BIODIVERSITY CREDIT ALLIANCE

Foundations for a Digitally Native Biodiversity Credit Market: Integrating Digital Trust Infrastructure

Issue Paper No. 4

MAY 2026

A new market in nature credits needs the best possible start

The Biodiversity Credit Alliance (BCA) exists to guide the development of a credible and scalable biodiversity credit market capable of earning the trust and confidence of a broad spectrum of market participants. Key among them are Indigenous Peoples and local communities who live at the frontline of the nature crisis and are represented by International Environmental Guardianship (IEG), an independent member-based organization of Indigenous Peoples, Local Communities and Afro-Descendants. Together we are working to ensure strong foundations and principles exist and can be applied by all entrants to the market.

Our Mission

BCA is a voluntary international alliance that brings together diverse stakeholders to support the realization of the Kunming–Montreal Global Biodiversity Framework, in particular Targets 19(c) and (d), which "encourage the private sector to invest in biodiversity" utilizing, amongst others "biodiversity credits ... with social safeguards."

Our mission is twofold:

- Help steer the development of a biodiversity credit market by building a framework of high-level, science-based principles.
- Provide guidance and encourage best practice for market participants on the application of these principles, empowering them to achieve and maintain equitable, high-quality transactions that meet strict integrity criteria.

BCA was launched during the Fifteenth meeting of the Conference of the Parties to the Convention on Biological Diversity as an informal group of field-based conservation practitioners, researchers and standard setters. It has grown to include representatives of Indigenous Peoples, Local Communities and Afro-Descendant Peoples in the form of International Environmental Guardianship, as well as private sector representatives, including the World Business Council for Sustainable Development.

The BCA Secretariat is powered by United Nations Development Programme (UNDP) and supported by United Nations Environment Programme Finance Initiative (UNEP FI), Swedish International Development Cooperation Agency (SIDA), German Federal Ministry for Economic Cooperation and Development (BMZ), implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, European Commission (EC), Development Bank of Latin America and the Caribbean (CAF), and UNDP BIOFIN.

How this BCA Issue Paper was Produced

BCA Issue Papers are developed to provide background, analysis, and research on key topics relevant to the formulation of a market in biodiversity credits. BCA Issue Papers are led by members of the BCA Taskforce and co-created by a dedicated Working Group, composed predominantly of BCA Taskforce, International Environmental Guardianship (IEG) and BCA Forum members.

The BCA Digital Working Group was led by the Hedera Foundation, represented by Hania Othman and co-ordinated by Nova Institute represented by Christiaan Pauw. Working group members included CreditNature represented by Paul Jepson, EKOS represented by Sean Weaver, Rebalance Earth represented by Walid Al Saqqaf, and Green Digital Finance Alliance represented by Catherine Foster.

The paper was submitted for an initial review to a panel of technical experts constituting BCA Forum Members and partners. Post this review, the working group incorporated the panel's feedback into the paper which benefited with contributions from the following institutions: Eppel Sustainability Ltd represented by Sara Eppel, Green Praxis represented by Jerome di Giovanni, Hashgraph represented by Giuseppe Bertone, Natural State represented by Jenny Farmer, Regen Network represented by Tica Lubin, and UNDP represented by Vu Hanh Dung Nguyen, Dominique Mieguim Nginpogni, and Douglas Marett.

The paper was then soft launched at a CBD COP16 side event as a working draft before it was submitted to IEG (International Environmental Guardianship) members, for further review and consultation during which specific inputs, feedback and suggested wording were provided by Nathalie Whitaker representing Toha Network, WarīNkwī Flores and Esther Netshivhongweni.

Finally, the paper was submitted for Forum Review where it benefitted from further feedback and refinement thanks to the Great Barrier Reef Foundation represented by Kristina Koenig, Nutawa sagl represented by Casper Vander Tak, NTT Data represented by Mireia Vilaplana, Seatrees represented by Orion McCarthy, Sintropica Capital Natural represented by Fernando Henrique de Sousa, University of Nottingham represented by Richard Field, and Yale University School of Forestry and Environmental Studies represented by Florencia Montagnini.

Coordination and editorial support was rendered by the BCA Secretariat (Manesh Lacoul, Josh Brann, Jacques Massardo, Belicia Teo and Saeng Touttavong).

Suggested citation: Biodiversity Credit Alliance (2026). Foundations for a Digitally Native Biodiversity Credit Market: Integrating Digital Trust Infrastructure. Issue Paper.

Table of contents

Disclaimer and Feedback

The primary objective of this paper is to establish guiding principles that can be reflected and embedded within rule-based digital solutions for biodiversity credit issuance, transfer, and retirement. The aim is to ensure that these processes are accurate, well-documented, verifiable, equitable, and transparent, thereby fostering trust and efficiency within biodiversity credit markets. This work represents preliminary efforts to articulate the foundational elements required for a digitally native biodiversity credit market, including the role of digital trust infrastructure in supporting market integrity. Given the current lack of a standardized legal framework, pinning down the digital logic with precision remains challenging. As such, it is recognized that certain areas may require further development and refinement.

Any feedback should be shared with Josh Brann and Manesh Lacoul as representatives of the BCA Secretariat (secretariat@biodiversitycreditalliance.org)

Executive Summary

The global shift toward a nature-positive economy requires financial mechanisms capable of directing substantial new resources toward the conservation, restoration, and sustainable use of biodiversity. Biodiversity credits have emerged as one such mechanism—with the potential, if designed well, to mobilize private sector finance at the scale needed to close the biodiversity finance gap, estimated at US$ 700 billion per year. For this market to develop with integrity, credibility, and equitable participation, it must be built on strong digital trust infrastructure.

This Issue Paper—Foundations for a Digitally Native Biodiversity Credit Market: Integrating Digital Trust Infrastructure—offers the first comprehensive framework for how digitally native biodiversity credits can be created, transacted, and retired within a transparent, interoperable, and rights-based digital ecosystem. Developed through extensive collaboration across BCA Taskforce members, Indigenous Peoples, Local Communities and Afro-Descendant Peoples through IEG, technical experts, standards bodies, and digital innovators, it provides foundational guidance for designing the digital infrastructure that could underpin a high-integrity global biodiversity credit market.

Why Digital Representation Matters

Biodiversity markets involve complex ecological data, diverse stakeholders, and multi-layered transactions. Traditional record-keeping and semi-digital systems cannot provide the transparency, verification, comparability, and auditability required for biodiversity credits to be trusted and scaled.

Digital representation—using cryptographically secure, machine-readable, interoperable digital artifacts—enables:

- **Transparency**, by making all relevant data accessible, tamper-evident, and traceable
- **Auditability**, through verifiable digital records and decentralized validation
- **Comparability**, via standardized schemas, ontologies, and data structures
- **Efficiency and reduced transaction costs**, through automation and smart contracts
- **Equity and inclusion**, by embedding rights-based safeguards and Indigenous Data Sovereignty into digital systems

A digitally native market is not simply a digitized version of today's systems—it is a fundamentally new architecture that leverages the capabilities of digital technology to create trustworthy, scalable, and equitable biodiversity credit systems.

Core Elements of a Digitally Native Market

The paper sets out the essential components of digital representation for biodiversity credits:

1 Standardized Data Structures and Definitions

Digital biodiversity credits require harmonized schemas, taxonomies, ontologies, identity systems (DIDs and verifiable credentials), and naming conventions to ensure interoperability across platforms, jurisdictions, and standards.

2 Representation Quality

Digital artifacts must accurately reflect ecological realities. The paper outlines how validity, reliability, accuracy, uncertainty, and causal attribution must be encoded in representation methods, including metadata, measurement rules, and methodological safeguards.

3 Lifecycle of a Digital Biodiversity Credit

The paper maps a fully digital lifecycle from:

- **Origination** (project design, validation, monitoring, verification, issuance)
- **Distribution** (trading, transfer, secondary markets)
- **Retirement** (final destruction of the token enabling a biodiversity-related claim)

Digitally native workflows—via verifiable compute, content-addressable storage, digital MRV, decentralized review, and smart contracts—can dramatically enhance efficiency, reduce risk, and improve integrity.

4 Stakeholders and Legitimate Claims

Digital artifacts clarify what claims can be made by each actor—originators, financial capital providers, intermediaries, and end users—ensuring that value flows are transparent and that claims cannot be misrepresented or duplicated.

Market Requirements: Equity, Transparency, and Scalability

To meet BCA's vision of a transparent, trustworthy, and equitable global market, the paper defines key market requirements:

- **Equity:** fair compensation and benefit-sharing for all contributors, especially Indigenous Peoples, Local Communities and Afro-Descendant Peoples
- **Transparency:** open data on methodologies, pricing, MRV, project attributes, and benefit flows
- **Scalability and Efficiency:** streamlined digital processes, automated safeguards, and liquidity-enabling platforms

Digital representation enables all three, ensuring that the market is not only functional, but fair and durable.

Looking Ahead: Digital Public Infrastructure, Nature ID, and Possible Next Steps

The conclusion of the paper points toward a broader vision: the creation of **Digital Public Infrastructure (DPI) for nature**—shared, open, interoperable digital systems that underpin the entire biodiversity credit ecosystem and other nature-related finance instruments. This includes open ontologies, data schemas, verifiable identities, tamper-evident storage, digital MRV modules, registries, and governance protocols. This represents a potential future pathway for scaling and integrating the digitally native market architecture described in this paper across jurisdictions and systems.

A major opportunity highlighted is the development of **Nature ID**: a global, verifiable system for uniquely identifying ecological features, species, datasets, and interventions. Nature ID would significantly strengthen the integrity of biodiversity MRV, reduce monitoring costs, and improve comparability across projects and jurisdictions.

The paper also emphasizes that digital transformation must be rights-based and inclusive. Future work by the BCA Digital Working Group will focus on:

- **Indigenous Data Sovereignty**, ensuring communities control data derived from their lands and knowledge systems
- **Indigenous cultural and ecological IP protections** embedded directly into digital workflows and permissions
- **Capacity building and bridging the digital divide**, including low-bandwidth tools, community-led pilots, and training

- **Open, modular digital components**, such as workflow engines, smart contracts, and verifiable compute methods
- **Demand-side integrity**, complementing supply-side digital safeguards to ensure accurate, non-duplicated biodiversity-related claims

Conclusion

Digital representation, as part of broader digital trust infrastructure, is foundational to the development of a credible, scalable, and just biodiversity credit market. It enables markets to embody transparency, efficiency, and comparability, while safeguarding rights, strengthening community participation, and ensuring the environmental and social integrity of every issued unit.

This Issue Paper marks an early but critical contribution toward building the digital infrastructure required to support nature-positive finance globally. The next phase—advancing Nature ID, co-creating DPI for nature, operationalizing Indigenous Data Sovereignty, and investing in digital capacity for communities and countries—will be essential to ensuring that biodiversity credit markets not only function, but truly deliver on their promise: mobilizing meaningful, equitable, and verifiable investments in the protection and restoration of the world's biodiversity.

Purpose and Scope of this Paper

This is the first version of "Foundations for a Digitally Native Biodiversity Credit Market: Integrating Digital Trust Infrastructure", setting out foundational elements for the development of a high-integrity, digitally native biodiversity credit market. It incorporates practical experience, research, collaboration, and expertise from diverse stakeholders, and is grounded in key digital principles including **auditability, discoverability, transparency, immutability, and scalability**. The paper is written as guidance for practitioners across the biodiversity credit ecosystem, outlining the foundational elements and digital trust infrastructure required for a digitally native biodiversity credit market. By clarifying the structural requirements for the digital representation of biodiversity credits, including those relating to key credit attributes, the paper seeks to strengthen transparency, integrity, and confidence in emerging biodiversity credit markets.

Objective

The primary objective of this paper is to provide a set of guiding principles that can be reflected in digital infrastructure supporting biodiversity credit issuance, transfer, and retirement, enabling biodiversity-related claims to be accurate, comprehensively documented, verifiable, equitable, and transparent.

How this Paper is Organized

Part 1 **Background, Key stakeholders, Accounting Principles and Market Requirements**—lists key stakeholders in the market, with particular reference to the value that is exchanged between them and their responsibility to record and report it in order for the market to operate efficiently. Readers familiar with stakeholder roles, value exchange, and associated accounting and reporting responsibilities in non-digitally native biodiversity credit markets may wish to skip directly to Part 2.

Part 2 **Fundamentals of Digital Representation**—outlines key concepts and definitions that can be used in the establishment of a digitally native biodiversity credit market.

Part 3 **Lifecycle of a Digitally Native Biodiversity Credit**—describes the three phases in the lifecycle of digitally native biodiversity credits: their origination, distribution, and retirement.

Part 4 **Digital Requirements**—explores technological zones that connect attributes of nature with the needs and practices of finance and ESG reporting, and outlines the effective organization, structure, and use of data required to support a high-integrity, digitally native biodiversity credit market.

Part 5 **Considerations for Implementation of Digitally Native Biodiversity Credits**—highlights considerations for implementation, with particular focus on community participation and the embedding of Indigenous Data Sovereignty and Intellectual Property into digital infrastructure.

PART 1: Background, Key Stakeholders, Accounting Principles and Market Requirements

1.1 Background

As the world grapples with the need to achieve a nature-positive economy, the urgency to deploy strategies that counteract existing biodiversity loss has grown. This has stimulated private sector demand for opportunities to participate in biodiversity conservation and enhancement in a manner that integrates with private sector approaches to financing. Within this context, biodiversity credits have been identified by the Kunming-Montreal Global Biodiversity Framework (GBF) as one of several instruments that have the potential to mobilize private sector finance for nature.

There is a cost inherent in the protection of nature. According to the United Nations Environment Programme's *State of Finance for Nature Report*, this cost manifests as a US$ 700 billion annual financing gap that must be closed by 2030 to halt and reverse biodiversity loss. Biodiversity credits are a mechanism that can unlock new sources of funding for nature conservation. As such, the focus is not to put a price on nature, but to price the labor and technology required to protect, conserve, and restore it.

Due to the dynamic complexity of nature and society, it is essential that biodiversity credit markets are founded on strong principles of transparency, traceability, and accessibility. Markets will only scale if they are underpinned by high-integrity and equitable systems that are grounded in trust. This, in turn, requires digital systems capable of embedding these properties directly into market infrastructure.

A *digitally native* biodiversity credit market isn't just about converting paper-based information and processes into digital form. It involves leveraging the unique features and capabilities of digital technology to create innovative, efficient, and transparent ways of operating which would not be possible in a non-digital environment.

For instance, by adopting distributed data management systems that utilize decentralized technology and open standards, it becomes possible to enable seamless data sharing and the reuse and recombination of data across different platforms and use cases. Distributed data systems also empower Indigenous Peoples, Local Communities and Afro-Descendant Peoples, custodians of biocultural knowledge and the living relationships that connect them to their lands, to maintain data sovereignty and control access rights and permissions, while still allowing for shared insights and collaborative analysis.

In this way, digital infrastructure becomes more than a technical layer, it forms the foundation for **trust, interoperability, and accountability** in biodiversity credit markets, allowing data to be structured and connected in a way that aligns biodiversity outcomes with broader sustainability goals. Achieving this begins with the digital representation of a biodiversity credit—a structured and verifiable digital record that captures the ecological and social attributes of the credit's underlying impact, enabling surrounding systems to operate with transparency and inclusivity.

1.1.1 Definition of a Biodiversity Credit

After an extensive process of broad stakeholder engagement that sought to balance a wide variety of divergent but legitimate viewpoints, BCA has proposed the following definition for a biodiversity credit:

> "A biodiversity credit is a certificate that represents a measured and evidence-based unit of positive biodiversity outcome that is durable and additional to what would have otherwise occurred."[1]

The certificate referred to in this definition represents a suite of benefits delivered by the underlying project activity aimed at biodiversity recovery, preservation or risk reduction that results from the application of organization, know-how, labor and technology. This paper sets out the requirements for the digital representation of a biodiversity credit.

In related work, a set of High-Level Principles defining integrity criteria for high-quality biodiversity credits—including durability, transparency, equity, and verification—was developed by Biodiversity Credit Alliance in partnership with several organizations including the International Advisory Panel on Biodiversity Credits (IAPB) and the World Economic Forum (WEF). While developed independently, this paper addresses similar integrity considerations by exploring how such criteria can be incorporated into the digital representation of high-integrity biodiversity credits.

1 See BCA (2024, p. 7), Definition of a Biodiversity Credit Issue Paper No. 3.

1.1.2 The Need for Standardization

All actors in the emerging biodiversity credit market share an ambition to build on learnings from other environmental markets to enhance rigor, transparency, and scalability. A significant challenge lies in distinguishing between the myriad technological solutions available and identifying those that support **market-wide interoperability, comparability, and trust**.

As technology, business, and environmental market solutions continue to converge, the expertise needed to identify impactful solutions grows increasingly important. A useful analogy is the development of Bluetooth standards. Initially, each provider had its own standard, leading to fragmentation and inefficiencies. The formation of the Bluetooth Special Interest Group (SIG), established a unified standard that greatly improved interoperability, reliability, and user confidence across devices.

Similarly, in the realm of digital biodiversity credits, there is the risk of fragmentation if each entity develops its own approaches. To ensure these digital representations (of biodiversity credits) are reusable, verifiable, and comprehensible across systems, a shared approach to data structures, protocols, and governance, akin to the role played by Bluetooth standards, is essential. Such alignment supports interoperability and helps establish the digital trust required for a coherent and scalable market, ultimately serving all practitioners and end users more effectively.

1.1.3 The Implementation of Digital Trust Technologies

The modern *cryptographic trust stack*, the layered technology that makes verifiable digital trust without centralized intermediaries possible, has its roots in early research in cryptography, distributed systems, and fault-tolerant computing beginning in the 1970s. The basic cryptographic approaches in use today (the so-called *cryptographic primitives*, which include hashing, public-key cryptography, and digital signatures) and integrity-preserving data structures forming the basis of current decentralized systems (e.g., Merkle trees), were also developed in the last quarter of the 20th century. Work on distributed consensus systems continued through the 1980s and 1990s. In 2008, an open, permissionless consensus mechanism using *proof-of-work* to coordinate participants without a central authority came to public attention.

More recently, these technologies were used to create systems for cryptographically verifiable digital identities that do not require trusted intermediaries (e.g., decentralized identifiers and verifiable credentials). Today, a growing number of application systems, including smart contracts and decentralized applications, are built upon these cryptographic primitives, integrity-preserving data structures, distributed consensus, and digital identity technologies, contributing to the emerging infrastructure for digital trust.

The maturation of the modern cryptographic trust stack makes it possible to imagine a rule-based digital platform for biodiversity credits. These technologies can be used to transparently and immutably record and share data on biodiversity benefits delivered, and integrity attributes associated with those benefits. Implementing these technologies can enhance integrity, transparency, and trust. This enables biodiversity credit originators to issue digital assets and transact them with parties seeking to generate the underlying biodiversity benefits by purchasing (and eventually retiring) the assets.

Distributed Ledger Technology (DLT) allows for the digital representation of the entire biodiversity credit value chain (including the chain of custody), facilitating a high-integrity, transparent, and efficient marketplace.

Public-key cryptography enables end users (market participants) to assert their ownership of digital assets (biodiversity credit certificates) and securely communicate and transact with peers. This is possible because mathematically linked pairs (a public key for encryption and a private key for decryption) are utilized. The public key is freely distributed, but the private key is held confidentially.

Content-addressable storage systems enable tamper-evident data storage by addressing data with a unique digital identifier based on the content of the data itself. This unique identifier, or hash, acts as a fingerprint to ensure authenticity and immutability.

Smart contracts allow for the autonomous execution of previously agreed arrangements between parties on a digital network and can be used to perform various forms of automation.

The adoption of a digital framework for biodiversity credits, underpinned by security standards and emerging technologies, would support the development of shared, interoperable, and trustworthy digital infrastructure for accounting, reporting, and exchanging biodiversity impacts. Such a framework has the potential to serve as a tool for aligning conservation activities with global biodiversity targets and demand, offering an actionable pathway for stakeholders.

1.1.4 The value of digital representation

The value of the digital representation of a biodiversity credit certificate is **dependent on the integrity of the quality system that underlies it**. For the value of the biodiversity credit to be apparent, its digital representation must contain digitally accessible evidence of its integrity attributes. These include (but are not limited to) activity type, benefit delivered, measurement reporting and verification (MRV), additionality, pricing transparency, permanence safeguards, social safeguards, and the period over which the impact occurred.

1.2 Key Market Stakeholders

With an understanding of key market participants and how value is exchanged between them, it becomes easier to see the potential for technology to be implemented throughout the biodiversity credit value chain. While the biodiversity credit value chain includes a diverse set of stakeholders, this paper examines the market from a broad perspective. For simplicity, stakeholders are grouped into five categories: financial capital providers, originators, supporting entities, intermediaries, and end users.

At the simplest conceptual level, biodiversity credit projects need natural capital in the form of ecological infrastructure (i.e., an ecosystem), and technical resources to deliver interventions that maintain or cause beneficial biodiversity impacts in the target ecosystem. Technical resources require financial resources. The way that financial resources are provided to projects in a biodiversity credit market is ultimately through the sale of biodiversity credits to biodiversity credit buyers. However, financial capital providers are often needed to fund the establishment of projects since there is often a long delay before cash flows from the sale of biodiversity credits are realized.

Project **originators** include the **ecosystem owner** (providers of natural capital, which may include land owners, legal tenants or custodians) and the **project developer** (provider of technical resources). Project originators secure project revenue by raising financial capital (selling an opportunity for a return on investment), selling biodiversity credits, and by way of benefit sharing.

The originator of biodiversity credits is the person/entity seeking to make an **origination biodiversity-related claim** and is the **source of biodiversity credits**. An origination biodiversity-related claim is a claim to have caused beneficial biodiversity impacts by providing necessary technical resources to the biodiversity project. Origination biodiversity-related claims are delivered in the form of project reporting that is third-party verified to a recognized standard. Without the originator there would be no supply of biodiversity credits and no market.

Biodiversity credit **buyers** include both **intermediaries** (e.g., traders in a secondary market) and **end users** (the organization/person seeking to make an **end user biodiversity-related claim**). The end user, the party who buys and ultimately retires the credits, plays a unique and fundamental role in the biodiversity credit transaction value chain. The consumer and end user in a biodiversity credit market is the natural or legal person seeking to make a **financial biodiversity-related claim** (e.g., for Taskforce on Nature-related Disclosures reporting). A financial biodiversity-related claim is a claim to have caused beneficial biodiversity activities, outcomes or impacts by providing necessary financial resources to the biodiversity project. Without end users there would be no demand for biodiversity credits, no biodiversity credit market, and no financial or non-financial benefit for any other value chain stakeholder.

BCA's *Demand-side Sources and Motivation for Biodiversity Credits (Issue Paper No. 1)* presents information on the potential sources of demand for biodiversity credits (regulated and voluntary), attributes of credits that may influence buyer behavior, as well as standards and principles that are likely to be important to some or all these demand sources (BCA, 2023).

Financial capital providers are the suppliers of financial capital to biodiversity credit projects. Financial capital is needed for project establishment and to get the project to the point at which it can issue and sell biodiversity credits and thereby become financially self-sustaining. Providers of financial capital include those seeking a financial return on investment (investors), and those not seeking a financial return on investment (grant providers). Whilst capital providers deliver important financial resources to biodiversity credit projects, their primary reason to participate in biodiversity markets is to provide capital and enable project establishment. Capital providers can make **impact investment claims**.

Other stakeholders in the biodiversity credit value chain include entities that set standards or requirements, such as regulators and voluntary standards bodies. Organizations involved in providing assurance against these standards include various validation and verification bodies (VVBs), as well as independent validators and verifiers. Crediting programs and registries govern the trade and use of credits or certifications produced under these standards, while credit rating agencies evaluate the risks associated with specific standards, project types, regions, or developers.

On the practical side, best practice setters and methodology developers create implementation and measurement tools. Specialized service providers offer services related to implementation or monitoring.

Intermediary services providers are entities that provide demand-side facilitation services to support market functioning. This includes brokers, resellers, traders, trading platforms, and programs.

A secondary market is a market that is facilitated by intermediaries where tradable assets such as digital biodiversity credits are sold by the originator, purchased or brokered by an intermediary, and potentially on-sold many times until consumed by a consumer. A secondary market is, therefore, dependent on consumers functioning as the sink for biodiversity credits.

Intermediaries are not biodiversity credit suppliers or consumers, but instead function as **biodiversity credit reservoirs** that hold biodiversity credits and/or facilitate their transfer between the ultimate source and ultimate sink. Because biodiversity credit intermediaries are neither biodiversity credit suppliers nor consumers, they cannot make a financial or technical biodiversity-related claim. Intermediaries do, however, provide liquidity to the market and can legitimately make **biodiversity market supporting claims**.

Table 1 summarizes the claims that can be made in the biodiversity credit value chain by each of the parties involved (column one) and also provides examples of claims that can not be legitimately made (column four). The digital artifact associated with each claim is described in column two.

Table 1: Validity of claims in biodiversity credit value chains

Claimant	Digital Artifact	Valid Claim	Invalid Claim	Remarks
End user	End user certificate – biodiversity-related claim	Has retired x biodiversity credits, and thereby provided the necessary demand and financial resources for the delivery of positive biodiversity outcomes in the project area	Has unilaterally caused the positive biodiversity impact	Without end-user demand and willingness to pay for biodiversity credits, the market for such assets could not exist; end users therefore constitute a necessary condition for the existence of the market
Intermediary services provider	Intermediary services certificate	Has provided intermediary services to enable a biodiversity market to function, thereby supporting positive biodiversity outcomes in the project area	Has unilaterally caused the positive biodiversity impact	Ownership without retirement of tradable assets does not equate to end-use or end-use claims; intermediary service providers are not obligatory service providers for a biodiversity credit project but can be obligatory for enabling scale
Financial capital provider	Impact investment certificate	Has provided the financial capital necessary to initiate positive biodiversity outcomes in the project area	Has unilaterally caused the positive biodiversity impact	Financial capital providers are not obligatory service providers for a biodiversity credit project but can be obligatory for enabling scale; the financial capital provider can be the originator or the end user
Originator (technical resources / project developer)	Origination (technical resources) certificate	Has provided the technical resources to cause positive biodiversity outcomes in the project area	Has unilaterally caused the positive biodiversity impact	The technical resources provider is an obligatory stakeholder in a biodiversity credit project; the technical resources provider can also be the natural capital provider

Claimant	Digital Artifact	Valid Claim	Invalid Claim	Remarks
Originator (natural capital provider / ecosystem custodian)	Origination (natural capital) certificate	The originator has provided necessary natural capital / resources for the delivery of positive biodiversity outcomes in the project area	Has unilaterally caused the positive biodiversity impact	Provision of natural capital is necessary for a positive biodiversity outcome, and the provider of this capital is an obligatory stakeholder in a biodiversity credit project

In many contexts, **Indigenous Peoples and local communities** play a crucial role as owners or users of natural resources where biodiversity credits are generated. As key rights-holders, their involvement may extend across the value chain, from the governance, design, and implementation of biodiversity crediting projects to monitoring, reporting, and equitable benefit-sharing.

The broader public, often involved only through the media, represents the widest category of stakeholders.

Each party in the value chain can legitimately make certain claims about their contribution to the lifecycle of a specific biodiversity credit.

1.3 Accounting Principles

There is broad consensus among practitioners of various forms of environmental accounting as to the basic principles of accounting for environmental impacts. For example, the World Business Council for Sustainable Development / World Resources Institute (WBCSD/WRI) Greenhouse Gas Protocol[2], the Clean Development Mechanism (CDM)[3] Project Standard for Project Activities as well as the International Organization for Standardization's ISO 14064, all share a set of accounting principles. These principles are also applicable when accounting for positive biodiversity outcomes represented by biodiversity credits.

The relevance of these principles in the context of digital biodiversity credits is elaborated below, along with examples of mechanisms that can be employed to ensure compliance.

2 See WRI and WBCSD (2004, p. 7), GHG Protocol Corporate Standard, and WRI and WBCSD (2005, Section 4.1, p. 23), GHG Project Protocol.
3 See UNFCCC (2019, Section 5, p. 8), CDM Project Standard for Project Activities.

1.3.1 Relevance

The data, methods, criteria, and assumptions that are used should be appropriate for the intended use.

1.3.2 Completeness

All requirements should be met and all relevant information that may affect the accounting and quantification of biodiversity impacts should be provided.

1.3.3 Consistency

Representations made should enable meaningful comparisons over time and between activities, entities, and environments.

1.3.4 Conservative Accuracy

This principle relates to the quality of measurement and means that biases and uncertainties are reduced as much as is practical, and that conservative assumptions, values, and procedures are employed when uncertainty is high. In this context, conservative means that measures should be taken to ensure that the positive biodiversity outcome is not overstated.

1.3.5 Transparency

In terms of the positive biodiversity outcomes represented by a biodiversity credit, representation should provide clear and sufficient information to enable users to assess the credibility and reliability of the unit of value originated, and the biodiversity-related claims arising from the acquisition of such units. The link between representations to their precursors must be maintained.

Together, these accounting principles help ensure that biodiversity credits credibly and transparently represent positive biodiversity outcomes. This emphasis is consistent with the High-Level Principles which uphold positive outcomes for nature. However, credible environmental accounting alone is not sufficient to ensure the effective functioning of a market in biodiversity credits. Appropriate market design and governance structures are also required.

1.4 Market Requirements

BCA´s vision is a transparent, trustworthy, and efficient global market in biodiversity credits founded on just and equitable principles and underpinned by innovation. Achieving this vision requires carefully designed market mechanisms that build on the accounting principles described above while ensuring that biodiversity credit markets function in a fair, transparent, and efficient manner.

The market requirements set out in this section address these broader market design considerations, translating them into practical design requirements for biodiversity credit market infrastructure and mechanisms, thereby supporting the development of a transparent, equitable, and scalable biodiversity credit market. In doing so, they are consistent with the High-Level Principles, particularly their emphasis on equitable participation and good governance.

1.4.1 Equitability

In the context of biodiversity credit markets, equitability means ensuring that all participants in the value chain, from Indigenous Peoples and local communities to project developers, investors, traders, retailers, and end users, have the opportunity to derive fair compensation from their contributions. This requires:

Fair compensation mechanisms which involve the implementation of data, distribution, and pricing structures that allow for the adequate benefit of all stakeholders, particularly those directly involved in conservation and restoration efforts. The aim is to ensure that a significant portion of the revenue generated from credit sales supports on-the-ground activities capable of delivering positive biodiversity outcomes.

Efficiency ratios which are metrics to evaluate the proportion of financial resources that directly contribute to positive biodiversity outcomes versus administrative and transactional costs. A favorable efficiency ratio is indicative of a market that maximizes the allocation of funds toward its intended environmental impacts.

Fair trade which ensures that unit prices are at least cost-based, thereby also ensuring that the price paid by the end user accurately reflects fair compensation delivered to value chain participants (including justifiable risk compensation for such participants).

1.4.2 Transparency

In biodiversity credit markets, transparency requires several layers including:

Market Information accessibility to ensure that all market participants and stakeholders have access to comprehensive data about market operations. This includes the specifics of biodiversity credit transactions, methodologies used for credit generation, attributes of these methodologies, and the outcomes of conservation projects.

Auditability which establishes robust systems for auditing and verification to confirm the authenticity of credits and the integrity of transactions. This includes third-party verification and traceability.

Price transparency that facilitates access to pricing information, including the basis for credit pricing. This supports cost-based pricing, reflecting the actual cost of generating the credits, including the consideration of opportunity costs (i.e., the cost of forfeited opportunities), and ensures that prices are fair and justifiable.

Stakeholder transparency that ensures the benefits and revenues from credit sales are correctly allocated to stakeholders, ensuring a transparent value/price distribution model.

1.4.3 Efficiency and Scalability

Efficiency and scalability are critical for the growth and effectiveness of the biodiversity credit market. This requires the following:

Liquidity and discoverability which requires the development of platforms and exchanges that facilitate the easy discovery and trading of biodiversity credits, enhancing market liquidity and enabling participants to efficiently buy and sell credits.

Cost effectiveness which involves the streamlining of project development and credit generation processes to minimize costs, making it more attractive for investors and project developers to engage in the market without compromising market integrity.

Scalability which involves the implementation of technological solutions and standardized data frameworks and methodologies that allow for rapid scaling of projects, from initiation through to the generation and sale of credits. This includes reducing the time and complexity involved in project validation and credit issuance, thereby accelerating the project cycle.

Fungibility or comparability which requires that to the extent possible, given the diversity of positive biodiversity outcomes, a level of consistency in biodiversity credits is provided. The market will need to be tested regarding the kind of homogeneity typically required in fungible instruments. Transparent, cost-based unit pricing combined with standardized measurement, reporting and verification will provide some form of comparability in an otherwise very diverse sector. Consistency in terms of standardized agreement between buyers and sellers may increase participation and help participants mitigate their risk.

Collectively, these requirements support the development of a biodiversity credit market that is efficient, scalable and capable of supporting broad market participation. Beyond these operational considerations, a core consideration for a digitally native biodiversity credit market is the supply of trustworthy units into the market. The way that such units are used is a demand-side integrity consideration that may result in certain issues that arise with regard to compensatory claims (e.g., biodiversity offsetting), impact claims (nature-positive assertions and the risk of greenwashing), and double counting safeguards (specifically as they relate to end-use claims). These issues are beyond the scope of this document and will be elaborated on in future BCA work on demand-side integrity.

Double counting in nature markets has been defined by the Integrity Council for the Voluntary Carbon Market (ICVCM) to include the elements in Table 2 below, here adapted for biodiversity credits.

Table 2: Double counting in nature markets

Type	Description	Integrity*	Safeguard
Double issuance	One positive biodiversity outcome issued as two biodiversity credits in same or dual registries	No	Legal declaration of originator stored on DLT
Double use	One biodiversity credit used to claim achievement of multiple targets	No	Legal declaration of end user stored on DLT
Double claiming (with mandatory domestic scheme)	A biodiversity crediting program issues a biodiversity credit that is also covered by a mandatory domestic financing scheme	No	Eligibility rules of biodiversity credit program stored on DLT
Double claiming with national targets	A biodiversity crediting program issues a biodiversity credit that is also counted towards a national biodiversity target	Yes	Eligibility rules of biodiversity credit program stored on DLT

*'Integrity' here refers to whether this type of double counting is legitimate and has integrity.

PART 2: Fundamentals of Digital Representation

This part of the paper lays the groundwork for the characterization of digital biodiversity credits by describing how a digital artifact can represent a real-word impact.

Section 2.1, *Digital Artifacts* is an introduction to the term and describes cryptographic digital artifacts as a special class. Section 2.2, *Digital Value* addresses how a cryptographic digital artifact can be a carrier of value. Section 2.3, *What can be Digitally Represented?* discusses how claims and requirements are digitally represented within the context of an ecosystem that creates and uses tokens of biodiversity uplift, avoided loss or maintenance. Lastly, Section 2.4, *Agents and Roles* covers what it means to act in a digital ecosystem that creates and uses tokens of biodiversity uplift, avoided loss or maintenance.

2.1 Digital Artifacts

Digital artifacts represent aspects of the material world, societal relationships and conventions (e.g., currency, moral, or legal rights) or even completely imaginary worlds in the context of a digital network. A digital network is a community of connected electronic devices that can communicate among themselves. The Internet is the best example of such a digital network.

A simple example of a digital artifact is a photo posted on a social media platform on the Internet (the digital network). Anyone with access to the network and privileges on the social media platform, can access the photo. The photo represents that part of the world which is depicted in the image. The representation quality is typically a function of the image resolution. While an (unedited) photo represents a real object in the world from a particular perspective and at a certain point in time, a picture of Spiderman represents a fictional character that exists only in the imaginary world of the Spiderman stories. A contract stored on a computer or network is a digital artifact representing a relationship between parties consisting of the rights and obligations of each party.

Cryptographic digital artifacts are a special class of digital artifact where each artifact is unique and is secured by a cryptographic key. Cryptographic keys use one-way mathematical functions to ensure that data can only be read by a reader who possesses a unique, usually secret, piece of information (referred to as a key). Because each artifact is unique and owners can assert their ownership, cryptographic digital artifacts are suited to be used for the exchange of value. A cryptographic digital artifact that is used to represent something is commonly referred to as a *token*.

In the context of any representation, it is useful to distinguish between its *sense* and its *reference*. The sense is the means of representation while the reference is that which is represented. In the context of biodiversity credits, *that which is represented* are the agents, activities and environments (including artifacts, landscapes, and organisms) involved in actions to enhance or maintain biodiversity. The same thing can be represented by a variety of means. The means of representation will always involve a medium (the thing that can be altered to serve as a vehicle of communication) and a format (a defined structure and encoding system for the processing, storage, or presentation of data). In the context of biodiversity credits, there are many potential media (physical or digital) and many formats through which the same actions to enhance or maintain biodiversity and its outcomes and impacts can be represented.

The way in which a token represents a thing is referred to as the token's *properties*. The changes that a token is able to undergo or cause another token to undergo, are referred to as its *behavior*. Properties and behaviors of tokens are discussed in Appendix 1.

2.2 Digital Value

Cryptographic digital artifacts can, in principle, be used to store and transfer value because they are unique, contain information, and ownership can be asserted. The value of a cryptographic digital artifact to buyers and sellers, like other things, is subjective and driven by preferences. Pure cryptocurrencies are examples of digital artifacts that represent nothing outside the network on which they function. In contrast, digital environmental assets like biodiversity credits, represent actions, outputs, and outcomes outside the digital network. The external phenomena to which biodiversity credits refer are the conservation, maintenance, and restoration of biodiversity within specific geographical, temporal, and measurement boundaries.

The value of biodiversity tokens will thus be determined by:

- The value of that which is represented
- The quality of the representation itself (i.e., the ability of the medium and format to represent the value)

2.2.1 The Value Represented

The subjectivity inherent in markets means that the value of any transaction is determined by those participating in the transaction. Similarly, not everyone cares equally about ecosystems and human interventions designed to protect and/or enhance their intactness and associated functionality as ecological infrastructure or natural capital.

For example, given limited resources, people may differ on whether it is more important to conserve the Amur leopard (*Panthera pardus orientalis*) or the Caucasian leopard (*Panthera pardus ciscaucasica*). Such a value judgment may be determined by completely subjective factors (e.g., one's place of birth or personal experience) or by different ethical considerations (e.g., should one prioritize conservation efforts based on numerical scarcity or those based on ecological function?).

Since differences in value judgements or the philosophical basis from which value judgements are derived are unlikely to be universally settled, the purpose of the representation of this aspect should rather be to *present the basis of value clearly to end users so that they can confidently make decisions*.

Other aspects of the value represented can be more objectively assessed.

Intermediate objectives (i.e., objectives that are instrumental in achieving other objectives) are less important than ultimate objectives (i.e., the desired state of the environment of concern) because their relationship to the ultimate objective is subject to greater uncertainty. In general, representations of outcomes are preferable to representations of activities or inputs, and conversely representations of impacts are preferable to representations of outcomes. This is because, in the context of conservation, maintenance or restoration of biodiversity, the objective of an activity is its outcome, and the objective of the outcome is its impact. For example if, in an attempt to conserve a specific species in a specific location, someone builds a fence and implements regular patrols in order to prevent poaching and preserve a specific species, it would be preferable if the final impact (the population of the species of interest in the area) could be directly quantified as opposed to the outcomes (the fence and the arrests made) or even the activity (the building of the fence and employing of rangers). In practice, there is a gradient in two directions: activities and their outcomes are easier to measure compared to impacts, but the causal relationship between activities, their outcomes and the resultant impacts are difficult to estimate, especially as the complexity of the environment of concern and the temporal distance between action and impact increases. In practice a balance needs to be struck between quantification and valuation of activities, outcomes, and impacts depending on the context.

The basis of a biodiversity token's value must be clear. It should be clear whether the token represents an activity, an outcome, or an indicator of the desired state itself. The end user must be able to understand the relationship between what is represented by the token and an ultimate desired state.

BCA Issue Paper No. 1: Demand-side Sources and Motivation for Biodiversity Credits makes it clear that end users' willingness to purchase a biodiversity credit is influenced by means of representation. Key factors include the *speed and simplicity* of transactions and the *tradability or transferability* of the assets as well as their *auditability and comparability* (BCA, 2023, pp. 19-20). Properties such as these should therefore be design targets for creators of digital infrastructure and artifacts for the biodiversity credit market.

2.2.2 Representation Quality

Representation quality is the degree of validity, accuracy, and reliability with which a valued action or state is represented by a digital artifact. Representation quality broadly depends on two aspects:

- The quality of the representation methods
- The quality of execution of those methods

Quality of the representation methods

The quality of the methods used to create digital representation of real-word agents, activities, environments, and states relies in the first place on the relationship between the parameters measured and the phenomenon it purports to represent.

Construct validity reflects a need for the justification of a relationship between indicators and what they claim to represent. Most complex phenomena can only be measured indirectly. Biodiversity is one such complex phenomenon. The question that arises when someone purports to represent a complex phenomenon with a token is if there even exists such a phenomenon and if the metrics in terms of which the token value is expressed adequately represent the essence of that phenomenon.

A representation method should therefore contain or refer to a justification for the relationship between the indicator (i.e., the definition of the metric in terms of which the token value is expressed) and the desired state it purports to represent.

Measurement validity expresses the relationship between a measurement instrument or method and the aspect of the thing or phenomenon it intends to represent. It is the answer to the question: "Are you measuring what you think you are measuring?"

A representation method should therefore justify the validity of its measurement instruments or methods and indicate quality procedures to ensure the validity of measurements that may include requirements for capturing meta-data or redundancy measures.

Accuracy expresses how close a measurement, observation, or statement is to its actual value. Intuitively, high accuracy is preferable to low accuracy. In practice, however, higher accuracy is often associated with higher cost. There is therefore a need in each context to define a level of accuracy that is of practical significance. Practical significance refers to the level of change in a measurement that would lead to a different function, evaluation, or decision.

A representation method should therefore define the level of accuracy required for each measurement. Where statistical methods are employed, the statistical power requirements should be explicitly stated.

Reliability concerns the consistency of repeated measurements. High reliability may be an indicator of validity. Representation methods may include requirements for minimum variance between instruments or between repeated measurements.

Quality of the execution

The second determinant of representation quality is the quality of the execution of the representation method.

Execution quality relates to:

- The validity of the method to the specific context of application
- The precision with which the method is executed
- The extent to which the execution is documented
- The comprehensiveness of quality assurance and quality control procedures applied
- The degree to which uncertainty is quantified
- The correspondence between alternative valid measurement methods (triangulation)

BCA Issue Paper No. 1: Demand-side Sources and Motivation for Biodiversity Credits also lists thirteen factors that influence end users' willingness to purchase a biodiversity credit. At least five of these are related to representation quality: *Transparency on Free, Prior and Informed Consent, Evidence, Clear rights, Auditability, and Comparability*. In each of these cases, the clarity and completeness of documentation is a common factor. In the case of *Comparability*, the quality of the methods applied is also relevant (BCA, 2023, pp. 19-20).

2.3 What can be Digitally Represented?

In the context of an ecosystem that creates and uses tokens of biodiversity uplift, avoided loss or maintenance, there are two broad classes of things that can be digitally represented: *claims* and *formal statements*.

A *claim* is an assertion about any particular thing.[4] The things that are potentially the subjects of claims may be environments, objects, artifacts, relationships, agents, activities, events, or representations. The basic structure of a claim is: '*x* is a *y*' or '*x* has property *y* (with value *z*)'. Any naming or categorization (such as "my name is John" or "this is an apple") follows the structure '*x* is a *y*'. Any description follows the structure 'x has property *y*' and any measurement (such as "this table is 76 cm high") follows the structure '*x* has property *y* with value *z*'. All data are claims. Metadata, in so far as it is data, is also a claim. Implicit in all claims are a claimant and the time at which the claim was made. The minimum metadata that will exist for every datum is therefore the claimant and time of claim.

Formal statements, unlike claims, are not assertions about the real world but are instead concerned with the representation, structure, or rules that govern a formal system. Formal statements specify how things are defined, categorized, related, or processed within a formal system. For the sake of convenience, formal statements can be subdivided into requirements, definitions, and functions.[5]

A *requirement* is a condition or set of conditions that an environment, object, artifact, relationship, event, or representation must satisfy. The basic structure of a requirement is: 'for *x* to comply with *y*, it must conform to *z*'. All rules are requirements. A *definition* categorizes or labels something by providing an explicit description. *Functions* are formal statements that describe transformations or operations within a system. For example, the square root function is defined as a process that, for a given non-negative number *x*, returns a number y such that $y^2 = x$.

Examples of different types of claims and requirements that may be digitally represented are:

- **Claims**
  - An allocation or assertion of a right (e.g., a title, option)
  - A claim about the real or counterfactual dimensions of an activity

4 Readers familiar with semantic web technologies will recognize the similarity between this paragraph and the Resource Description Framework (RDF) and the Web Ontology Language (OWL), both of which are based on the semantic triple (Subject–Predicate–Object). See RDF 1.1 Concepts and Abstract Syntax.

5 This is only for convenience because a definition can be formulated as a requirement and a requirement can be formulated as a function: For example, saying "The definition of a mammal is a warm-blooded vertebrate animal characterized by the presence of hair or fur and mammary glands" is equivalent to saying "For something to be called a mammal, it must be a warm-blooded vertebrate animal with hair or fur and mammary glands." In turn, a requirement can be viewed as a function that returns "compliant" or "non-compliant".

    - A claim about the real or counterfactual state of an environment
    - A claim about a state change—since a state change is the difference between at least two states, a claim about a state change implies at least two claims about states at different points in time
    - A claim about a causation of a state change—this is the claim that a state change is due to the activity of an agent, this is the core claim that a biodiversity credit represents
    - A claim about the output of an activity
    - A claim about the outcome of an activity, outcome being the ecological infrastructure (short term state change due to activity)
    - A claim about the impact resulting from a series of outcomes, referring to the quality of outcomes
- **Formal statements**
    - Definitions (schemas)
    - Transformation (functions)
    - Regulation (*x* must *y* for it to be *z*)
    - Agreements (e.g., a contract: x undertakes to do y if z does *a*)

On a cryptographic digital network, claims are represented by tokens while formal systems give rise to procedures, functions, and smart contracts. Data are represented by tokens, which can include various types such as cryptocurrency tokens, non-fungible tokens (NFTs), or even tokens representing specific assets or rights. These tokens can be used to represent claims or ownership of assets, among other things.

However, requirements may be directly incorporated into procedures, functions, smart contracts, or other forms of executable code. Smart contracts are digital contracts where terms of the agreement between buyer and seller are directly written into code. These smart contracts can automate and enforce the rules and requirements of transactions, such as transferring tokens only under certain conditions or triggering actions based on specific events. Beyond simple two-party buying and selling, smart contracts can manage complex relationships between multiple parties, automate processes, or trigger actions.

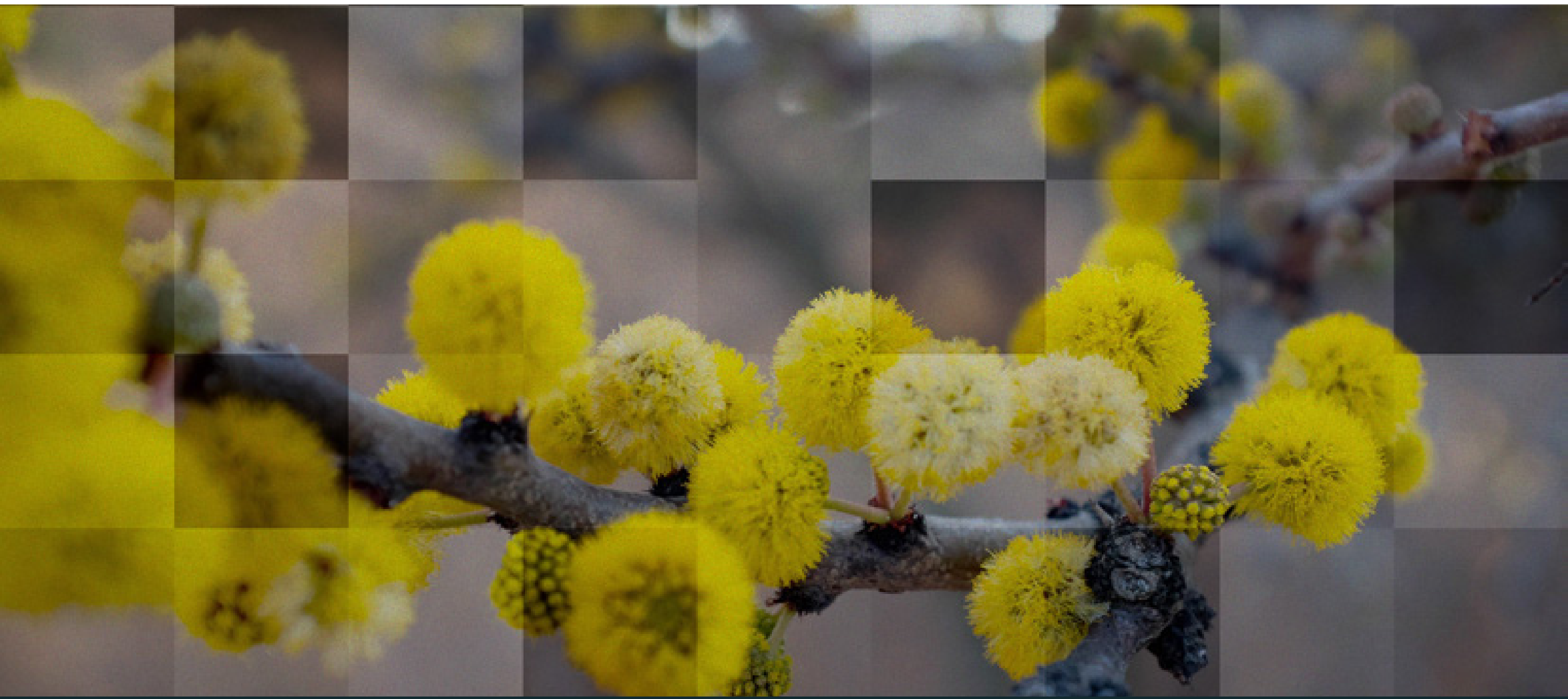
2.4 Agents and Roles

To act in a digital environment is to create formal systems and make claims. *Formal systems* are created as schemas for digital artifacts or as procedures and functions that cause the creation, application, or mutation of digital artifacts. *Claims* are made by creating, using, changing, or destroying digital artifacts. The context in which these actions can take place is the digital network and potentially those media to which the content of the network can be transformed.

On a digital network, agents are entities with the ability to create, use, change, or destroy digital artifacts. Depending on the mechanisms of the network, these agents are typically identified by unique identifiers or addresses that are usually secured by cryptographic means. These identifiers may represent natural persons, legal persons, or cyber personas. In ecosystems where identity is asserted through a cryptographic key, identity can be "stolen" if the key becomes known to another party. On a digital network, deterministic programs or artificial intelligence may be able to carry out the same actions as a natural person and may in fact be indistinguishable from one. There are situations where it may be necessary to require proof that a specific agent is indeed a natural person.

Agents usually enact roles. A role is a set of predefined behaviors for an agent regarding a specific activity. In practice, these roles are mediated by permissions that circumscribe the ability of agents to perform certain actions with regard to specific digital artifacts (i.e., roles relate to token behaviors). For example: a token may be defined in such a way that only the owner can delete (burn) it.

Appendix 1 provides an overview of token properties and behaviors, leaning strongly on the Interwork Alliance's (IWA) Token Taxonomy Framework.



PART 3: Lifecycle of a Digitally Native Biodiversity Credit

A *digitally native biodiversity credit* is a biodiversity credit that is substantiated, verified, issued, and transacted entirely on a digital platform and that is not merely a digital record of another process.

This paper differentiates three phases in the lifecycle of digital representations of biodiversity outcomes and/or biodiversity conservation outcomes or outputs. Each phase comprises a series of stages representing specific processes or events within the market.

The first phase concerns the process through which these representations are created. This first phase is referred to as *origination* and is covered in Section 3.1, *Origination of Digitally Native Biodiversity Credits*.

The second phase concerns the intermediary trade of digital representations of biodiversity outcomes before being consumed by the end user. This phase is referred to as *distribution*.

The third phase concerns the consumption of the biodiversity unit by an end user for the purpose of making a biodiversity-related claim. This claim constitutes the ultimate financial driver of the outcome (i.e., without the consumer there would be no purpose for originators or distributors). This phase is referred to as *retirement*, because the unit is permanently taken out of circulation. The second and third phases are dealt with in Section 3.2, *Distribution and Retirement of Digitally Native Biodiversity Credits*.

The phases mentioned above differ according to key market roles, which may be classified as follows: the role of *market operator*, which establishes and maintains the market and enabling infrastructure; the role of *supplier*, which develops and implements biodiversity credit projects; and the role of *buyer*, which uses the asset for the purpose of making a claim.

An overview is provided in Table 3 below where each column represents the perspective of a different market role, namely that of the market operator/s (column one), a project developer (column two), and a buyer of digital biodiversity credits (column three). The rows are ordered chronologically for each role. Not all roles are equally active at the same time. The three phases are indicated by heading rows spanning all three columns.

Table 3: Outline of the market, project and asset lifecycles

Market (market operator perspective)	**Project** (supplier perspective)	**Asset** (buyer perspective)
Origination phase		
1. Protocol development		1. Strategy development: Choose the assets to acquire for the business purpose (e.g., compliance, voluntary offsetting, public relations, etc.)
2. Standard setting		
3. Market infrastructure development		
4. Supplier development		
5. Supply development	1. Business development	2. Estimation of required volumes
	2. Project development	3. Pipeline development (forward agreements etc.)
6. Project registration	3. Project validation	
7. Auditing project results	4. Project implementation	
	5. Monitoring	
	6. Verification	
8. Issuance of units	7. Receipt of issued units	
Distribution phase		
9. Ongoing market education	8. Sale of unit	4. Acquisition
		Secondary trade (optional)
Retirement phase		
10. Operation of a retirement registry		5. Retirement
		6. Public claims based on retirement

3.1 Origination of Digitally Native Biodiversity Credits

This section describes the *origination* phase from the three different perspectives outlined in Table 3 (the market as a whole, the individual project, and the buyer). For each of these perspectives, the description of the non-digitally native origination phase is followed by the articulation of the digitally native instance of such an origination phase.

3.1.1 Market Origination

Nature markets are rapidly developing. While the establishment of a digitally native biodiversity credit market shares many of the requirements of a non-digital market, it also requires the following stages:

Protocol development involves the establishment of a shared vision, which is a prerequisite for a market of nature-positive activities or states to come into existence. For such a vision to take hold, there needs to be a group of actors with a sufficiently shared conception of what those activities or states are. Moreover, some of these actors must be willing to pay for the implementation of those activities or the realization of those states.

A further requirement is the identification of mutually agreed indicators for these valued activities and states, or at minimum, there must be consensus on how to derive such indicators.

Standard setting involves the establishment of quality control and quality assurance rules to safeguard the integrity of issued units. Supply-side standards focus on creating safeguards focused on the creation of tradable tokens. Demand-side standards focus on safeguarding the claims that can be made by end users (e.g., biodiversity-related claims). In this subsection, supply-side standards are discussed.

A standard defines key activity-related elements such as eligibility criteria, the scope of project boundaries (e.g., temporal, geographical, ecosystem service), the scope of activity types, additionality, leakage and permanence rules, and measurement, reporting and verification protocols.

Standards identify and define valued states with one or more indicators for each. Every indicator will have a definition, rationale, unit of measure, data requirements (e.g., data quality, data security), calculation frameworks, and reliability and validity conditions. The standard may define these or refer to already established indicators.

A standard also contains procedures for registering and/or accrediting agents for fulfilling various key roles to be performed under the standard. These roles include project developers, validation and verification bodies (VVBs), unit registries, and transaction intermediaries.

Market infrastructure development is a prerequisite for the rest of the ecosystem. This is principally focused on the infrastructure for asset creation, transfer or trading, and retirement.

Supplier development begins once the preconditions for a market (basic registry and trading infrastructure, a standard, and supporting methodologies) are in place. At this stage, suppliers of tradable assets and specialized service providers must emerge for the market to start functioning.

The education of potential market participants remains an ongoing function, typically led by standard-setting bodies.

Supply development depends on the availability of methodologies that enable project developers to quantify biodiversity outcomes in a manner consistent with the standard and therefore generate tradable units.

Methodologies can be developed by individual project developers, standards, or expert interest groups. Methodologies provide procedures for the quantification of valued activities, outputs, or outcomes defined by the standard for a specific context or activity type. A methodology will contain applicability conditions to delineate baseline scenarios, project scenarios, and project activities to which it applies.

The scope of methodologies will typically include integrity and measurement safeguards for activities, outputs, or outcomes, as well as social, cultural, legal, and financial project attributes.

Once developed, a methodology is audited by a reputable validation and verification body to demonstrate compliance with the standard. Standards include requirements for this process (e.g., number of reviewers, votes required, public consultation requirements, etc.)

Project registration involves the submission of projects by suppliers for inclusion in the market. At this stage, the standard applies administration processes to assess and register proposed projects in accordance with its rules.

Auditing project results begins as projects are implemented and monitoring reports are submitted. At this stage, the standard oversees the auditing of project outcomes in accordance with its established rules.

Issuance of units begins upon completion of the prescribed audits. At this stage, the standard body issues units in accordance with its rules. As buyers purchase these assets from the original suppliers for the purpose of retirement, the standard or a delegated entity must operate a retirement registry.

The stages described above define the foundational processes required for market origination. In a digitally native market, these same processes are implemented through digital systems that enable automation, verifiability, and interoperability.

3.1.2 Digitally Native Market Origination

To establish a digital standard for nature assets, the market origination processes described in Subsection 3.1.1 must be implemented in a digitally native manner.

The degree to which a standard functions as a digital entity can vary. In a standard implemented as a digitally native standard, all actions are digitally recorded and executed.

A digitally native market isn't just about converting existing paper-based information and processes into digital formats. Instead, it involves actively using the unique features and capabilities of digital technology to create new and improved ways of operating that would not be possible in a non-digital environment.

Digitally native methodologies implement the requirements defined during protocol development and standard setting as executable functions within workflow and calculation engines.

For a digitally native market to exist, participants must be connected to a **digital network** where transactions take place, corresponding to the market infrastructure development stage in Section 3.1.1, but implemented as a shared digital environment for coordination, execution, and record-keeping.

A **digitally native methodology validation and accreditation** process corresponds to the standard-setting functions described in Section 3.3.1, but is implemented through structured digital workflows that manage the approval and deployment of methodology versions. This process may draw on practices such as version control and continuous integration and deployment, enabling controlled evolution of standards while maintaining consistency and auditability.

A digitally native market is built on three key elements. These elements provide the digital implementation of the core components of market origination described in Section 3.1.1:

1. **Standardized data structures:** These are agreed-upon **formats** for organizing and storing information
2. **Defined procedures:** These are specific processes or operations that can be performed on the data; these procedures can be written as **functions** that take the standardized data as input
3. **Networked operation:** The procedures are run on a digital network—market participants can send data to this network, where the procedures process it; the results of these operations are then stored on the network, representing the current state of the market

This system allows for a standardized, automated, and accessible way of conducting market operations digitally.

Typical **formats** may include standardized schema, reference ontologies, and naming and identification conventions. Standardized token and role definitions and function signatures (i.e., name, parameters, return type) also form part of standardized data structures.

Typical **functions** include:

- Approval of functions and artifact definitions (e.g., approval of methodologies, token definitions), corresponding to protocol development and standard setting in Section 3.1.1
- Allocation of identifiers (e.g., registering users), corresponding to supplier development
- Association of data with identifiers based on requirements (e.g., updating user reputation), corresponding to project registration
- Allocation of roles (permission sets) to identifiers based on requirements (e.g., approving auditors)
- Creation of digital artifacts (e.g., minting of digital tokens), corresponding to the issuance of units

Networks implementing these standardized data structures and procedures may be either private or public, provided they support the interoperability, traceability, and transparency required for market operation.

Together, these components represent the digitally native implementation of the market origination lifecycle, enabling the processes described in Section 3.1.1 to operate with greater automation, traceability, and verifiability.

3.1.3 Project Origination

Project origination refers to the processes through which biodiversity credit projects are designed, developed, and prepared for market participation. While these processes may be implemented in digitally native environments, the underlying stages remain consistent. The origination of biodiversity credit projects comprises the following stages:

Business development involves project conceptualization and feasibility analysis. During this stage, the project developer assesses the feasibility of alternative courses of action and calculates the potential risks and rewards, while determining the appropriate issuing standard and asset type. Financial requirements are defined and included in the feasibility analysis. Access to market data on prices and volumes as well as data on the process itself, is particularly valuable at this stage.

Project design and development involves the design and development of a detailed proposal describing the project activity, justifying the choice of methodology, and performing an ex-ante calculation of the project's impacts. This stage also defines the monitoring procedure and describes the safeguards implemented by the project to avoid harm and address stakeholder concerns.

Project validation is the process through which a project design document or project description is audited for compliance with the requirements of the selected standard and methodology. This involves a third-party audit of the project description by an accredited validator.

Project implementation is where the project developer executes the project in accordance with the approved design and captures data in accordance with the monitoring procedure defined in the Project Design Document (PDD). This stage also requires adherence to rules set by the selected standard that govern the communication and approval of any deviations from the original design or monitoring procedures.

Monitoring and reporting are the processes through which the results of an implemented project activity are measured in accordance with its validated design. This entails the execution of the monitoring procedure that was specified during the design phase and subsequently validated. The frequency of monitoring is typically also specified during the design phase. Data quality assurance and data quality control are also part of the monitoring process.

Verification is the process by which a competent third party provides assurance on whether a monitoring process has been executed in accordance with its validated design and presents a fair representation of the impact of the project activity.

Receipt of issued units occurs once the standard has completed the issuance process and allocates units to the project. At this stage, the project developer receives units representing the verified impact of specific project activities over a defined period, expressed in accordance with the applicable methodology. The receipt of these units marks the transition from project implementation and verification to participation in the market, enabling the supplier to hold, transfer, or sell the units.

3.1.4 Digitally Native Project Origination

A digitally native project origination phase mirrors the stages of non-digitally native project development but implements them through digitally native systems, enabling automation, verifiability, and interoperability across the lifecycle.

A **digitally native project design** may be implemented as a policy on a policy workflow engine or stored in a standardized, machine-readable format, typically on a public registry. This enables consistent interpretation, automation, and reuse of methodologies and project definitions.

A **digitally native project design validation** process may be carried out on a digital platform according to an established validation protocol, implemented as a policy on a policy workflow engine. Digital validation can more easily be implemented in a decentralized fashion where multiple parties evaluate aspects of the project design document and the project itself. In such a scenario, the project design document would be open to a pool of accredited validators, who can validate specific parts or the document as a whole. Such a system allows specialization (e.g., fact-checking by local entities, assessments of additionality by experts). A digitally implemented standard has rules and thresholds for what it means to pass validation that can be automatically enforced.

Digitally native project implementation directly captures all project implementation data as well as monitoring data in a digital format. This ensures that data is structured, attributable, and immediately usable in downstream processes.

A **digitally native monitoring** process starts with digital data capture linked to trustworthy storage (e.g., on a content-addressable storage system) connected to verifiable compute. This enables continuous, auditable, and tamper-evident monitoring of project outcomes.

A **digitally native verification** process may be conducted in a decentralized manner by multiple parties orchestrated through a policy workflow engine or smart contract. Decentralized digital validation and verification have great potential to increase efficiency and reduce the time required for verification while maintaining integrity.

A **digitally native issuance** process may be carried out through automated systems such as a Function-as-a-Service (Faas), smart contracts or policy workflow engines, ensuring that units are issued only when all predefined conditions have been met.

A **digitally native project cycle** is one that is designed from the outset to operate in a digital ecosystem. Table 4 below summarizes how digital artifacts differ between digitally native project cycles and those that are not. Digital artifacts that function in an ecosystem that is not fully digitally native are referred to as *Level 1.* These are still digital artifacts but their prime users are human. *Level 2* digital artifacts belong to digital ecosystems with higher degrees of integration, automation, and cryptographic guarantees of immutability, verifiability, and non-repudiation, allowing for greater efficiency. For example, a pdf document listing the rules of a certain standard or methodology is a Level 1 digital artifact. It is in a digital form but is meant primarily to be read and interpreted by humans. It is not inherently designed for automation, or to provide cryptographic proof of its authenticity. If the same set of rules is implemented in a policy workflow engine, or as a Function-as-a-Service (FaaS) or a series of smart contracts or as an application, it would be a Level 2 digital artifact that can be understood by humans, but where machine readability, automation, and cryptographic proof of authenticity are inherent design features.

Table 4: Digital artifacts through the project lifecycle

Phase	Digital infrastructure/artifact	Artifact format(s)
Market development	Level 1: World Wide Web	Text, PDF, image, HTML
	Level 2: Blockchain or DAG (Directed Acyclic Graph)	Tokens, VCs, VPs, DIDs
Standard setting	Level 1: Digital records of rules	Text document
	Level 2: Digital rule execution (policy workflow engine)	Policy workflow engine / function or application
Methodology development	Level 1: Digital records of methodologies	Text document
	Level 2: Digital rule execution	Function / calculation engine
Methodology validation	Level 1: Manual approval of electronic text documents	Text of correspondence and minutes; final text of methodology
	Level 2: Akin to CI / CD process using version control and automated testing of code changes	Updates of function / calculation engine
Pipeline development	Level 1: Email correspondence, contracts in pdf	Text of correspondence
	Level 2: Nature investment tokens	Tokens giving the investor a stake in the potential outcomes of an activity
Project development	Level 1: Digital records of PDD	Text, images and spatial data formats (KML)
	Level 2: Digital creation and validation of PDD	Appropriate indexable and machine-readable data structures using open, composable schemata
Project validation	Level 1: Digital validation records	Text: Validation correspondence and report
	Level 2: Digitally coordinated, cryptographically signed, multi-layer validation system	VCs produced by combination of validators and methods
Project implementation	Level 1: Project data digitized	Combination of relational databases, spreadsheets, scripts (R/Python) and custom applications
	Level 2: Digitally native project data; every interaction or activity is digitally captured and immutably stored	Data on content-addressable storage, open composable schemata, verifiable compute platform
Monitoring & reporting	Level 1: Digitized monitoring report	Spreadsheets, text, images and videos
	Level 2: Integrated digital MR system (quality system)	Data in a composable database based on immutable storage, transformations on verifiable compute platform
Verification	Level 1: Digitized monitoring report	Spreadsheets and text
	Level 2: Verification integrated digital MR system	VCs produced by combination of validators and methods
Issuance	Level 1: Digital recording of issuance process	Custom software platforms operated by standards bodies
	Level 2: Decentralized, rule-based execution of issuance rules	Tokens issued by smart contracts or policy workflow engine

3.1.5 Transaction Origination

Referencing Table 3, Column 3, this section describes the non-digitally native origination of environmental asset acquisition and use from the perspective of the buyer.

For a buyer, what is termed *origination* in Table 3, involves the decision to acquire environmental assets (biodiversity credits) for eventual use which involves their retirement and the making of specific biodiversity-related claims. The initial stages of the business cycle from the perspective of the buyer comprises the following stages:

Strategy development involves a natural or legal person choosing to acquire environmental assets and using them for a specific purpose. For non-speculative buyers (i.e., those not purchasing for the purpose of reselling at a profit), the objective of buying biodiversity credits is to make a financial biodiversity-related claim (see also the discussion under Section 1.2). Persons or businesses may want to make such claims for a variety of reasons, including legal compliance or voluntary contribution. A financial biodiversity-related claim is a claim to have caused beneficial biodiversity activities, outcomes, or impacts by providing necessary financial resources to the biodiversity project. The overall objective (e.g., compliance, voluntary offset, public relations, etc.) will largely determine the attributes of the assets to be acquired.

Demand estimation begins once the type of asset to be acquired has been determined. It involves the process by which a natural or legal person makes an estimate of the quantities and attributes desired and the price they are willing to pay.

Supply development typically follows when an entity has a good idea about the nature and volume of assets it wants to acquire. Supply development involves taking steps to secure future supply. This may include forward sale agreements with project developers or other means of securing access to supply, such as buying call options.

3.1.6 Digitally Native Transaction Origination

Strategy development remains primarily a human-led process, as it reflects organizational values, motivations, and constraints. However, digitally native systems can support strategy by providing improved access to standardized, verifiable, and comparable information on biodiversity credits and their underlying impacts.

Demand estimation can be significantly enhanced by digitally native approaches. Where buyers seek to align purchases with their own biodiversity impacts or targets, digital tools can enable more precise measurement, monitoring, and attribution of those impacts. This supports more informed decision-making and improves the alignment between demand and environmental outcomes.

Supply development is increasingly enabled by digitally native market infrastructure, allowing for more efficient and transparent growth of supply. Buyers can identify, evaluate, and secure future supply through digital platforms that support forward agreements, option contracts, and other mechanisms. These systems improve visibility into available and anticipated supply, reduce transaction friction, and support more effective market participation.

While such capabilities are still emerging in biodiversity markets, digitally native systems provide a clear pathway toward more transparent, data-driven, and trustworthy mechanisms for matching supply and demand.

3.2 Distribution and Retirement of Digitally Native Biodiversity Credits

Referencing Table 3, Column 3, this section describes the distribution and retirement phases from the perspective of the buyer.

3.2.1 Asset Distribution and Retirement

Acquisition is the process whereby an entity becomes the owner of environmental assets issued to a project owner or owned by another entity.

Secondary trade is when entities buy assets in order to resell them later (either at a profit or based on other motivations). Secondary trade contributes to the liquidity of the market because of the difference in risk appetites and volume requirements between market participants.

Retirement, in the context of environmental tokenization, refers to the process of permanently withdrawing a token from circulation. This action establishes an irrevocable claim of final economic causality for a specific environmental activity, outcome, or impact represented by said token because the retirement destroys the token.

The primary objective in acquiring and subsequently retiring a nature-based token, is to substantiate public claims regarding environmental stewardship. By retiring such a token, an entity can definitively demonstrate its commitment to, and responsibility for, a particular environmental benefit.

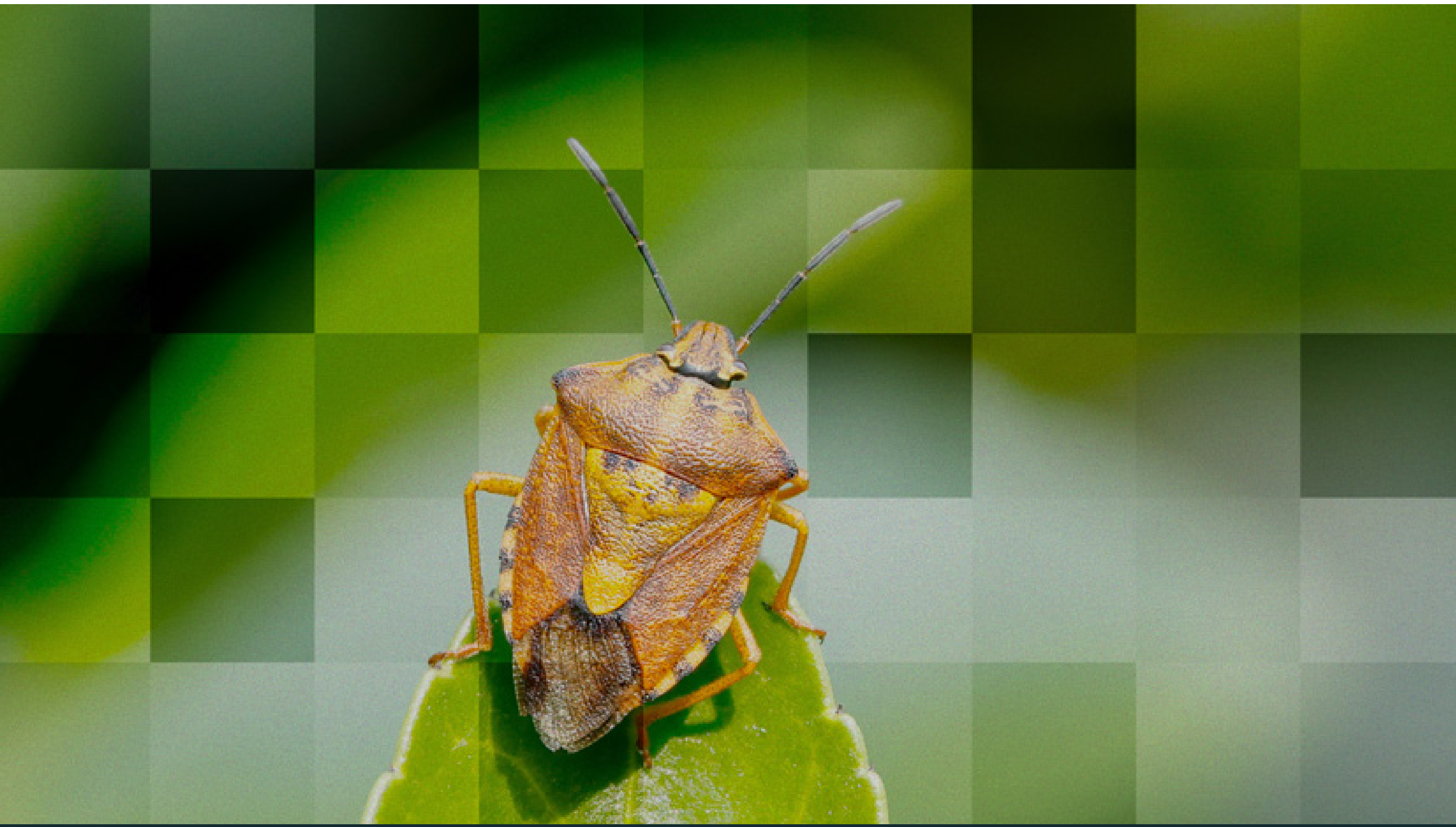
3.2.2 Digitally Native Asset Distribution and Retirement

In a digitally native market for biodiversity credits, the processes of acquisition, secondary trade, and retirement described in Section 3.2.1 are implemented through digital systems that enable the actions of the market participants and their accompanying claims to be recorded and presented transparently and efficiently.

Biodiversity credits represented as digital artifacts can be issued, transferred, and retired on a cryptographically secured digital network (e.g., blockchain, DAG, or hashgraph). Transactions on such networks record not only the underlying biodiversity-related activities, outcomes, or impacts, but also the identities of market participants (e.g., standard-setting bodies, project developers, intermediaries, and end users).

This enables each stage of the asset lifecycle—from issuance to transfer and final retirement—to be linked through a verifiable chain of transactions. As a result, biodiversity-related claims can be directly associated with identifiable and auditable records, including the original issuance, subsequent transfers, and final retirement by the end user.

The availability of transparent and verifiable transaction data can also facilitate more accurate demand estimation by potential participants. Digitally native market infrastructure further enables more efficient supply development, including the use of digital platforms for future contracts and forward sales.



PART 4: Digital Requirements

4.1 Zones of Quantification and Accounting

Nature credits, of which biodiversity credits are a subclass, are a new class of financial asset whose value is linked to the reporting utility of quantified units of ecosystem and biodiversity change associated with specified activities and sites.

The value of these assets, and hence confidence in emerging nature markets, is dependent on quality assurance that can withstand scrutiny from activists, regulators, scientists, communities, and the media. Given the dynamic complexity of ecosystems and society, credit markets need to be founded on new levels of transparency, traceability, and accessibility—in short—trust. The elements described in this section collectively form the digital trust infrastructure required to support a high-integrity, digitally native biodiversity credit market.

Nature credits are intangible assets created by technological zones that connect attributes of nature with the needs and practices of finance and ESG reporting. Technological zones (TZ) are spaces where differences between realities, technical practices, procedures, and needs have been reduced to common standards that enable productive flows of information. Digital technologies enable the design of technological zones that connect the complexity of ecosystems and rural regeneration with the digitalization of the finance sector, involving the creation of systems of technological zones that leverage technologies such as blockchain, AI, mobile computing, and data analytics to create new assets, efficiencies, and services.

Technological zones create market infrastructure, forming key components of the digital trust infrastructure that enables transparent, verifiable, and interoperable biodiversity credit markets. A nature fintech market infrastructure is a *zone of quantification* interfacing with a zone of *environmental accounting*. The first zone must translate characteristics of ecosystems and biodiversity into quantifiable measures expressed in metrics and indices that represent comparable and stable units of change that can be verified and instantiated as digital artifacts. The second zone must translate these units into assets that:

- Can be accounted for on balance sheets and/or reported as a nature finance-related KPI or claim
- Simultaneously provide a transparent and cost-efficient means for originators and owners of these assets to be held accountable for their quality, socially and ethically as well as ecologically

This requires key information on their *lifecycle* to be verified and converted to digital artifacts that can be linked to the first TZ in a transparent, immutable, and accessible *trust chain*.

A **data model** is integral to the design and functioning of these technological zones, serving as the architectural blueprint for organizing and translating environmental and social characteristics into quantifiable and actionable digital assets. It underpins both the *zone of quantification* and the *zone of environmental accounting*, providing a structured framework that dictates how data representing ecosystem and biodiversity changes, and project development and implementation are captured, stored, processed, and shared. Through defining the relationships among various data points and establishing standardized formats for data representation, a shared data model can ensure consistency, comparability, and interoperability across different platforms and stakeholders. Such a shared data model will facilitate the accurate and reliable translation of complex environmental and land asset data into metrics and indices that can be understood and acted upon within the financial sector. Crucially, the data model supports the development of robust verification and traceability mechanisms which are critical for establishing trust in the nature credit market.

4.2 Data Pipelines and Workflows

Data pipelines and workflows serve as the arteries through which data flows, from ecosystems and habitats, through a series of transformations to its minting as digital assets, while respecting **data sovereignty** to ensure that all data is handled in compliance with regional regulations and ownership rights. Data sovereignty ensures that biodiversity data remains under the control and jurisdiction of its source entity or geographic region, upholding local governance policies and protecting the rights of data providers and Indigenous communities. Ultimately, biodiversity data is retired following its use in reporting, maintaining integrity throughout its lifecycle. These pipelines and workflows create the **"trust chain"** necessary for verifiable, compliant data usage, enabling organizations to confidently share, validate, and report on biodiversity impact and conservation efforts.

The journey typically begins with **data ingestion**, the process of collecting biodiversity data from various sources, such as field research, remote sensors, or local communities, while adhering to both data quality and data sovereignty standards. This involves determining where the data originated, ensuring it reflects local ecological knowledge, and verifying that it can be shared under the appropriate legal framework. It is critical that the provenance of the data is documented, and any associated permissions or restrictions are enforced, ensuring that sensitive biodiversity information is used appropriately and transparently.

Once ingested, the biodiversity data undergoes **transformation**, a crucial step where raw data is cleaned, normalized, and structured into a format suitable for analysis and conservation reporting. This might involve checking for duplicates/omissions, identifying outliers, removing irrelevant information, or aggregating data points. Data sovereignty principles ensure that any transformations respect the original data permissions and protect the rights of the communities that contributed this information, particularly when Indigenous or culturally sensitive data is involved.

With standardized and compliant biodiversity data in place, organizations can **integrate** diverse data sources, enabling automated verification and real-time monitoring of biodiversity impact. Throughout this process, data sovereignty principles ensure that sensitive information, such as species locations or traditional ecological knowledge, is handled with the consent and oversight of the communities and regions from which it originated.

By building strong digital infrastructure that respects biodiversity data sovereignty, organizations can ensure that the digital assets minted from it—whether they be conservation credits, biodiversity tokens, or habitat preservation certificates—are grounded in trust, accuracy, and equitable use. This approach fosters high-integrity biodiversity markets, reduces the burden on data providers, and empowers communities and organizations to focus on meaningful biodiversity protection and restoration.

4.3 Models, Schemas, Taxonomies and Ontologies

The effective organization, structure, and utilization of data is foundational to digital credit systems and forms a core component of the digital trust infrastructure that supports them. Four concepts facilitate and ensure the underlying quality and integrity of a digital credit system.

Data models are conceptual frameworks that outline the types of data within the system, how the data is related, and the rules governing it. They provide a high-level overview essential for understanding the structure and organization of data and the digital representation of changes in the state of nature and ecosystems.

Data schemas are detailed blueprints derived from data models, specifying the exact structure of a database. This includes the definition of tables, fields, data types, and the relationships between them. Data schemas translate conceptual designs into practical database structures.

Taxonomies are categorizations that organize data into structures based on attributes and themes. They simplify data flows, navigation and retrieval, enabling efficient data management, faster retrieval analysis, understanding, and importantly auditing. In addition, taxonomies promote standardization in terminology and concepts across different data sets and systems, bringing consistency and interoperability in nature credit markets. This promotes cross-cultural understanding and helps to bridge language differences, making it easier for all stakeholders to disseminate information with a shared understanding of the market.

Ontologies extend the hierarchical organization provided by taxonomies with a richer semantic framework that encompasses relationships beyond mere categories. They define not only entities and categories but also the varied and complex relationships between them. Ontologies enable a deeper understanding of a domain and support advanced data analysis and inference.

4.3.1 Reference Ontology

This subsection presents a minimal data model based on the *Anthropogenic Impact Accounting Ontology Suite* and the definition of a biodiversity credit formulated in BCA Issue Paper 3. This ontology suite contains three complementary ontologies: the *Claim Ontology* (hereafter CLAIMONT, https://w3id.org/claimont), the *Impact Ontology* (hereafter IMPACTONT, https://w3id.org/impactont), the *Information Communication Ontology* (hereafter *INFOCOMM*, https://w3id.org/infocomm), and the main *Anthropogenic Impact Accounting Ontology* (hereafter *AIAO*. See https://w3id.org/aiao). The AIAO was being developed under the auspices of the Standards Working Group of the Climate Action and Accounting Special Interest Group (CA2SIG) of the Linux Foundation Decentralized Trust and aims to provide a fundamental ontology for all forms of anthropogenic impact accounting. It is presented here as an example of how an ontology can be used to create a consistent high-level data model that can be extended and on which standards can be built.

As with other forms of anthropogenic impact accounting, biodiversity credits are based on the assumption that people impact the environment through their actions. Expressed as a formal premise, this can be stated as: Agents engage in *activities* that impact *environments*.

A biodiversity credit is a representation of a statement that follows this underlying pattern. The paragraphs that follow will elucidate the core classes of the AIAO and its complementary ontologies and evaluate its relevance to serve as the basis for a data model to represent biodiversity credits throughout their lifecycle.

In the AIA Ontology, instances of all classes may be subject to controls. The axiom for the control class is that "A control limits or directs a thing."[6] All definitions, roles, rules, and specifications are instances of the *control* class.

Control

Data type	Content
string	mode
any	subject
any	value
string	logical operator
State	condition
repeated Control	controls

A control has a *mode* which can either be binding (obligatory) or non-binding (non-obligatory). A control has a *subject* (i.e., the thing that is limited or directed), and a *value* and *logical operator* giving the content of the limitation or direction. In a simple control such as the requirement: "The protected area should be greater than 1 hectare", the protected area is the control subject, 1 hectare is the value and the logical operator is greater than (>). There may be certain states that must exist for a control to be applicable. This is captured in the *condition* field. The control class can be nested in itself, because a control can be nested[7] in other controls. In this manner, the way in which standards accredit methodologies, which in turn use tools, can be modeled.

In the context of biodiversity credits, all definitions, requirements, methodologies, and procedures are *controls*.

Agents

The first axiom of the AIAO is: "An *agent* engages in an *activity*." The structure of the AIA:Agent class is shown in the table below. An agent is identified by an unambiguous identifier of which the implementation is dependent on the technology used. An agent can belong to one of only three agent types. The AIA:AgentType class can take the values: "*Natural person*", "*Legal person*" or "*Cyber persona*". An agent can be classified according to numerous classifications, depending on the context.

6 In the Web Ontology Language (OWL), the root class from which all other classes inherit is *owl:Thing. owl:Thing* can represent any kind of entity. See OWL Web Ontology Language Reference.

7 Nesting typically refers to something that is contained within another similar type of thing, creating a hierarchical structure. In data structures, nested elements are those that are contained within another element of the same type. The concept of nesting is often used to describe hierarchical relationships, where one thing is enclosed within another in a layered manner. A layer often refers to a level of separation within a system or structure. Layers are typically stacked on top of each other, with each layer serving a specific purpose or function. In graphic design software, layers allow users to organize and manipulate different elements of a digital representation independently. The concept of layers is used to create modular and flexible systems where each layer can be modified or replaced without affecting other layers.

A *Classification* can be considered to contain three components: the classification system, the version of that system, and a value. Standards will typically provide such classifications and also prescribe which are compulsory. For legal persons, this may be their organization type, e.g., private company or public company.

The *Identification* class follows the same pattern: it references an external registry and a value in that registry. For natural persons, such identification may include an identity number in a national population registry. For legal persons, this may be their company registration number in a national registry.

The AIA:Agent class can be nested in itself, i.e., an instance of AIA:Agent can contain other instances of the AIA:Agent class. This means that the AIA:Agent class can be used to describe organizations with their employees and officials. In such a case, one of the classification systems to which the classification of natural persons nested inside a legal person will refer, may be that entity's organogram.

Agent

Data type	Content
repeated Identification	identifications
AgentType	type
repeated Classification	classifications
repeated Agent	agents

Roles

A *role* is a set of predefined behaviors for an agent concerning a specific activity; as such, a role is a control. The most important roles relevant to the origination and use of biodiversity credits have already been mentioned in this document. The relationship between an agent and an activity (AIA:AgentActivityRelation) can be described as being governed by a specific role, often formalized as a control (e.g., a contract). Note that the role is not an enduring attribute of an agent, because people and entities change roles over the course of their lifetimes or over the course of the lifecycle of a specific project activity.

AgentActivityRelation

Data type	Content
Activity	activity
repeated Agent	agents
repeated Control	roles

Activities

BCA Issue Paper No. 3 defines a biodiversity outcome as the difference between a scenario with and without project activities. A project activity can be seen as a narrower implementation of the general activity class contained in the AIA ontology.

Its structure is given in the table below. Depending on the technology on which it is implemented, an AIA:Activity can have an identifier, label, or description. An activity always has at least one agent as its subject. The structure allows for multiple agents connected to predefined roles. In this way, the structure of complex activities where multiple agents are involved in different roles can be represented. BCA Issue Paper No. 3 refers to different scenarios—some of those scenarios are real, while others are counterfactual. It is therefore needed to have a *modality* property that can have two possible values: "Real"—for activities that were actually carried out, or "Counterfactual"—for possibilities that were not realized. This makes it possible to use the AIA:Agent class to describe a baseline scenario (which is by definition counterfactual) and a project scenario (that actually took place) and do an additionality assessment.

All activities are located in time and space. The data structure should therefore contain *Location* and *Period* objects.

In the context of a biodiversity credit, the *classification* field may be used to classify the activity type into categories relevant to biodiversity objectives. All activities are subject to some controls. The most basic control is the objective of the activity. In the context of biodiversity credits, the objectives may be categorized into either: Uplift, Avoided Loss or Maintenance. Activities are often subject to multi-layered controls like strategies and management plans. The recursive nature of the AIA:Control class makes representation of activities with complex controls possible.

All activities transform inputs into outputs by some means. These aspects are captured in the inputs, outputs, and instruments fields. As with the other AIA classes, activities may contain sub-activities. This allows for the representation of complex activities such as biodiversity management plans.

Activity

Data type	Content
string	description
repeated AgentActivityRelation	agent-activity-relations
Modality	modality
Location	location
Period	period
repeated Classification	classifications
repeated Control	controls

Activity

Data type	Content
repeated Instrument	instruments
repeated resource outputs	inputs
repeated resource	outputs
repeated Activity	activities

Environments

In the AIAO, any physical thing or collection of things can be defined as an environment. An environment can be defined by a set of interrelated properties, described by indicators. In most cases, location will be one of the parameters. BCA Issue Paper No. 3 refers to a *target ecosystem* or *population*. When the AIA:Environment class is used to model data compliant to the BCA definition, the location, critical properties of the environment described by indicators, and sub-environments of the *target ecosystem* will be defined in an AIA:Environment object. The choice of indicators will typically be prescribed in a methodology and will be determined by the definition of what "measures of biodiversity" are for that ecosystem or population.

The same can also be done for the population of a specific species.

As with the other AIA classes, environments can be nested. This allows for detailed description of complex environments.

Environment

Data type	Content
string	description
repeated Indicator	indicators
repeated Environment	environments

A structure based on the IMPACTONT:Indicator class is shown below. Apart from an implementation-dependent label or identifier, an indicator has a definition, a unit of measure and possibly a rationale. It may belong to a number of classifications (e.g., International System of Units).

Parameter

Data type	Content
repeated Identification	identifications
string	definition
string	unit of measure
string	rationale
repeated Classification	classifications

States and state differences

Environments have *states*. A state is the value of a property of an environment at a specific point in time. This is a crucial class for the purposes of biodiversity credits. Issue Paper No. 3 describes a biodiversity credit as "... a certificate that represents a measured and evidence-based unit of positive biodiversity outcome that is durable and additional to what would have otherwise occurred." The biodiversity outcome is then defined as "an improvement in measures of biodiversity, a reduction in threats to biodiversity, or prevention of an anticipated decline in measures of biodiversity."

The IMPACTONT:State class is suited to express what the core content of a biodiversity credit is, as defined in Issue Paper No. 3. A "positive biodiversity outcome" is a realized state (i.e., modality = "Real") while the "measures of biodiversity" are the indicators for important properties of the environment of concern (referred to as the *target ecosystem or species population*).

The potential of states to be counterfactual or real (modality) is essential for describing the baseline scenario and thus, additionality (another core element of the definition given in Issue Paper No. 3). Furthermore, since indicators can be recursive, complex measures of biodiversity, such as indices based on multiple sub-indices or component indicators, can be reconstructed.

The IMPACTONT:State class can be the subject of a provenance property. The provenance is the activity through which the state has been measured. This aligns with the BCA definition that biodiversity credits are an "evidence based unit".

State

Data type	Content
Indicator	indicator
Activity	provenance
Modality	modality
Period	period
string/numeric	value
repeated State	states

Change is the difference between two states of the same environment over time. What constitutes a positive change in an indicator will in most cases be obvious but this must be determined by the standard or methodology. States can also be compared between scenarios (e.g., one counterfactual and one real, or two counterfactual scenarios).

The three types of biodiversity outcomes described in Issue Paper No. 3 can all be expressed as states (and eventually as state differences), but in a different way for each.

Uplift is perhaps the simplest to express as a state difference. One defines a state in terms of relevant indicators, and possibly sub-states, that have possible values for which the desirability is known. For some indicators (like indices of integrity of functionality) the maximum is the desired value, but others may have an optimum value. The state difference is then simply the difference between the values of the measured project scenario on the one hand and the counterfactual baseline scenario on the other, which, in the case of *uplift*, is expected to be positive.

Where an activity is aimed at *avoided loss*, there are two possible approaches. The first approach is to directly measure threats. Such threats may be present inside or outside the ecosystem. The state difference is then the difference in the presence or intensity of such threats in the measured project scenario compared to the counterfactual baseline scenario. The second approach is to express changes in the state in the same way as with the uplift objective, but in this case a positive change is not the expected outcome, as a neutral or even less negative than anticipated difference in the presence of imminent threats, may in such a case, be viewed as progress. In both these cases, where possible, an AIA:Environment instance should be defined that includes the ecosystem or population of concern, as well as the threats.

In the case where the objective of an activity was *maintenance*, the assumption is that the ecosystem or species is very healthy and functions close to the desired values of the chosen parameters. The state difference between the measured project scenario and the counterfactual baseline scenario is not expected to be large, as the assumption is that the ecosystem or population is already healthy and is maintained as such. Including indicators of prospective threats in the definition of the environment of concern, even when their current values indicate no threat, may be a good practice in this case.

Claims

A *claim* is a statement about a thing. The Claim Ontology (CLAIMONT, http://w3id.org/claimont) has been created to describe claims in the context of impact accounting. Every claim is made by an agent and contains a subject, predicate, and object. It may be accompanied by attestations that evidence the support claim.

Claim

Data type	Content
Agent	claimant
any	subject
any	verb
any	object
any	context
repeated any	attestations
Agent	claimant

Impact Claims

The AIA:ImpactClaim is the key class in the AIAO as this is where everything comes together: an *impact claim* is a claim that an *agent* implemented an *activity* that impacted an *environment*.

A data structure based on the AIA:ImpactClaim class is shown below.

ImpactClaim

Data type	Content
Agent	claimant
Period	accounting_period
repeated Activity	activities
Control	methodology
Repeated StateDiff	state diffs
ImpactPathwayPosition	imp_pw_pos
repeated ImpactClaim	impact claims

The core of an impact claim is a state difference that captures the uplift, threat reduction or continued intactness of the ecosystem or population of concern. An impact claim has a *claimant* (the AIA:Agent making the claim) and an *accounting period*, which is the time over which the state difference is calculated.

A biodiversity credit is an impact claim where the environment of interest for which a state difference is calculated is an ecosystem or population, and where the parameters of concern are biodiversity outcomes, defined as either (possibly complex) measures of biodiversity or indicators of threats to biodiversity—either in the short term (threat reduction) or the long term (maintenance).

Optionally, the impact claim can indicate the position of the environment for which the state difference is calculated on the impact pathway between the activity and the ultimate objective. Possible values are: “Driver”, “Pressure”, “State”, “Exposure”, and “Effect”. The last two are less relevant in the context of biodiversity. The position on the impact pathway is different for each of the three types of biodiversity outcomes described in Issue Paper No. 3. In the case where *uplift* is directly calculated, the ultimate objective and the activity and the state difference calculated are the same. In this case *ImpactPathwayPosition* is State, since the desired state of the environment of concern is directly quantified. In the case of *avoided loss*, the position on the impact pathway would be *Pressure* since an imminent threat is addressed and it is believed that removing the threat will lead to the desired state of the ecosystem or population. *Maintenance* activities address long-term drivers of changes in ecosystems and populations in the belief that stabilizing these drivers will lead to the preservation of the ecosystem or population. In such a case *ImpactPathwayPosition* is *Driver*.

BCA Issue Paper No. 3 makes it clear that durability and additionality are key concerns.

Additionality can most simply be seen as the presence of a baseline scenario that is separate from the project scenario (i.e., that the project activity would not have taken place in any event and that the states resulting from the project activity would not have been achieved in any case). The impact claim should therefore contain the difference between the state resulting from the (by definition counterfactual) baseline scenario and the state actually achieved after implementation of the project activity.

Standards may be developed around the durability requirement. This may include specification on the duration of the accounting periods, but also requirements to monitor and address states related to the first two positions on the impact pathway (Drivers and Pressures).

4.3.2 Technical Implementation Considerations

In Subsection 4.3.1, how this data model should be implemented was intentionally not considered or specified. This subsection gives an example of how one of the classes in the AIAO can be implemented using W3C Verifiable Credentials (VCs). An AIA:Agent enacting a specific AIA:Role within the context of a specific activity will be used as an example.

The *credential subject* would be the agent (natural person, legal person, or cyber persona) whose role is being attested. This would likely be represented by a Decentralized Identifier (DID) associated with the agent. The *issuing authority* could be an entity that defines and manages the relevant roles.

The VC could contain the following properties:

Agent: A DID reference to the agent the role applies to.

Role: A reference (possibly a Unified Resource Identifier) to the specific role definition within the relevant classification system.

Validity period: Dates specifying the validity period of the assigned role. This is relevant as roles can change over time.

Issuance date: Date the credential was issued.

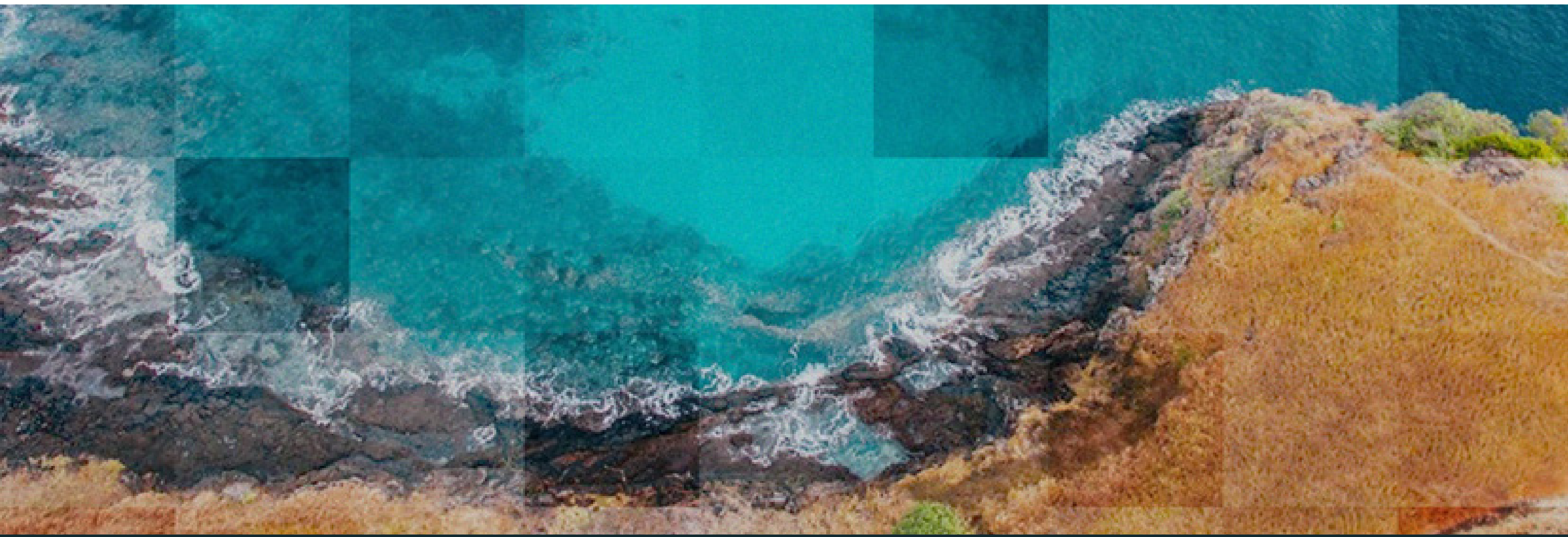
Issuing authority: DID of the organization issuing the credential.

The issuing authority would sign the credential with their private key, creating a verifiable digital signature. This allows anyone to verify the authenticity and integrity of the credential using the issuing authority's public key. A mechanism for revoking credentials may be necessary.

4.3.3 Minimum Identification Requirements

There are minimum requirements for identification within the context of digital biodiversity credits that should include at least:

1. The digital network should allow for the unambiguous identification of agents, activities, and environments
2. Agents should be unambiguously identifiable in all claims (as the claim subject and, where applicable, the object of the claim) and all transactions
3. To the maximum extent possible, the digital network should facilitate the identification of digital agents on the network with real-life natural or legal persons; where non-human actors are present (e.g., trading bots, AI agents) this should be transparent to other users
4. Environments should be identified in a manner that facilitates accurate identification; digital representations of localization should have the number of dimensions required for reasonable representation of the spatial extent of the environment, e.g., a point should not be used to demarcate an area; likewise, an area cannot be used to demarcate a volume
5. Data sources must be unambiguously identified with the appropriate metadata; this must include at least an unambiguous identification of the instrument and a timestamp identifying each observation



PART 5: Considerations for Implementation of Digitally Native Biodiversity Credits

5.1 Implementation Challenges

To implement tokenization and advanced data traceability methods in the biodiversity credit market, practitioners must address several challenges. The escalating threat of climate- and nature-related risks to biodiversity can only be managed or mitigated if these risks can be effectively tracked and converted into actionable insights. For practitioners in the digitally native biodiversity credit market, the data that capture these climate- and nature-related risks, such as geospatial imagery and biodiversity metrics, can differ significantly from the conventional financial data they have been dealing with to date. Biodiversity data tends to be more voluminous, unstructured, heterogeneous, and diffused across disparate internal and external sources. These concepts have not traditionally been within the domain of financial markets until now, nor have they been systematically adapted to the performance attributes that drive decision-making around biodiversity credits.

In addition, legacy technology systems are often not equipped to absorb this data, nor can they accommodate the computing power needed to generate indicators via machine learning and other big data analytics. The hosts of the data, whether conservation organizations or third-party providers, may have been outside the orbit of biodiversity credit practitioners until now, complicating matchmaking and coordination around data sharing. Compounding these challenges is the issue of accessibility to technology and training needed to effectively onboard biodiversity data. Many organizations, especially those in remote areas or from Indigenous communities, may lack the technical resources, digital infrastructure, or knowledge to contribute their data to digital platforms. This "digital divide" creates a technical barrier that hinders meaningful participation in the biodiversity credit market, leaving valuable data and perspectives out of the ecosystem.

Successful integration of performance attributes requires collaboration and data sharing among conservation organizations, government bodies, and private sector participants. Because biodiversity data is often large, complex, and derived from diverse sources such as satellite imagery and field surveys, integrating and managing this information to support performance attribute tracking remains technically demanding.

Another critical factor is ensuring the reusability of biodiversity data. Because biodiversity data is often collected by different stakeholders using varied methodologies, and is stored in isolated silos, it lacks interoperability and standardization, making it difficult to integrate and reuse.

By adopting distributed data management systems that utilize decentralized technology and open standards, seamless data sharing, reuse, and recombination across different platforms and use cases can be enabled. Distributed data systems also ensure that data sovereignty is maintained, as contributors can control access rights and permissions while still allowing for shared insights and collaborative analysis. This approach not only maximizes the value of existing data but also reduces duplication of effort and resources.

Consequently, organizations looking to embed sustainability performance attributes into their biodiversity credit frameworks may face high hurdles and long delays in establishing the data architectures underpinning attribute integration, which may discourage them from undertaking this integration to begin with. The technical demands of data standardization, verification, and integration require both financial investment and training programs to onboard participants, ensuring that all contributors—from local conservation organizations to global institutions—have the capacity to manage and share data effectively.

Successful integration of sustainability performance attributes depends not only on collaboration among conservation organizations, government bodies, and private sector participants, but also on accessible technology, training, and interoperable data systems. Robust distributed data management systems can improve the reuse and sharing of biodiversity data across projects and platforms, enabling more efficient collaboration and contributing to a more cohesive biodiversity credit market.

5.2 Community Participation in a Digitally Native Biodiversity Credit Market

A digital first approach, that makes use of emergent technology to address the structural challenges referred to in the previous section, has many upsides. Even so, without the full and equitable participation of Indigenous and local communities, the market risks low uptake, weak growth and will not achieve its potential. In many of the world's biodiversity hotspots, Indigenous Peoples' and local communities' stewardship of nature is exactly what the market is attempting to value. The early stage involvement of Indigenous and local communities in the design of a digital first market is critical, not only because it is just and fair, but because meaningful community inclusion is an enabler of market integrity and scalability. The following subsections explore how community participation can overcome structural challenges.

5.2.1 Communities as Data Providers

In biodiversity-rich areas, data collection is difficult due to the remote and fragmented nature of ecosystems and the high cost of audits and external advisory services. Indigenous and local communities are often the most direct witnesses to environmental changes but are usually underutilized in monitoring efforts. By involving communities, critical first-mile data, such as species observations or habitat conditions, can be gathered directly from the source. Geospatial data and biodiversity metrics, when combined with local insights, provide a more holistic view of ecosystem health and risks.

In cases where local communities collect data that is subsequently analyzed and reported by multiple parties, it is important to have complete and transparent metadata so that collection, analysis, and reporting can be carried out consistently across those parties. A critical requirement, however, is that permissions to use remain under the control of the community who collected the data.

There are data storage technologies that incorporate permissions at the data-level (e.g., Fluree: https://flur.ee). Such an approach means that data can be shared with multiple market participants (e.g., government body, an NGO, or a private investor) without the need to recompile information once these users have been given the appropriate permissions. Such control empowers communities and promotes transparency, as communities can decide with whom, and under what terms, their data is shared.

5.2.2 Tokenization and Data Traceability

One of the key innovations in biodiversity credit markets is the tokenization of biodiversity metrics, converting data points into digital tokens that represent specific environmental outcomes, such as species recovery. For Indigenous Peoples and local communities, the biodiversity data they collect can be tokenized, giving their contributions tangible value within the credit market. These tokens can be used to track improvements in biodiversity, adding traceability to the system and creating financial incentives for continuous data collection.

With a unified data vault, this traceability becomes even more powerful. Every interaction with the data, from its collection by a community member, to its use by a biodiversity credit issuer, can be logged, ensuring transparency and accountability in the data lifecycle.

5.2.3 Addressing Information Access Challenges

At the origin of critical biodiversity value chains, there are significant information access challenges. Conservation organizations, governments, and private investors often rely on periodic audits or costly advisory services to gain insight into local biodiversity conditions. These efforts, while useful, are often infrequent and expensive, and they fail to capture the dynamic nature of biodiversity risks. By inviting communities to participate regularly in biodiversity monitoring, these challenges can be mitigated. Local participants provide timely, on-the-ground data, which can be updated more frequently than traditional audits allow.

Furthermore, this approach lowers costs for external stakeholders, as they no longer need to rely exclusively on expensive third-party audits. Instead, they can tap into the community's ongoing data contributions, creating a more sustainable and scalable model for biodiversity monitoring.

5.3 Embedding Indigenous Data Sovereignty and Intellectual Property into Digital Infrastructure

Indigenous Data Sovereignty (IDS) refers to Indigenous Peoples' rights to own, control, have access to, and possess data that derives from them, and which pertains to their members, knowledge systems, customs, or territories. It includes data governance that comprises principles, structures, accountability mechanisms, policy relating to data governance, privacy and security, and legal instruments.[8]

Box 1. Indigenous Peoples Intellectual Property Rights: UNDRIP Article 31

Indigenous Peoples have the right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions, as well as the manifestations of their sciences, technologies and cultures, including human and genetic resources, seeds, medicines, knowledge of the properties of fauna and flora, oral traditions, literatures, designs, sports and traditional games and visual and performing arts. They also have the right to maintain, control, protect and develop their intellectual property over such cultural heritage, traditional knowledge, and traditional cultural expressions.

Source: United Nations, United Nations Declaration on the Rights of Indigenous Peoples, Article 31.

8 See UN (2018), Right to Privacy: Note by the Secretary-General (A/73/438).

While underpinned by international instruments, concerning Indigenous Peoples’ self-determination, lands, territories, resources, and cultures, the implementation of IDS is often insufficient in practice. The collection, use and application of data about Indigenous Peoples, their lands, and cultures often fails to meet Indigenous Peoples’ current and future data needs.

Hence, emerging digital frameworks concerning biodiversity data must ensure that IDS is embedded into the very infrastructure of such digital frameworks. In this regard, emerging best practice includes examples such as the CARE Principles: Collective benefit, Authority to control, Responsibility, and Ethics; the use of Traditional Knowledge (TK) and Biocultural (BC) Labels for Provenance and Metadata; and the 3Cs Rule: Consent, Credit, Compensation.

In addition, Indigenous Peoples in some parts of the world are developing their own principles suitable to their specific context and jurisdiction, such as First Nations Principles of OCAP (ownership, control, access, and possession), and the MAIAM NAYRI WINGARA Principles.

Unless IDS is embedded into digital infrastructure, then such data collection may undermine Indigenous Peoples’ self-determination, and further exacerbate existing inequalities and power asymmetries. Embedding IDS into the digital infrastructure must not be limited to the supply-side (origination), but rather, be embedded into all stages, including the distribution, and retirement phases. This should ensure Indigenous Peoples’ ownership, control, and access to such data.

It is good practice for entities who design, execute, monitor, and validate and verify biodiversity credit generating activities to show the extent to which IDS has been incorporated in its design, governance, implementation and monitoring.

While further work is required to ensure that the digital infrastructure ensures IDS at all levels, the following best practices should be embedded into such infrastructure.

CARE Principles for Indigenous Data Governance (Collective benefit, Authority to control, Responsibility, and Ethics)

The digital infrastructure should be designed so that:

- The use of Indigenous data results in tangible and collective benefits to Indigenous Peoples
- The use of Indigenous data ensures that Indigenous Peoples can exercise control, access, and use of data

- External entities fulfill their responsibility to engage respectfully with Indigenous data, ensuring that its use supports capacity development, strengthens community data capabilities, and contributes to the preservation and strengthening of Indigenous languages and cultures

- Indigenous Peoples' ethics inform the use of data across time in order to minimize harm, maximize benefits, and promote justice[9]

Indigenous Data Provenance in Metadata: Traditional Knowledge (TK) and Biocultural (BC) Labels

To operationalize the CARE principles within digital biodiversity credit systems—and to support fair and equitable benefit-sharing—it is important to ensure that sufficient information is retained about the origins, governance, and permitted usages of data.

One emerging best practice is the use of provenance, protocol, and permission labels,[10] including Traditional Knowledge (TK) and Biocultural (BC) Labels developed through the Local Contexts Initiative, which provides tools to support Indigenous data governance.

3Cs' Rule: Consent, Credit, Compensation

The digital infrastructure should be designed so the use of Indigenous Peoples' data:

- Is used only subject to their Free, Prior, and Informed Consent

- Is subject to the crediting of Indigenous Peoples from whose lands, territories, and resources such data was derived

- Is subject to mutually agreed monetary or non-monetary compensation or benefit-sharing[11]

Communal Intellectual Property (IP)

Communal IP is a right that communities have over their intellectual property, such as traditional knowledge, folklore, and genetic resources. In this view, communities are considered a unity, with common historical, cultural, and genealogical relations. This means that communities can have their own property, including intellectual and cultural properties.

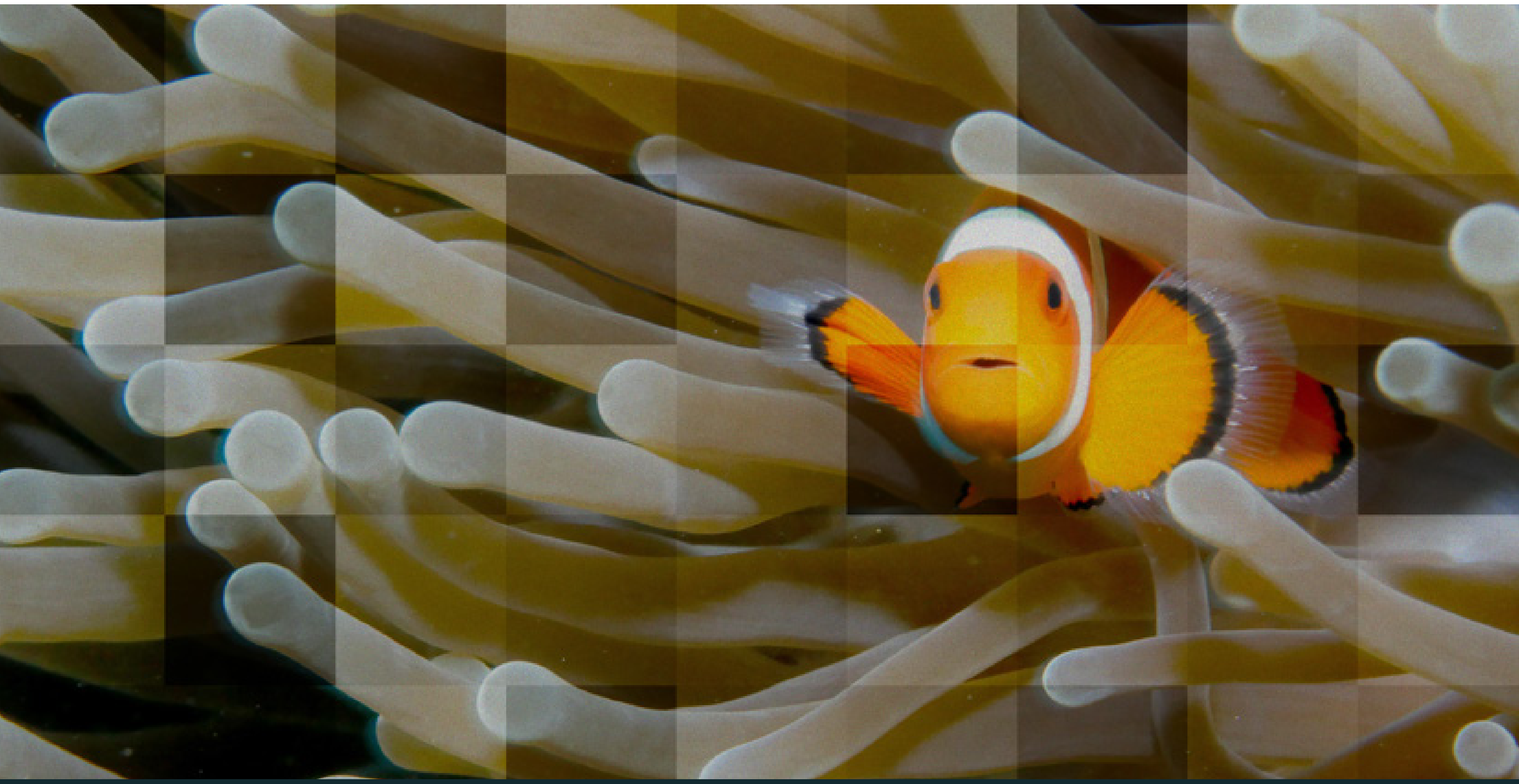
Communities create, maintain, and enhance their intellectual property, and individuals contribute to this process within the context of communal values. While individuals are the physical creators of communal IP, the community as a whole holds the right to it.

9 See GIDA, CARE Principles for Indigenous Data Governance.
10 See Local Contexts, Traditional Knowledge and Biocultural Labels Overview (Zenodo).
11 See Mo'otz Kuxtal Voluntary Guidelines.

In summary, the success of integrating sustainability performance attributes into biodiversity credits relies on effective collaboration and data sharing among diverse stakeholders, including conservation organizations, private sector participants, and government agencies. Communities, as data owners, become essential players in this network, contributing valuable insights that improve the accuracy and relevance of biodiversity credit metrics.

However, managing large, complex data sets from diverse sources is technically demanding. A centralized platform that can integrate and standardize these inputs, while allowing communities to maintain control over their data, provides a pathway for more efficient collaboration. Communities can provide access to their data on their own terms, choosing which parties can view or utilize the information for sustainability reporting, biodiversity credits, or performance tracking.

Empowering communities with tokenized biodiversity data by adopting a unified data vault approach with tokenized biodiversity metrics, enables communities to play a pivotal role in the biodiversity credit market. Their contributions help overcome the challenges of data access, traceability, and integration that currently hinder the market. This model not only incentivizes ongoing community participation but also promotes transparency and accountability, ensuring that biodiversity credits are backed by reliable, locally sourced data. Through collaboration, data control, and simplified reporting, communities can drive better outcomes for both biodiversity conservation and the emerging biodiversity credit market.



Conclusion

The development of high-integrity biodiversity credit markets represents one of the most significant opportunities to mobilize private finance at the scale required to halt and reverse biodiversity loss. Yet the credibility, equity, and long-term viability of these markets will depend not only on strong ecological science and rigorous safeguards, but on the creation of digital systems capable of ensuring transparency, accuracy, accessibility, and trust across a highly diverse and rapidly evolving global landscape. This Issue Paper provides an early attempt to articulate the foundational architecture of a digitally native biodiversity credit market and the digital trust infrastructure required for such a market to scale with integrity.

A key message from this paper is that high-integrity digital representation is not a convenience or an efficiency upgrade: it is a structural prerequisite for enabling biodiversity credit markets to function as transparent, equitable, and trusted mechanisms within a complex global ecosystem of standards, actors, rights-holders, and technologies. Digital infrastructure enables what no paper-based or semi-digital system can: cryptographic proof of origin, verifiable lineage, tamper-evident data storage, automated safeguards against double counting, standardized taxonomies, and interoperable market-wide protocols. These foundations are essential for ensuring that the market is not defined by fragmentation, opacity, and methodological divergence, but instead by coherence, comparability, inclusivity, and high-integrity impact.

At the same time, digitalization cannot be pursued solely as a technical exercise. Biodiversity credit systems must embed justice, equity, and rights-based approaches at their core, ensuring that Indigenous Peoples and local communities—who safeguard much of the world's remaining biodiversity—are not sidelined by digital transformation, but empowered by it. This requires digital infrastructures that are designed to reflect and uphold Indigenous Data Sovereignty, protect culturally grounded intellectual property, codify Free, Prior and Informed Consent (FPIC) in digital workflows, and guarantee equitable benefit-sharing through transparent and traceable value flows. For digital systems to function as tools for empowerment, they must also help close the digital divide through targeted capacity building, accessible tools, and intentional design for low-connectivity and low-resource environments.

Toward Digital Public Infrastructure for Nature

One of the clearest insights emerging from this work is the need for shared, interoperable Digital Public Infrastructure (DPI) for nature. The biodiversity credit market—and broader nature finance architecture—will require open, composable digital layers that can support:

- interoperable data schemas and ontologies
- verifiable and privacy-preserving identities (DIDs and VCs)
- content-addressable storage and tamper-evident data
- transparent and rule-based issuance, transfer, and retirement
- modular, open-source calculation engines and MRV workflows
- publicly accessible registries for both supply- and demand-side integrity

From a Digital Public Infrastructure perspective, these systems should be designed as open, interoperable, and trustworthy public-purpose digital ecosystems, rather than as fragmented or proprietary technologies. Embedding DPI components such as interoperable data exchange layers, digital identity systems, and transparent governance mechanisms, can enable countries to align biodiversity market operations with broader national digital transformation strategies.

Without DPI, the market risks a fragmented patchwork of proprietary tools that undermine comparability, accessibility, and trust. With DPI, digital trust infrastructure and digital representation become foundations for public benefit, enabling actors across jurisdictions and geographies—governments, communities, standards bodies, project developers, financial institutions—to operate on a shared and trustworthy digital commons. Applying DPI design principles ensures that these systems can operate across jurisdictions while supporting interoperability, transparency, and data sovereignty.

When developed within a DPI-aligned framework, both public and private networks can interoperate through open standards and shared trust mechanisms, enabling inclusivity, national ownership, and the long-term sustainability of biodiversity market infrastructure.

Nature ID and the Future of Verifiable Ecological Intelligence

Looking ahead, a major opportunity lies in the development of a global Nature ID framework—an open and verifiable identification system for ecological features, species, habitats, data sources, and interventions. Nature ID would form the backbone of digital MRV, enabling systems to connect specific claims, observations, and datasets to uniquely and cryptographically identifiable ecological entities or processes. This could support:

- standardized MRV protocols
- verifiable links between digital artifacts and physical ecological realities
- seamless integration with remote sensing, eDNA, sensor networks, and community science
- radically improved auditability and attribution

Nature ID, as part of a broader digital ecosystem, could substantially reduce monitoring costs, increase confidence in ecological outcomes, and improve the comparability of biodiversity metrics over time.

A Forward Workplan for the BCA Digital Working Group

Realizing the vision outlined in this paper will require sustained collaborative effort beyond the publication of this Issue Paper. The Digital Working Group, together with the broader BCA community and IEG, is well-positioned to advance several streams of work.

1. **Indigenous Data Sovereignty and Indigenous IP,** developing the following:
    - protocols for Indigenous-controlled data layers
    - digital consent and permissions architectures that operationalize FPIC
    - mechanisms for representing culturally grounded knowledge without compromising security or sovereignty
    - governance frameworks that ensure community control over digital assets, identity, and IP
2. **Capacity building and bridging the digital divide**, including the following priorities:
    - accessible training modules for communities, project developers, and government partners
    - low-bandwidth and offline-first tools

- community-led digital infrastructure pilots
- partnerships with universities, NGOs, and technology organizations to expand local technical capacity

3. **Development of modular, open, digital components**, advancing interoperable digital building blocks such as:
   - open schemas and ontologies
   - verifiable compute modules for MRV
   - smart contract templates for issuance and retirement
   - decentralized validation and verification architectures
   - tamper-evident registries and audit trails

4. **Strengthening market integrity** in alignment with the High-Level Principles, future guidance on demand-side integrity, and global policy processes under the CBD and GBF, to address:
   - digital safeguards against double claiming across domestic and international systems
   - transparency requirements for claims and impact reporting
   - interoperability across standards and registries

5. **Advancing Digital Public Infrastructure for Nature**, convening partners to co-design:
   - shared protocols for Nature ID
   - open-source tooling for project design, monitoring, and reporting
   - multi-level governance models for digital nature infrastructure
   - alignment with national biodiversity strategies and reporting frameworks

Closing Reflections

Digital systems alone cannot solve biodiversity loss—but without robust digital foundations, biodiversity credit markets cannot scale with integrity. High-integrity digital representation, supported by robust digital trust infrastructure, provides the connective tissue linking ecological outcomes, community participation, financial flows, assurance mechanisms, and end-user claims. It is the key to ensuring that biodiversity credits move beyond experimentation toward global adoption rooted in transparency, equity, and trust.

This Issue Paper marks an early but essential chapter in that journey. The next phase—building digital public infrastructure for nature, advancing Nature ID, operationalizing Indigenous Data Sovereignty, strengthening community capacity, and co-designing interoperable digital systems—will require collaboration across disciplines, sectors, geographies, and knowledge systems. Through this work, the biodiversity credit community can help lay the digital foundations for a global nature-positive economy that is not only scientifically rigorous and technically robust, but also just, inclusive, and grounded in the leadership of those who steward biodiversity every day.

Acronyms

AML	Anti-Money Laundering
AIAO	Anthropogenic Impact Accounting Ontology
BCA	Biodiversity Credit Alliance
BC	Biocultural
CARE	Collective benefit, Authority to control, Responsibility, Ethics
CDM	Clean Development Mechanism
CA2SIG	Climate Action and Accounting Special Interest Group
CI / CD	Continuous Integration and Continuous Deployment
eDNA	Environmental DNA
DAG	Directed Acyclic Graph
DID	Decentralized Identifier
DLT	Distributed Ledger Technology
DPI	Digital Public Infrastructure
FaaS	Function-as-a-service
FPIC	Free, Prior and Informed Consent
GBF	Global Biodiversity Framework
GIDA	Global Indigenous Data Alliance
IAPB	International Advisory Panel on Biodiversity Credits
ICVCM	Integrity Council for the Voluntary Carbon Market
IDS	Indigenous Data Sovereignty
IEG	International Environmental Guardianship
ISO	International Organization for Standards
IWA	Interwork Alliance
KML	Keyhole Markup Language
KYC	Know Your Customer
MR	Measurement and Reporting
MRV	Measurement, Reporting, and Verification or Monitoring, Reporting, and Verification
NFT	Non-Fungible Token
OCAP	Ownership, Contral, Access, and Permission
OWL	Web Ontology Language

PDD	Project Design Document
RBA	Rights-based Approach
RDF	Resource Description Framework
TK	Traditional Knowledge
TTF	Token Taxonomy Framework
TZ	Technological Zone
UNDRIP	United Nations
UTXO	Unspent Transaction Output
VC	Verifiable Credential
VP	Verifiable Presentation
W3C	World Wide Web Consortium
WBCSD	World Business Council for Sustainable Development
WEF	World Economic Forum
WRI	World Resources Institute

Appendix 1: Overview of token properties and behaviors

Token Properties

The IWA's Token Taxonomy Framework (TTF)[12] classifies tokens based on five properties. These are: Token Type, Token Unit, Value Type, Representation Type and Supply.

Token Type: A token can either be *Fungible or Non-Fungible*. This property indicates whether tokens are interchangeable or unique. Fungibility is the property of a collection of items that are mutually interchangeable with other items of the same type in the context of a particular use because their characteristics are considered to be uniform. On commodity markets, commodities like oil are fungible assets because one barrel of Brent Crude Oil is considered to be equivalent to another. In the same way, shares in a company are fungible if they belong to the same class. *Fungible* tokens are tokens that share a set of attributes, are of equal value and can be used interchangeably. *Non-fungible tokens* are unique representations that cannot be used interchangeably because they have unique and irreducible attributes.

Token Unit	A token can either be *Fractional, Whole*, or a *Singleton*. This property describes the divisibility of a token. A token may be divisible, indivisible and singular.
Value Type	A token represents value as something *Intrinsic* or by *Reference* to another object of value. Tokens representing biodiversity inputs or outcomes will by definition always be of the *Reference* value type.
Representation Type	Tokens may share a *Common* representation or may be *Unique*, in their representation. "Common tokens share a single set of properties, are not distinct from one another, and balances are recorded in a central place. These tokens are simply represented as a balance or quantity attributed to an owner's address where all the balances are recorded on the same balance sheet. A unique token has its own identity, can have unique properties, and be individually traced. Common tokens are like money in a bank account and Unique tokens are like money in your pocket." (TTF:Token classification)

12 See IWA, Token Taxonomy Framework.

Supply	The supply of tokens may be *Fixed*, *Capped-Variable*, *Gated*, or Infinite. "A capped-variable supply will allow for a maximum number of tokens to exist at any given time, with quantities added and removed within the quantity cap. A gated supply is common in crypto-currencies, where tranches of tokens are issued at certain points in time or events. A gated supply indicates up front the quantities in each tranche and when the tranche is issued that will represent the total quantity for the class, like a cap."

Additionally, there's a Template Type which can either be Single or Hybrid, which indicates relationships or dependencies between tokens. Hybrid tokens combine a parent token and one or more child token(s).

Token behaviors

A large range of token behavior exists. Common token behaviors include being mintable, burnable, divisible or indivisible, pausable, delegable, and holdable or attestable.

We will discuss the most relevant behaviors in the paragraphs below following the definitions of the IWA's Token Taxonomy Framework.

Attestable	An attestable token has the ability to provide a requester with cryptographic proof that the owner of an account is the holder of a certain token or credential. An example would be the ability to check if a specific account is the owner or holder of a diploma token.
Burnable	A burnable token is a token that can be placed in a permanent non-use state that cannot be reversed without destroying its history. Where a token represents a specific asset, the token is burned at the point where the asset ceases to exist in its original form. Where the token represents a right, the token is burned when the right is revoked. In cases where the token represen ts a single-use, like casting a vote or entry to an event, the token is burned upon use. Burning will likely play an important part in the use of biodiversity tokens.
Compliant	A regulated token needs to comply with several legal requirements, especially KYC (Know Your Customer) and AML (Anti Money Laundering). A compliant token fulfils all legal requirements on-chain without interaction from an off-chain entity.
Credible	A token class that implements this behavior is burned or retired with the credit token created on its behalf being recorded.

Delegable	A token class that implements this behavior will support the delegation of certain behaviors to another party or account to invoke them on the behalf of the owner without seeking permission up to a certain allowance.
Divisible	A divisible token has the ability to be divided from a single whole token into fractions, which are represented as decimal places. The extent of the divisibility (in the number of decimal places) is a property of the token.
Encumberable	An encumberable token has restrictions preventing certain behaviors like transfer, burning from working while it is encumbered. An example of such an encumbrance is when a bank grants a loan for an owner to buy a property but also enters into a contract with the owner encumbering the property title preventing the owner from being able to sell the property before paying off the loan.
Fabricate	Unique tokens can be fabricated from a base tokenization capability present in the platform being used. The result will be a single token of some quantity of the type. This is analogous to writing a check: The amount of the check functions like the quantity on a token and the denomination functions like the type of token.
Holdable	The explanation in the TTF of a holdable token is: "Every token instance has an owner. The Transferable behavior provides the owner the ability to transfer the ownership to another party or account. A hold specifies a payer, a payee, a maximum amount, a notary and an expiration time. When the hold is created, the specified token balance from the payer is put on hold. A held balance cannot be transferred until the hold is either executed or released. The hold can only be executed (partially or the full amount) by the notary, which triggers the transfer of the tokens from the payer to the payee. If a hold is released, either by the notary at any time, or by anyone after the expiration, no transfer is carried out and the amount is available again for the payer."
Indivisible	An indivisible token cannot be divided from a single whole token into fractions (this is the same as being divisible to 0 decimals). Indivisible tokens are common for items where division does not make sense or where the token already represents the smallest unit. Examples include property titles and inventory items.
Issuable	An issuable token has a controlling party (the issuer) who is the only one able to mint, transfer or burn tokens. Other parties can inspect (only their own) holdings, but may not transfer tokens.
Logable	A logable token will record log entries from its owner with a generic payload.

Mintable	A mintable token will support the minting or issuing of new token instances. These new tokens can be minted and belong to the owner or minted to another account. For a token representing a biodiversity activity, outcome or impact, the process of minting will be controlled by a predefined set of rules and a quality standard (see next section).
Non-Transferable	By definition, every token instance has an owner. The Non-transferable behavior prevents the owner of a token from changing. Such a token is also called a soul-bound token.
Offsetable	The TTF defines this behavior as follows: "A token class that implements this behavior is burned .... with its value being applied to offset another balance. ... This behavior extends the traditional burn or retire behavior by requiring an offset target id so that the token being offset is correlated with the appropriate emission. Once a token is offset, it can no longer be used." This behavior is potentially very important if tokenized biodiversity offsets are to be implemented.
Overdraftable	A token that implements the overdraftable behavior has the ability to grant an overdraft credit limit to a wallet owner, who can then make transfers or create holds without the required (positive) balance. This means that available balances of this type of token can become negative, and they can accrue interest over time that is chargeable by the issuing institution.
Pausable	Tokens that implement this behavior have the ability to halt trades and free all transfers.
Processable	A token class that implements this behavior is burned or retired when the next token is issued in a supply chain of tokens, like retiring an ecological claim once a processed claim token is created. Using this behavior, it is possible to structure the origination processes as a succession of tokens.
Redeemable	Tokens implementing this behavior function analogous to an admission ticket that is torn on entry. Redeeming a token removes an asset from the business network and guarantees that it can no longer be transferred or changed.
Revocable	A revocable token has a controlling party, the issuer, is able to retire/burn tokens that it has issued, regardless of owner. This behavior may be paired with the replacement property set.
Roles	A token that implements this behavior has the ability to restrict invocations (e.g., mint or burn) to a select set of parties or accounts that are members of a role or group.
Transferable	Every token instance has an owner. The Transferable behavior provides the owner the ability to transfer the ownership to another party or account.

Glossary

Activity: An activity is an action carried out by an *agent* with an implicit or explicit objective, using inputs and producing outputs that lead to state changes in an environment.

Agent: A natural or legal person who is able to will and act.

Auditability: The ease with which a system, process, or dataset can be verified.

Biodiversity: The variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. See Convention on Biological Diversity (1992).

Biodiversity credit: A biodiversity credit is a certificate that represents a measured and evidence-based unit of positive biodiversity outcome that is durable and additional to what would have otherwise occurred. See BCA Issue Paper No. 3: Definition of a Biodiversity Credit (2024).

Certificate of investment: A document certifying that an investment in an activity produces positive biodiversity outcomes, avoided loss or biodiversity maintenance.

Certificate of gain: A document certifying the achievement of a positive biodiversity outcome.

Claim: A statement about a thing or state.

Comparability: The ease with which similarities and differences between things can be recognized and assessed.

Content-addressable storage: A method of storing information based on its content, where the reference of a piece of data is a cryptographic hash of its content (aka content ID). A cryptographic hash is a type of function that takes any input and turns it into a fixed-length string of characters that looks random. Even a tiny change in the input will create a completely different output. This makes it useful for checking if data has been changed or for keeping data secure. This makes the storage tamper-evident: any change to the data will result in a different hash, altering its reference and making modifications detectable.

Continuous Integration and Continuous Deployment (CI / CD): A set of software development practices that automates and streamlines the process of getting code changes from development to production. This incorporates version control and automated building and testing.

Cryptographic: Using cryptography. In the context of this document in particular: using cryptography to secure transactions and prove that a representation is original.

Decentralized Identifier (DID): A globally unique identifier controlled by an entity, enabling verifiable, persistent, and self-sovereign digital identity. See World Wide Web Consortium, Decentralized Identifiers (DIDs) v1.0.

Digital: Represented electronically.

Directed Acyclic Graph (DAG): A concept from mathematical graph theory applied in computer science as a data structure. A graph consists of a set of vertices (or nodes) and a set of edges (or links) connecting them. In a directed graph, the edges have a specific direction. This means that information can only flow in one way from one node to another. An acyclical directed graph cannot have cycles or loops in the graph, meaning one cannot start at a node and follow the edges to get back to the same node. Such a data structure can be used used for scheduling, version control and transaction ordering.

Discoverability: The ease with which something can be found.

Distributed ledger technology (DLT): The infrastructure and protocols that enable secure, transparent, and decentralized recording of transactions across a network of computers.

Ecological infrastructure: Refers to the natural or semi-natural structural elements of ecosystems and landscapes that are important in delivering ecosystem services. It is similar to 'green infrastructure', a term sometimes applied in a more urban context.

Financial biodiversity-related claim: A claim to have caused beneficial biodiversity impacts by providing necessary financial resources to the biodiversity project.

Financial resources: Funds and assets that finance the activities of a project or organization and their investments. In simple terms, financial resources are the monies that keep a project or organization operating, and there are several ways a project or organization will raise and use its financial resources.

Free, Prior and Informed Consent (FPIC): A specific right granted to Indigenous Peoples recognized in the UN Declaration on the Rights of Indigenous Peoples (UNDRIP), which aligns with their universal right to self-determination. FPIC allows Indigenous Peoples to provide or withhold/withdraw consent, at any point, regarding projects impacting their territories. FPIC allows Indigenous Peoples to engage in negotiations to shape the design, implementation, monitoring, and evaluation of projects.

"Free" implies that stakeholders, and rights holders such as Indigenous Peoples and local communities are not pressured, intimidated, manipulated or unduly influenced and that their consent is given without coercion;

"Prior" implies seeking consent or approval sufficiently in advance of any authorization to access traditional knowledge, respecting the customary decision-making processes in accordance with national legislation and time requirements of Indigenous Peoples and local communities;

"Informed" implies that information is provided that covers relevant aspects, such as: the intended purpose of the access; its duration and scope; a preliminary assessment of the likely economic, social, cultural and environmental impacts, including potential risks; personnel likely to be involved in the execution of the access; procedures the access may entail and benefit-sharing arrangements;

"Consent" or approval is the agreement of the Indigenous Peoples and local communities who are holders of traditional knowledge or the competent authorities of those Indigenous Peoples and local communities, as appropriate, to grant access to their traditional knowledge to a potential user and includes the right not to grant consent or approval;

"Involvement" refers to the full and effective participation of Indigenous Peoples and local communities, in decision-making processes related to access to their traditional knowledge. Consultation and full and effective participation of Indigenous Peoples and local communities are crucial components of a consent or approval process.[13]

Impact: A state change in an environment resulting from an activity or event.

Immutability: The impossibility to change something. In the context of DLT and content-addressable storage, this refers to the unchanging nature of data once it has been recorded on the ledger.

Indigenous Peoples and local Communities: The Convention on Biological Diversity does not define the terms "indigenous and local communities" or "indigenous peoples and local communities." The United Nations Declaration on the Rights of Indigenous Peoples does not adopt a universal definition for "Indigenous peoples", and a definition is not recommended.[14]

13 See CBD, Decision XIII/18, annex, paras. 7–8, Mo'otz Kuxtal Voluntary Guidelines.

14 The United Nations Declaration on the Rights of Indigenous Peoples does not adopt a universal definition of "indigenous peoples." See United Nations Permanent Forum on Indigenous Issues, Study of the Problem of Discrimination Against Indigenous Populations (Martínez Cobo Report). Guidance regarding local communities is also available in Convention on Biological Diversity Decision XI/14 and UNEP/CBD/WG8J/7/8/Add.1.

Indigenous Peoples' and community conserved territories and areas (ICCAs): Indigenous Peoples' and community conserved territories and areas are natural and/or modified ecosystems containing significant biodiversity values, ecological services and cultural values, voluntarily conserved by Indigenous Peoples and local communities, both sedentary and mobile, through customary laws or other effective means.[15] Areas conserved by Indigenous Peoples and local communities could potentially be recognized as protected or conserved areas, subject to their "prior, informed consent" or "free, prior and informed consent" or "approval and involvement" or request, according to the national circumstances.

Liquidity: The ease with which these assets can be bought and sold at a fair price.

Managed activity: The activity that a business engages in in the normal course of its business. Examples include operating a manufacturing facility. This is used in contrast to a project activity.

Market: A market is a place where parties can gather to facilitate the exchange of goods and services. The parties involved are usually buyers and sellers. The market may be physical, like a retail outlet, where people meet face-to-face, or virtual, like an online market, where there is no physical presence or contact between buyers and sellers.

Minting: The process through which a unit of a cryptographic token is created on a network. The term evokes the creation of physical coins and is used for both fungible and non-fungible tokens. It applies to networks that operate on an account-based model as well as those using an unspent transaction output (UTXO) model.

MRV: Measurement, Reporting, and Verification or Monitoring, Reporting, and Verification. The complementary and interdependent process through which the impact of activities is determined, communicated and assured.

Outcome: The concrete and measurable changes brought about by a project activity in the short term.

Output: The concrete and immediate products or services created by implementing an activity.

Origination biodiversity-related claim: A claim to have caused beneficial biodiversity impacts by providing necessary technical resources to the biodiversity project.

Project activity: An activity with a defined start and end and a specific objective. In the context of biodiversity credits, a project activity is an activity specifically aimed at uplift, threat avoidance or maintenance of biodiversity.

15 See ICCA Consortium, Discover ICCAs.

Public-key cryptology: A cryptographic system that uses a pair of linked keys to encrypt and decrypt information.

Rights-based approach (RBA): A rights-based approach to development is a framework that integrates the norms, principles, standards and goals of the international human rights system into the plans and processes of development. In this frame it is critical that the six principles of RBA be adhered to; universality, indivisibility, equality and non-discrimination, participation, and accountability.

Rights-holders: Individuals or groups holding certain rights

Scalability: The ease with which a system, process or activity can increase in magnitude.

Statistical power: Statistical power is the probability of detecting a prespecified effect in case that effect actually exists using a specific test in a specific context. It is therefore the probability that a hypothesis test will correctly reject a false null hypothesis (that no such effect exists), thereby detecting a true effect when one exists in the population. It is mathematically defined as $1 - \beta$, where β is the probability of a Type II error (failing to reject a false null hypothesis). Higher statistical power indicates a greater likelihood of identifying a real effect where such an effect exists in reality, and a corresponding lower risk of false negatives (failing to detect an effect where the effect actually exists).

Technical resources: Technologies, knowledge, and expertise to deliver outputs to a project or organization. In simple terms, technical resources are the services provided by a project developer or project coordinator to enable a biodiversity project to be certified, implemented, and to issue biodiversity credits.

Token: A unit of value or utility that exists on a network.

Traditional knowledge: The knowledge, innovations and practices of Indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity.[16]

Transparency: The ability for an outside party to understand a system or process.

Unit: A single quantity regarded as a whole in a calculation. Includes types such as biodiversity credit, nature credit, digital unit. Broader than the term 'credit' because it does not imply a debit.

Validation: The process through which a project design is checked for formal compliance to a standard. This is typically done before registration.

16 Derived from Article 8(j) of the Convention on Biological Diversity and endorsed in Decision VII/16F, annex, para. 6(h), Akwe: Kon Guidelines.

Verification: The process through which a monitoring report is evaluated for compliance to its validated project design. This is done after each monitoring cycle.

Verifiable Credential (VC): A secure and tamper-evident digital credential issued by one entity to another that is verifiable using cryptography.

Verifiable Presentation (VP): A W3C-defined data format that allows a "Holder" to present one or more Verifiable Credentials, or specific claims within them, to a "Verifier" in a verifiable and privacy-preserving manner. The VP may include cryptographic proofs and is designed to support selective disclosure and secure validation. See World Wide Web Consortium, Verifiable Credentials Data Model.

W3C: World Wide Web Consortium. The body that develops standards and guidelines that enable the World Wide Web. See World Wide Web Consortium.

Web3: A new iteration of the World Wide Web that incorporates decentralization, distributed ledger technology, and token-based economics.

References

Biodiversity Credit Alliance. (2023). *Demand-side Sources and Motivation for Biodiversity Credits (Issue Paper No. 1).*

Biodiversity Credit Alliance. (2024). *Definition of a Biodiversity Credit (Issue Paper No. 3).*

Convention on Biological Diversity. (1992). *Convention on Biological Diversity.*

Convention on Biological Diversity. (2004). *Decision VII/16F: Akwe: Kon Guidelines.*

Convention on Biological Diversity. (2012). *Decision XI/14: Article 8(j) and Related Provisions.*

Convention on Biological Diversity. (2016). *Decision XIII/18: Mo'otz Kuxtal Voluntary Guidelines.*

Convention on Biological Diversity. (2019). *Mo'otz Kuxtal Voluntary Guidelines.*

Global Indigenous Data Alliance. (n.d.). *CARE Principles for Indigenous Data Governance.*

ICCA Consortium. (n.d.). *Discover Indigenous Peoples' and Community Conserved Territories and Areas (ICCAs).*

InterWork Alliance. (n.d.). *Token Taxonomy Framework.* GitHub.

Local Contexts. (2024). *Traditional Knowledge and Biocultural Labels Overview.* Zenodo.

United Nations. (2018). *Right to privacy: Note by the Secretary-General (A/73/438).*

United Nations Framework Convention on Climate Change. (2019). Clean development mechanism: Project standard for project activities. *UNFCCC CDM Project Standard for Project Activities.*

United Nations Permanent Forum on Indigenous Issues. (1982). *Study of the Problem of Discrimination Against Indigenous Populations (Martínez Cobo Report)*.

World Resources Institute, & World Business Council for Sustainable Development. (2004). The greenhouse gas protocol: A corporate accounting and reporting standard (Rev. ed.). GHG Protocol Corporate Standard.

World Resources Institute, & World Business Council for Sustainable Development. (2005). The GHG protocol for project accounting. GHG Project Protocol.

World Resources Institute & World Business Council for Sustainable Development. (2004). The greenhouse gas protocol: A corporate accounting and reporting standard (Rev. ed.). *https://ghgprotocol.org.*

World Wide Web Consortium. (2004). *OWL Web Ontology Language Reference.*

World Wide Web Consortium. (2014). *RDF 1.1 Concepts and Abstract Syntax.*

World Wide Web Consortium. (2022). *Decentralized Identifiers (DIDs) v1.0.*

World Wide Web Consortium. (n.d.). *Verifiable Credentials Data Model.*

World Wide Web Consortium. (n.d.). *World Wide Web Consortium.*

Photo credits

Images apdapted for this publication.

BCA Vision

BCA's vision is a transparent, trustworthy and efficient global market in biodiversity credits founded on just and equitable principles, and underpinned by innovation.

BCA works to facilitate the transition to a nature-positive economy aided by an integrated, efficient and scaled biodiversity credit market. BCA considers biodiversity credits to be an effective complement to, but not a replacement of, the private sector's supply chain transformation efforts. BCA views biodiversity credits as an effective mechanism for advancing the private sector's participation in ecosystem restoration and transformative landscape approaches in line with science-based principles.

We invite you to join us in achieving these ambitions

---

biodiversitycreditalliance.org