing vital biodiversity systems together with this group of stakeholders:

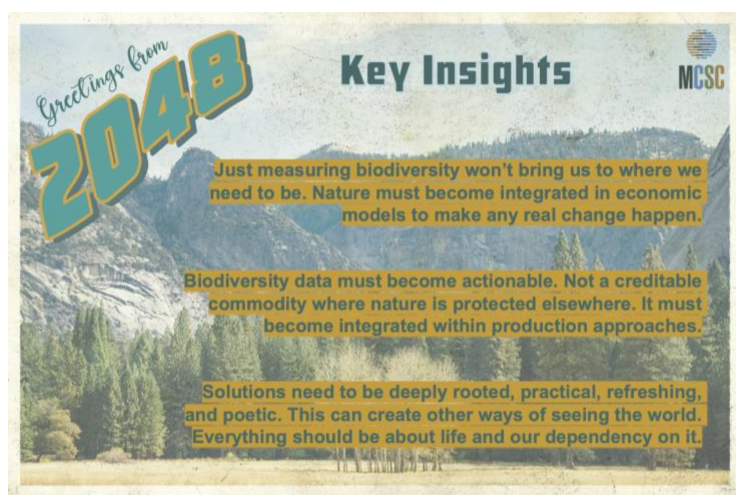
- Start by mapping expanding stakeholder networks to create more detailed overviews of the humans and other species/entities related to the data in focus. While these networks can infinitely expand, they help to think more extensively about the potential effects of creating biodiversity data systems.
- Ask whose data is captured and whose experiences are thereby ignored? How can this design output acknowledge its data limitation and account for its focus on certain environmental challenges over others?

- Reflect on how different living entities can become physically affected by the sensor technologies and the energy usage of data systems? How are these interventions and resource usages benefitting or harming the affected ecosystems and the communities within them?
- Speculate on the ways different ecosystem entities themselves would express and narrate their biodiversity data. What issues would they draw attention to? How would they design data systems to prioritize their challenges? What conflicts of interest emerge and how do these interfere with establishing healthy ecosystems? While it can be challenging to fully understand other life forms, multispecies design methods help to surface new perspectives that would otherwise be dominated by anthropocentric worldviews.
- What are the key long-term challenges and opportunities for these stakeholders? What data types and formats can best address these to create more resilient futures?

Key Stakeholder 2:
Corporations committed to move beyond compliance or impact metrics towards aligning their operations with ecological regeneration and the KMGBF vision.
These organizations are increasingly facing regulatory, public, and internal pressure to demonstrate biodiversity action and lower their environmental impacts, yet corporate sustainability specialists often operate with limited data and fragmented tools (Bassen et al., 2024; Dey, 2025; Wauchope et al., 2024). While large corporations are responsible for causing environmental damage, they also have the resources to lead global transitions, demand incentivizing policies, and guide whole sectors towards regenerative practices. Organizations such as the Science Based Targets Network (SBTN), the Task Force for Nature Related Financial Disclosures (TNFD), and the Global Reporting Initiative (GRI) are producing new guidance for companies to engage with biodiversity. Data platforms play a crucial role in this emerging landscape to support setting impact reduction targets and meeting reporting requirements. This stakeholder group now consists of key decision-makers responsible for configuring strategic choices using data systems that they neither designed nor developed, but through which they are expected to understand and interpret complex ecosystem data.

To better understand these challenges, we undertook 12 months of research including 8 interviews and 9 workshops with sustainability specialists at 13 member companies of the MIT Climate and Sustainability Consortium (MCSC, 2026), combined with desk research, tool prototyping, and sustainability report analyses on the rapidly changing landscape of corporate biodiversity assessment and reporting. This produced many new insights about the challenges and opportunities for this stakeholder group.





Images of materials from design research workshops with 13 member companies and connected stakeholders at the MIT Climate and Sustainability Consortium between September 2024-June 2025. These workshops identified current challenges and future opportunities for biodiversity assessment and reporting systems (images: MCSC, author 1).

A significant issue for these stakeholders is that currently available biodiversity assessment approaches are directly adapted from methods focused on carbon emissions, for instance by quantifying biodiversity impact intensities within supply chains or finding ways to offset harmful activities by investing in restoration projects across the world. However, biodiversity is far more complex than carbon because it encompasses entire ecosystems and this creates crucial challenges for companies in finding meaningful approaches towards lowering their biodiversity impacts. The data-driven methods create a problematic loop in which the design of data systems primarily caters to quantitative reporting requirements that are inherently limited by capturing ecosystems as fragmented data. In other words, biodiversity is turned into an issue of information (Bowker, 2000). In this approach, the problem for companies appears to be a structural lack of useful quantitative data that can establish biodiversity impacts, while – as some participants also mentioned – the actual problem is that biodiversity inherently escapes this type of quantification. There is an urgent need to design more realistic and effective ways for companies to establish pathways towards ecological regeneration.

Another fundamental problem for the use of ecosystem data in decision-making processes that emerged in this study is that many companies lack knowledge on the specific area where, for example, their raw materials and ingredients come from. This includes challenges of traceability within complex supply chains and inaccessible or protected information. This means that, even if corporate actors have the ambition and internal resources to gather biodiversity data, it often remains impossible to succeed. Data is furthermore often incomplete, it is difficult to establish causality of ecosystem phenomena, it is challenging to allocate impact when activities of different companies overlap in location. For corporate stakeholders, it is crucial that data systems developers respond to these challenges.

Extensive corporate resources are currently dedicated towards establishing trustworthy ecosystem data, while ideally, most resources should be spent on translating data insights into meaningful decision-making and action. The question should not be how to generate more data, but how these systems can help transition company activities towards regenerative and sustainable models; in other words, towards the KMGBF vision of living in harmony with nature. Biodiversity data systems currently do not support these goals and should be redesigned to assist corporate stakeholders in establishing more meaningful pathways towards ecological resilience. The design of such data platforms can be informed by the following, more detailed, insights that emerged from this research:

- Companies express a need for tools that support practical decision-making. Data collection itself is not enough to establish ambitious biodiversity goals. While data repositories can be crucial to produce new insights, corporate users request tools to more directly inform changes, to provide more guidance on how to interpret ecosystem predictions, to identify data relations between biodiversity and other environmental impacts (water, air, soil, carbon), and to obtain more practical tools that support biodiversity action.
- Corporate sustainability specialists understand that biodiversity is complex. They are seeking ways to integrate this understanding together with the complexity of large corporations, extensive supply chains, and long-term strategies. In this way, they find that what might be good for one ecosystem could be bad for another one. Similarly, such dilemmas also exist within organizations, where sustainability pathways contain non straightforward trade-offs between different business activities. They need tools that remain effective within this landscape where trade-offs between different decisions can be envisioned for complex environments and convince internal decision-makers.
- Various participants also reflected on the technical difficulties of using ecosystem data tools while having to understand the implications and limitations of different datasets. These systems are seen as overwhelming, raising questions regarding the expertise that is required to engage with biodiversity decision-making in corporate settings. This indicates that new design patterns that can mediate between ecological complexity and human comprehension might be needed.
- Perhaps surprisingly, corporate stakeholders also propose technologies that are poetic, creative, aspirational, visionary, magical, tenacious, fresh, and resilient. Besides terms like practical, useful, and accessible, these were the words that workshop participants used to propose the kinds of future technologies that would solve their biodiversity data challenges. Designers must be careful not to limit proposals to static corporate landscapes that disregard much more creative user ideas.
- Another ongoing question for establishing biodiversity commitments and setting targets is whether these are sufficiently robust, meaningful, or achievable (Hawkins et al., 2025). A grand challenge for the next decade will be to develop data systems that help corporations set meaningful targets across different scales, and demonstrate advancement towards those targets through trustworthy mechanisms. Besides regulation, this will become a crucial driver towards more ambitious corporate climate transitions.
- Resource-related questions raised by corporate sustainability specialists include: How to create a biodiversity business case to obtain internal funding? How can we create better incentives for companies who lead their sector towards ecological regeneration? How can economic values become better aligned with nature? How can we scale up biodiversity assessments across ecologically diverse sites while working within budgeting and resource constraints? These are important socio-economic considerations for using data tools. Designers must consider how vital data systems can best fit into or creatively expand these constraints.
- Early movers in this space are in favor of more standardized metrics that remain meaningful at different scales, more guidance on reporting, more stable long-term regulation that incentivizes sustainability engagement. Biodiversity specialists mention the need for data and technology to support these objectives, but new ideas about the role of data platforms to mediate between regulation, measurement, and environmental data are needed as these landscapes evolve and regulation changes.

Key Stakeholder 3:
Specialists who collect and engage with data including monitoring experts, citizen scientists, ecologists, local communities, and other ecosystem data users.
This broad stakeholder group includes users who interface with biodiversity data. Beyond corporate actors that are important economic drivers of new technologies (described in group 2), these include people who generate and engage with biodiversity data. Examples include users of sensor technologies such as camera traps, acoustic recorders, or collectors of eDNA samples. Furthermore, there are the people who manage increasingly large volumes of data that are being digitalized and standardized. Third, it includes data gatherers and citizen scientists who collect biodiversity data through publicly available mobile applications and platforms. Fourth, local level specialists in ecology and indigenous stewards of land engage with biodiversity data to produce new insights. Fieldwork undertaken with this diverse group of stakeholders between 2022-2024 was published in (Westerlaken, 2024, 2025) and included interviews with technology developers, ecologists, and a biodiversity restoration community in the Netherlands. This research showed a variety of data practices and produced new insights for biodiversity system proposals.

Images of fieldwork with biodiversity restoration communities, citizen scientists, and biodiversity monitoring specialists undertaken between March 2022-April 2024 (images by author 1).

This group of stakeholders has practical expertise in producing and working with biodiversity data. In this research, more details emerged for instance on how citizen scientists prefer to collect and engage with biodiversity data. Further work showed how different stakeholders within this group collaborate in developing biodiversity data platforms, and illustrated the power dynamics and hierarchies between different actors and at different stages in such projects. For this *Design Brief*, the following insights provide further guidance:

- The development of biodiversity technologies predominantly takes place in the Global North, with funding from both private and public sources. However, the impacts and data gathering of these platforms are also often located in the Global South, especially in biodiversity hotspots or areas that are under major climate pressure. The people across the world who are most impacted by biodiversity loss are usually not included as stakeholders in development processes. Many of these projects now claim to include participatory structures, but even these initiatives usually fail to provide local communities and knowledge holders with real data ownership or decision-making power. This leads to missed opportunities in integrating more unique and specialized biodiversity knowledge that can make these platforms much more effective towards supporting the KMGBF vision. Rather than treating ‘co-design’ as a buzzword to gain funding, new proposals for biodiversity systems should adopt more meaningful participatory structures into their development processes where local stakeholder knowledge and lived experiences can fundamentally influence design outputs (Westerlaken, 2024).

- In interviews and workshops with MCSC member companies, sustainability specialists addressed the importance of including both expert ecosystem knowledge and developing platforms that are practical and easy to use. This balance between complexity and legibility of data is a crucial challenge for current biodiversity systems. The deep familiarity with the nuances of local biodiversity data within this stakeholder group uniquely enables people to identify how ecological integrity can possibly be retained or improved in the development of decision-making tools. Especially with the use of AI analysis tools, this expertise now risks becoming outsourced to large language models that are unable to include contextual knowledge. Therefore, the inclusion of ecosystem experts and other people who engage with local biodiversity data is essential to developing effective data systems.
- The inclusion of local data producers such as citizen scientists, sensor users, or biodiversity monitoring specialists, raises questions about the ways their data can more directly support the KMGBF vision towards creating ‘a world of living in harmony with nature’. Available research on citizen scientist expectations in collecting environmental data shows that data gatherers often assume that their contributions will meaningfully support biodiversity conservation or restoration efforts (Kimura & Kinchy, 2016). However, in practice these large volumes of species observations are rarely integrated in decision-making processes and remain unused in digital repositories, creating a disconnect between data collection and impact. Designing new systems where these links become more tangible can create opportunities for individuals to more meaningfully contribute impactful data.

There is rich potential for creative proposals to emerge from the connections between each stakeholder group discussed here. Recent sustainability reports from the MCSC Member Companies further indicate that companies are actively engaging in biodiversity initiatives through direct collaboration with local stakeholders across the world. The interwoven relationships between these stakeholder groups present valuable but underexplored opportunities for design.

5. Design Criteria: Foreground Vital Aesthetics, Depth, and Ecological Value Systems

To articulate how the previous sections on the problem statement, objectives/design principles, and key stakeholder insights can be translated into more tangible pointers for new technologies, the *Design Brief* outlines three criteria that new biodiversity data systems should adopt. The following paragraphs provide more background details to the research rationale behind these statements.

Criterion 1: The design must center vital aesthetics.
In biodiversity data systems, aesthetic dynamics are often treated as surface-level considerations, something that is addressed with visual design only after the structures and features have been put into place by product managers, technologists, and data scientists. This detached understanding of design does not render aesthetic components as absent, but ensures precisely that the aesthetics of biodiversity systems are defined by these early-stage drivers. Aesthetic choices are inevitable at any stage of the design process and by not deliberately designing with more thoughtful aesthetic visions, these projects take on the default experiences and perceptions of their developers. We see sterile dashboards, ordered rows with environmental observations, rigid data categories, structured metadata, techno-futurist imagery, computational metaphors, high-resolution images of charismatic species, clean minimalism, and the overarching vision that ecosystems can be brought under control by humans with data; these are the dominating aesthetic dimensions of the developers of current systems (Westerlaken, 2025). And they might have very little to do with actual biodiversity or living ecosystems.

Instead, the real design question is how the vitality of ecosystems, and their rich aesthetic dimensions, can become a starting point for the design of these systems? This reorientation is essential to designing for the KMGBF's primary vision of 'living in harmony with nature', because it will enable users to draw more realistic connections between digital data and living ecosystem processes. To answer this question, we might travel through the rich literature on the aesthetics of nature that tries to undo a destructive modern attempt at separating between how nature is known and how nature is perceived (Bird-Rose, 2017; Despret, 2016; Leal Filho, 2019; Wilkie & Michael, 2023; Yusoff, 2012). In short, these works aim to reemphasize how attending to aesthetics is fundamental to understanding nature. The definition of aesthetics in this area of the humanities is much broader than thinking about the look and feel of designed platforms. Aesthetics here include sensory perceptions (touch, textures, smells, sounds), affective dimensions (emotional responses, or how things move us), power and politics (the ways things gain importance in the world), cultural relations (involving vast differences between societies and individuals), and more generally refers to how meaning is created for living beings.

For instance, many data systems currently present themselves as delivering objective knowledge (or facts) about nature. But according to these readings, such knowledge is inherently connected to aesthetic experiences, because meaning-making is shaped by the perceptive instruments and sensors we use to understand the world. To determine what counts as biodiversity data or indicators, humans select metrics that make certain entities visible, such as species taxonomies or representations on a map, while other ecosystem processes such as ecosystem relations and unknown entities risk dissolving further into the background. One telling result of this phenomenon is that two thirds of the world's species occurrence data in GBIF is currently about birds, and 90% of terrestrial species occurrence data is taken from within two kilometers of a road (Hughes et al., 2025). Data systems are thereby far from neutral artefacts, because they shape how nature becomes legible from computer screens, by expressing ecosystems as data points, which risks obscuring other aesthetics and entities that are equally if not more important to figure out how to best address ecosystem challenges (Abram, 2010). Aesthetics also vary widely among human cultures and societies. For instance, while current systems are predominantly focusing on species occurrence data through taxonomic references and geospatial representations of data, new design proposals should consider more diverse aesthetics of nature according to different end-users and stakeholders within these systems, including the experiences of Indigenous and local communities.

Many existing ecosystem platforms offer sterile views of nature where data appears as singular points on a map or numbers in an Excel sheet that should inform biodiversity action. But decisions about how to support sustainable transitions and ecosystem restoration inevitably involve far more complex realities. These decisions involve local contexts, political conflicts, relations between different ecosystems, contrasting incentives between stakeholders, emotional connections, and other complex tradeoffs. Such realities tend to disappear through the aesthetics of current data systems where ecosystem data is expressed according to computational logics (Westerlaken, 2025). Instead, a more groundbreaking starting point for designing for more vital aesthetics is to ask how living entities and non-deterministic processes can become integrated in these data platforms, and to design new data systems where these vital dimensions guide new data practices and decision-making processes (examples of these are discussed in section 7 of this paper). This is quite a different orientation compared to current biodiversity data systems that narrate human data capture as a one-directional human-nature interface. This reorientation engages biodiversity not as a detached dataset but as a living phenomenon that deeply affects humans and ecosystems. Identifying the important aesthetic qualities of aliveness in the ecosystem and the data in focus and its relations to broader biodiversity experiences, can thereby guide new visual, structural, and interactive elements.

Criterion 2: The design must foreground depth and complexity in biodiversity data.
One often articulated statement by corporate biodiversity assessment specialists and other stakeholders is that more quantitative biodiversity data is urgently needed, or that the quantification of biodiversity impacts is the primary goal of their work. At the same time, these users report that it is challenging to find trustworthy data, or that the large volumes of available data are not robust enough because they are often based on proxies, assumptions, and extrapolations. The idea that more quantitative data could create more understanding of biodiversity impacts is relevant, as more data coverage could mean more nature indicators. Yet volume is not the same as understanding: as datasets grow, relationships often fall away, and decision-making begins to be informed by select metrics (e.g., species richness) rather than the underlying ecosystem needs. When this problem is brought in conversation with the aforementioned risk of turning biodiversity primarily into an issue of information (Bowker, 2000), or when trying to connect it to the KMGBF vision of achieving ‘a world of living in harmony with nature’, the real problem appears to be locating enough useful data to make meaningful decisions. As corporate assessment specialists also described: rather than an issue of needing more quantification, environmental data poses challenges for finding quality, robustness, and trustworthiness within large volumes of data, and for preserving the relational context in which this data makes sense.

For instance, users reported that existing data is often contradictory and that it is difficult to find useful data amid growing biodiversity archives. How to find relevant insights within terabytes of camera trap footage or endless lists of species observations? How to deal with a lack of baseline data and large year-by-year variations due to unknown factors? How trustworthy are ecosystem statements produced by AI? Moreover, given the endless complexity of ecosystems and all their unknowable factors, each corporate activity or local environment under examination will prove more complicated than any data could capture. An all too narrow focus on quantitative biodiversity metrics risks obscuring nonlinear ecosystem processes that are easily missed by annual KPIs.

Here, more data does not necessarily provide the depth and complexity that is needed to understand how to best respond to local ecosystem challenges. This design criterion therefore demands that depth and complexity become foregrounded in designing systems to engage with quantitative data, to move beyond mere data production as a primary goal and toward systems where metrics are paired with qualitative depth.

As more quantitative environmental data is being generated through new sensors and sampling techniques, digital platforms that aggregate this data should not just be conceived as mere tools for data delivery. They should instead be understood as active mediators in processes of interpretation and meaning making. These tools must incorporate more thoughtful processes that drive decision-making towards the KMGBF vision and targets. Practically, this means centering the interpretation of data with local knowledge holders, engaging with uncertainty, assumptions, and trade-offs as prominently as with nature observations, adding more relational indicators alongside species counts, building reciprocity into data workflows, protecting sensitive data, and accounting for the energy footprint of data processes. Foregrounding depth means to deliberately design ways to connect biodiversity data to complex ecological and societal challenges to enable further discourse and decision-making. Data systems thereby move from static data repositories to tools that are designed to stimulate reflection, prompt conversations, and inform transformative actions.

Criterion 3: The design must attend to economic value in alignment with ecological dynamics
Across interviews and workshops, corporate stakeholders and commercial data system providers pointed to the necessity of developing a clear business case for biodiversity action. Sustainability specialists included in this research repeatedly state that regenerative ecosystems are most valuable far beyond economic gain, but also request data technologies that can demonstrate how long-term corporate success can be integrated with biodiversity targets. Such tools are especially helpful to gain internal funding, obtain budgetary approvals, and develop internal strategies with other company departments. Corporate stakeholders described this as a strategic process of using digital systems to gather trustworthy environmental data that can inform meaningful changes towards more ecologically regenerative company activities. These changes can be expensive, resource-intensive, risky, or involve other trade-offs that make it difficult to implement groundbreaking sustainable transitions among more conventional corporate activities.

These processes show that biodiversity decision-making in corporate environments is not just a matter of following top-down regulation or merely engaging in green branding. While those can be crucial for sector transitions, for designers of biodiversity systems it is essential to understand how data platforms shape decisions in more bottom-up processes as well. According to corporate stakeholders, if these systems are more specifically designed to help sustainability specialists accurately demonstrate the business advantages of undertaking biodiversity action, these become powerful tools to convince company boards and other internal decision-makers.

While CO2 emission reduction plans are more clearly informed by net zero pathways (e.g. ‘become net zero by 2040-2050’), equally important pathways towards corporate regenerative ecosystems are far less clear for companies. However, as CO2 emission pathways are maturing, insights emerged that should now shape corporate biodiversity action as well so that these pathways align with the KMGBF vision and become more robust and resilient in long-term economies. It was found that the commodification of CO2 emissions into credits and other trade systems has been largely unsuccessful in lowering actual emissions (Calel et al., 2025; Probst et al., 2024; Trencher et al., 2024). Climate science and relations between CO2 and other environmental impacts are continuously updated, creating corporate risks, uncertainties, and a lack of stable long-term guidance (Lamboll et al., 2023; Rockström et al., 2023; Steffen et al., 2015).

While biodiversity frameworks for corporate action are at risk of incorporating exactly the same problems, there are also opportunities here for developing data systems that can help avoid these pitfalls. To create these more resilient pathways, the KMGBF's main vision for 'a world of living in harmony with nature' by 2050, should be a guiding principle for new designs, without losing track of how corporate environments can successfully transition towards these futures. Moving towards ecological regenerative, resilient corporate processes inevitably requires companies to reconcile their business activities with ecosystem principles that emerged millions of years ago. What if, for example, businesses could integrate ecosystem dynamics such as evolutionary adaptation, regeneration, circularity, self-healing, seasonal cycles, flexibility, mutualism, and reciprocity into their business values for determining corporate success? These principles might not bend to human built economies, but will easily survive planetary catastrophes.

Thus, the strongest business cases will involve finding more creative ways to merge corporate success – for instance in terms of growth or value – with ecological regeneration, which will require decoupling growth and value from solely a monetary perspective. Literature that identifies these adaptive, long-term, diverse, and resilient ecological understandings of value and growth emphasize concepts of ecological economics (Brand-Correa et al., 2022; Common & Perrings, 2002), post-growth debates (Kallis et al., 2025; Wolters, 2023), diverse economies (Gibson-Graham, 2008), conviviality (Adloff, 2024), care (Puig de la Bellacasa, 2017), or Indigenous concepts such as *buen vivir* (Acosta, 2016) or the *honorable harvest* (Kimmerer, 2013). In other words, while currently available biodiversity data tools often push for further commodification of biodiversity, such approaches are risky for key stakeholders if they cannot address environmental concerns. More ecologically aligned proposals can benefit from making renewed business propositions by focusing on values that are already inherent in ecosystem processes. Examples of such proposals are shared in section 7 of this paper. By using data practices and tools as sources to help rethink what value can mean beyond solely a monetary perspective, sustainability specialists become empowered with platforms and data formats that attend to broader regenerative ecosystem processes that could become incorporated in formats for company success.

In sum, vital biodiversity systems that are response-able, organic, and relational – and developed for three key stakeholder groups (ecosystems, corporations, and data producers/users) – must meet three criteria including centering vital aesthetics, foregrounding depth, and attending to ecological value propositions.

6. Design Constraints: Design Within Ecological, Technological, and Socio-Political Limits

Thus far, this paper has expanded the rationale for each of the elements in the *Design Brief* that describes how to design vital biodiversity systems. This section collectively details the three constraints that frames the design space by defining its limitations.

Ecological Constraints

Ecosystem science is necessarily partial, because living environments far exceed scientific ways of understanding, taxonomizing, and documenting environmental entities and processes. For instance, most species (especially fungi, bacteria, algae and molds) exist outside the scope of scientific description because they have not yet been taxonomized. These classification processes are furthermore always limited to the methods, instruments, and perspectives that produced their data (Bowker & Star, 2000). In more encompassing knowledge production processes, scientific methods are combined with other ecological ways of knowing (Sanga & Ortalli, 2004), such as deeper experiences that emerge from living with ecosystems, observing changing landscapes, documenting historical and cultural perspectives, or attending to specific local ecosystem dynamics. The inherent partiality of ecosystem knowledge should not just become a deficit to be addressed with more metrics. Instead, it is a leading epistemic condition that should orient how biodiversity systems are designed.

This constraint asks innovators to balance rigorous ecological science while making space for the observational, local, and practitioner ecological knowledge that is crucial to make insights meaningful. However, rather than romanticizing epistemic pluralism it should be operationalized towards becoming response-able (see the Design Objectives section above on what response-ability means). Creative work can play a generative role within this constraint, by proposing new ways to engage ecological realities more deeply. These are not compromises between “science” and “other knowledge”, but examples of how rich ecological understanding itself can be a creative source to produce vital data systems.

Technological Constraints

Often, design recommendations foreground technological advancements as a main priority for new data system proposals. Within the context of this *Brief*, innovation ‘success’ is aligned to proposing technologies that are more vital and more in line with the KMGBF vision for ‘a world of living in harmony with nature’. This demands that technology is adapted to, rather than guides, pathways towards ecological regeneration.

Most biodiversity data tools that are currently emerging focus on the possibility of new technological features such as the automation of species monitoring or the use of AI to perform data analysis faster or in larger quantities. It may seem like such systems only add more data and are thereby inherently helpful. However, to better align digital innovation with the need for more vital biodiversity systems, the technological constraint here is one that limits the driver of technological innovation to the system’s ecological or vital intentions, and not the other way around. In other words, rather than creating ideas for new biodiversity systems from new technological features (such as increased computational capacities, new species monitoring sensors, more geospatial data abilities, or new algorithmic analysis possibilities), vital proposals must foreground the KMGBF’s vision, create a pathway towards regenerative ecosystems, and only then determine which technological features can support such goals.

Socio-Political Constraints

Corporate stakeholders working with biodiversity data as well as local restoration communities reported that it is challenging to translate environmental data into meaningful decisions, because it is unclear how biodiversity datasets are related to social, cultural, economic, or political knowledge and trade-offs. Furthermore, each biodiversity tool or platform draws attention to certain data while overlooking others. All designs thereby have socio-political effects that must be carefully considered. New biodiversity technologies risk exacerbating existing inequalities and produce questions regarding data sovereignty, labor, and political power (Gabrys, 2016; Gabrys et al., 2022). Even if the goal of these systems is to help address environmental challenges across the world, the way in which this is done can further harm minorities and less powerful stakeholders.

In the context of biodiversity systems, some documented issues showed how ecosystem monitoring tools are used to surveil minorities or for military purposes (Adams, 2019; Ritts et al., 2024), how local communities are put to work by performing voluntary species monitoring labor with unequal community benefits (Foster & Dunham, 2015), how undemocratic nation states target environmental technologies to control civilians (Gabrys et al., 2025; Goodall & Tehrany, 2022), or how conservation technologies have also created neoliberal business goals without supporting helpful environmental outcomes (Büscher et al., 2012; Turnhout et al., 2013).

This research shows that biodiversity systems are far from innocent, and must include thoughtful processes regarding how decisions, data, and interfaces shape power across humans and ecosystems. The constraint that is identified in the *Design Brief* therefore limits innovation to proposals that can provide transparency and thoughtful consideration about who and what new platforms serve and how decisions, data, and interfaces shape power across humans and ecosystems.

7. Design Openings: Propositions that Make new Realities Possible

What would it mean for a dataset to breathe? How do other life-worlds inspire monitoring? How can a new dashboard inspire humans to understand another species in new ways? What could a vital biodiversity credit system look like? How can more vital data tools help corporations drastically increase their nature-positive ambitions? What if environmental monitoring tools can forget, compost, or evolve? Can data platforms surface what is missing, not only what is measured? How could a more vital metric become part of corporate sustainability reporting? How can a quantitative data visualization be redesigned according to vital data principles? What if non-human species could initiate alerts in a dashboard system?

The design principles and criteria provide high-level strategies that can structure biodiversity technologies at any scale. In addition, the questions raised above are the design openings, from the *Design Brief*, intended to activate more tangible ideas towards vital biodiversity systems. Such propositions aim to provoke new ideas and provide a starting point for ideation processes. To design data systems that can inform ecological pathways, hybrid approaches that can integrate both analytical/scientific insights as well as narratives/scenarios that mediate other ecological realities can create the in-depth understandings that are needed to acknowledge complex decision spaces (Jonassen, 2012).

Besides finding new inspiration by following these questions into new areas for design, a portfolio of exemplary design work that aligns with the recommendations in the *Brief* (even if partially) also helps to create new possibilities. Proposals for new environmental technologies that align with several components of this *Brief* can be found in the field of design/artistic research:

For example, a 2021 artwork of Daisy Alexandra Ginsberg presents a digital tool to create a blueprint for a garden that is speculatively designed by a bee, butterfly, or other pollinator. Based on the user's location and climate, an algorithm seeks out the ecosystem preferences of local pollinators and presents a new garden design (Ginsberg, 2021). The human user can then plant the garden not according to their own aesthetic preferences, but in support of the greatest diversity of pollinator species (ibid.). People and organizations across the world have planted Ginsberg's pollinator gardens and documented the ecosystem responses. In these projects, the goal of the digital tool is not to document or monitor gardens most efficiently, but rather to use ecosystem data about pollinator and plant relations to propagate flourishing ecosystem interventions where pollinator species are put in charge of determining how the ecosystem evolves. This work aligns well to this *Design Brief* because it is rooted in the vital aesthetics of pollinator species rather than humans, and it implements organic design in the form of physical gardens as outputs. The tool is specifically designed for ecosystems as stakeholders and it redirects the value of biodiversity data from reporting data to creating living ecosystems themselves.

Another generative example includes a 2025 design exploration by Giaccardi, Nam, and Nicenboim. Their work presents digital interfaces that engage with available forest simulation data of an urban forest and reworks this data into more dynamic relational phenomena where users can create customized timelines that display different forest entities by traveling through multiple partial narratives (Giaccardi et al., 2025). Rather than treating environmental data as fixed fragments representing singular objects, this work deliberately visualizes multiplicities, fluid boundaries, movement, and intersections that deepens complex ecosystem data. By representing the possible preferences of different forest entities such as birds, earthworms, soil, and trees, decision-making about the forest's future becomes more informed by a variety of different data sources and the tensions between them. This work aligns well with the *Design Brief*, because it deliberately foregrounds the depth found in biodiversity data, and engages relations between different ecosystem entities that can better show the complexities and trade-offs between ecosystem processes and their data.

Thirdly, biodiversity data initiatives led by Indigenous communities are able to challenge dominant systems by integrating less conventional and locally important epistemologies, values, and relations to nature. An example includes Savimbo's rethinking of biodiversity credits into a less metric-driven and more locally adapted approach focusing on protecting the livelihood of forest communities. This initiative aims to reshape extractivist conservation economies by inviting small farmers and Indigenous groups who guard primary forests to participate in the biodiversity credit market (Savimbo, 2025). Another example includes Mapeo for ICCAs, a mobile application designed with and for local communities to enable custodians to map, monitor and support their territories of life (also called ICCAs) on their terms (Mapeo for ICCAs, 2025). Such projects help to expand economic and community-driven understandings of ecosystems and could lead to new types of data and value structures for protected forests.

These examples, as well as the design propositions listed in the *Brief*, open new design spaces that stretch current possibilities for the design of biodiversity data systems. Such works are part of a growing portfolio of vital designs that translate research findings aligned with this paper to new proposals and possible futures. By asking "what if" and "how about" questions, they resist the status quo of innovation in this field and embrace the plural, more complex realities of ecological and technological systems. Such design openings might not offer immediately scalable solutions, but they can provide a methodological interface between analysis and innovation, using approaches such as speculative design and foresight techniques, these artefacts help to undo the status quo of existing tools and lead to more ambitious transformations instead. This connects to the *Design Brief's* call with the need for more innovative ideas, as these propositions and artifacts identify emerging ideas, create new trends, and present still under-explored edge cases.

8. List of Data Resources

See below for a list of guidance frameworks and datasets that provides tangible input for new proposals. While such datasets and frameworks are continuously updated and redeveloped, they are foundational to the design of vital biodiversity systems. Key here is to rethink how data technologies can engage this data according to principles, criteria, constraints, and stakeholder needs outlined in this paper.

Open datasets on species occurrence:

- Global Biodiversity Information Facility (GBIF) with key contributions from citizen science datasets iNaturalist and eBird (Cornell Lab)
- Ocean Biodiversity Information System (OBIS, UNESCO, International Oceanographic Data and Information Exchange)
- Map of Life (Center for Biodiversity and Global Change at Yale University)

Open datasets on status and trends:

- Living Planet Index Database (Zoological Society of London and World Wide Fund for Nature)
- IUCN Red List of Threatened Species (International Union for Conservation of Nature and Natural Resources)

Open datasets on habitats and land use:

- Global Forest Change (Hansen et al. University of Maryland)
- Gridded Livestock of the World (Food and Agriculture Organization of the United Nations)

Open datasets on spatial priorities and governance:

- Protected Planet (World Database on Protected Areas, United Nations, International Union for Conservation of Nature and Natural Resources)
- Key Biodiversity Areas (The Key Biodiversity Area Partnership)

Guidance, scenarios, and policy documents for biodiversity assessment, and reporting:

- The Kunming-Montreal Global Biodiversity Framework (KMGBF)
- The Taskforce on Nature-related Financial Disclosure (TNFD)
- The Science-Based Targets Network for Nature (SBTN)
- The Intergovernmental Panel on Climate Change's Sixth Assessment Report (IPCC)
- The European Union's Corporate Sustainability Reporting Directive (CSRD)
- The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services Work Programme (IPBES)

Catalogues with currently existing digital tools and platforms that perform data aggregation, analysis, and visualization. These should be critically evaluated in relation to this research:

- The Taskforce on Nature-related Financial Disclosure's Tools Catalogue with >200 tools.
- NatureTech Collective's Directory with >900 tools.
- Global Nature Watch (Land & Carbon Lab) AI assisted geospatial analysis tool.

9. Conclusions

This document provides the research background and rationale to develop more vital biodiversity systems. Current data tools and platforms for biodiversity fall short of being meaningful to key stakeholders because they prioritize the logic of computation and data and lack a clear connection to the KMGBF's vision for a world of living in harmony with nature by 2050. This paper underscores that biodiversity data tools must evolve from being data-driven to being life-driven. By embedding vitality into design new biodiversity systems can help transition corporate, community, and ecological stakeholders toward regenerative futures. Designers, developers, biodiversity system funders, corporate sustainability teams, and other future-makers are called to support initiatives that transform biodiversity data from fragmented information into vital, actionable, and meaningful insights to support regenerative ecosystems.

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