Biodiversity credits:
learning lessons from other approaches to incentivize conservation

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Abstract

Biodiversity credits are an emerging vehicle for pro-environmental financing. Here we define and delimit biodiversity credits and explore the pathways through which credits can be issued. We scrutinize early evidence from pilots and suggest lessons from other market-based incentives for conservation and climate mitigation, including biodiversity offsets and forest carbon credits that have attracted large private funding flows, but have been questioned regarding their additionality, permanence, and leakage. All these issues apply to biodiversity credits, but they face yet another challenge: rendering biodiversity commensurable. While new monitoring technologies can help quantify biodiversity, tradeoffs exist between simple metrics that enable liquid markets, and costly ones that more adequately represent biodiversity. To avoid carbon and offset market mistakes, biodiversity credit design, implementation, and impact evaluation requires more robust crediting baselines, standards, and governance. Quality credits will be more expensive than those cutting integrity corners, which may dampen the expected biodiversity credit boom.

Keywords: Environmental finance, economic incentives, ecological economics, biodiversity monitoring, forest carbon, impact evaluation, equity, institutions

1. Introduction

Biodiversity is in ongoing decline: long-term data indicate monitored wildlife populations have declined on average by 69% over the last 40 years (Leung et al. 2020; WWF 2022). Powerful economic forces drive this decline through overexploitation, climate change, pollution, invasive species, and especially habitat loss as major pressures (Jaureguiberry et al., 2022). Resources allocated to address losses are insufficient, with an estimated global biodiversity funding gap of US$700-900bn/yr (Deutz et al., 2020). Constraints in public-sector finances have reinforced calls for increases in private conservation funding. The recent Kunming-Montreal Agreement (CBD-COP15) commits high-income countries to increase public biodiversity-related spending in low-income countries to US$30bn/year by 2030, while "mobilising" at least US$200bn/year primarily through "leveraging private finance, promoting blended finance… [and] stimulating innovative schemes such as… green bonds, biodiversity offsets and credits" (CBD, 2022).

Biodiversity credits have recently been defined as units intended to finance measurable gains in biodiversity through conservation or restoration (Ducros & Steele, 2022). Advocates see their great potential to mobilize private conservation finance (TBC 2022; GEF 2023; Ducros & Steele 2022; Nature Finance 2023; WEF 2022; Pollination 2023). However, biodiversity can be measured in multiple ways, is conventionally considered a public good, and is hard to compare across locations and contexts, thus making biodiversity inherently challenging to commodify and trade.

Economic incentive instruments specifically addressing the global biodiversity crisis are also needed beyond their potential to raise finance, but few incentives are available. One pre-existing, closely related tool, biodiversity offsets, are intended to encourage developers to widely avoid impacts on biodiversity ('no net loss') (Bull & Strange 2018). Conservation concessions have been a more niche tool to compete with exploitation, e.g. logging concessions (Niesten et al. 2004; Milne & Niesten 2009), yet receiving only limited traction (Wunder et al. 2008). Biodiversity-oriented commodity certification remains valid (Pagiola & Ruthenberg 2002; Tscharntke et al. 2015), but typically has had only limited conservation impacts (Börner et al. 2020). Any new biodiversity-focussed incentive tool should aim to lead to positive conservation impacts, promote application of the mitigation hierarchy when planning sustainable development, whilst supporting equitable resource transfers and the livelihoods of including indigenous peoples and local communities (IPLC).

Interest in biodiversity credits is thus proliferating, with various business and policy initiatives now investigating the potential to develop global credits markets (e.g., British-French International Advisory Panel on Biodiversity Credits in 2023; the World Economic Forum Biodiversity Credits Initiative), and early-stage trades occurring. Arguably though, rapid deployment has not yet been matched by conceptual clarity about credits definition, delimitation, and functioning, nor are several lessons from other economic tools for conservation or sustainable land use being duly integrated. Notably, poorly-executed market-based instruments can counter-productively cause unintended outcomes (Larrosa et al. 2016). Applying pseudo-instruments could publicly communicate an illusion of effective pro-conservation action, while *de facto* further justifying business-as-usual practices (Damiens et al. 2021). Here, we address these conceptual gaps and bring in comparative lessons from other conservation incentive mechanisms, thus aiming to constructively inform biodiversity credits development, and help reduce the risks of failure.

In the following, we first consider how to define and delimit credits from well-established biodiversity offsets, explore their intended function through an explicit theory-of-change diagram, and highlight different pathways through which credits can be issued (Section 2). We then review a sample from the universe of currently ongoing initiatives and their crediting pathways (Section 3). Next, we examine issues relating to biodiversity measurement and monitoring for crediting (Section 4). In Section 5, we reflect upon credits markets' supply and demand sides. Section 6 looks at topical challenges for credit design and performance indicators such as additionality, permanence, leakage, equity, and bundling options, as informed by other market-based instruments. In closing, Section 7 discusses the findings and synthesizes our recommendations.

2. Clarifying role and structure

a. Distinction between biodiversity credits and offsets

Originally, the term "biodiversity credits" emerged in the 1990s, related to US wetland mitigation and species banking (Bowsher and Reeves-Evison, 2019) and Australia's biodiversity offset system (Alvaro-Quesada et al., 2011; zu Ermgassen et al., 2023). Developers purchased or generated credits to compensate for biodiversity losses they had caused, with the intent to achieve at least 'no net loss'. Here "credits" referred to the units of biodiversity improvement then traded via biodiversity offset trades. A credit thus enabled buyers to make claims of biodiversity increases to offset biodiversity losses. Most offsets implemented historically have been mandatory regulatory offsets associated with compensation policies (e.g. US Clean Water Act; Bull & Strange, 2018).

However, recently biodiversity credit transactions ("biocredits", "certificates", "tokens" as alternative terms) have broadened, due to shifting demand. Firms increasingly want to commit to *nature-positive outcomes* that are not necessarily linked to losses, and thus distinct from offsets by going above and beyond their own impact compensation (TBC, 2022), delivering additional protection and conservation gains that actively enhance the state of biodiversity (Milner-Gulland et al. 2021). If a credit refers to a commodified quantified improvement in biodiversity, then one way of distinguishing between offsets and credits would be to say that offsets are a subset of credits that are compensating for a loss elsewhere, (Bull & Strange 2018; TBC 2022).

Onwards we will focus on this novel market segment, i.e. credits that are not converted into offsets. We adopt a definition of biodiversity credit transactions as *biodiversity gains that are not associated with a loss elsewhere* (Pollination 2023): These refer also exclusively to voluntary biodiversity units traded, without the "intention" to compensate for negative impacts and their regulation. Allegedly, they would constitute 'the icing on the cake' in firms' mitigation hierarchy: an additional step only after having demonstrably pre-achieved 'no net loss' across their operations and supply chains (Maron et al. 2023).

Nevertheless, in real-world settings both demand- and supply-side fungibility can *de facto* blur this conceptual delimitation – and sometimes trigger spillover-associated risks. First, effective avoidance, mitigation and restoration of project-scale biodiversity impacts is a goal few firms can fully achieve: residual impacts likely remain (TBC, 2022; Maron et al. 2023). Voluntary biodiversity credits could feasibly be used as compensation for losses that are unaddressed under existing regulatory frameworks. However, this could be a problem if integrity standards applied to biodiversity credits are laxer than for compliance offsets. If credits became tolerated as *de facto* compensation for damage to threatened biota without requiring 'like-for-like' ecological equivalence, this demand-side spillover could jeopardize biodiversity outcomes in compliance markets by facilitating a net loss of those biota – particularly that for which credits are challenging to create (Maron et al., 2023). Notably, if credits standards were weaker than for offsets in the same system, credits could undercut offsets both on price and quality, becoming 'offsets on the cheap'. For example, among multiple mechanisms for compensating impacts on endangered species in the USA, perceived differences in the stringency of requirements led to 'leaky demand' where more robust mechanisms were deemed to be undercut (White et al., 2021).

Second, some residual biodiversity impacts are of diffuse nature, not usually regulated or under direct control, and the particular biota affected are hard to identify. Examples include impacts identified in footprinting exercises across firms' value chains in life-cycle assessments (Bull et al. 2022). Implicitly, on-the-ground biodiversity gains sold as biodiversity credits could here be disclosed as voluntary measures to address these indirect nature-related financial risks and dependencies (TNFD, 2023) as part of corporate environmental social governance (ESG) strategies. In such cases, credits could demonstrably do good for biodiversity by indirectly counterbalancing hard-to-compensate damages – but this blurs the conceptual difference between offsets and credits as credits would in this case also be compensating for biodiversity losses.

Third, a corporate motive for voluntary credits demand can be the desire to mitigate against future regulatory risks, i.e., forestalling, preparing for, or even shaping future environmental regulations. Under the Kunming-Montreal Global Biodiversity Framework, nations agreed to "take legal, administrative or policy measures" to incentivise corporates and financial institutions to disclose biodiversity risks, dependencies and impacts (CBD, 2022), hence the boundaries between 'voluntary' and 'compliance' measures are likely to blur and shift in the coming years. What is a voluntary nature-positive biodiversity credits today could through legal changes become a compliance-linked measure tomorrow, thus potentially further blending sources of demand (cf. Section 5). 'Slippage' of environmental standards (Farber, 1999) could occur if the use of credits is ultimately favoured by regulators over like-for-like and additional offsets (Maron et al., 2023), or precludes efforts to reduce biodiversity loss through direct regulation of biodiversity harms.

Hence, the delimitation of credits from offsets is not absolute: some demand-side fungibility will mean some credits might ultimately be used for compensating for harms, be it as intentional substitutes, indirect supplements, or through legal changes over time. Limiting demand-side substitution, through measures to ensure the integrity across different mechanisms, is therefore key to minimise perverse outcomes. Nevertheless, supply-side fungibility also occurs: projects producing biodiversity gains can be demanded as both compliance offsets and voluntary credits, as already observed in practice in some jurisdictions (Section 3). The added demand might increase scarcity in offset markets, thus theoretically providing more incentives for upfront avoidance of biodiversity impacts, as a potentially desirable spillover effect. Interactions between offsets and credits are so far little understood, or studied empirically.

b. Biodiversity credit functioning

Biodiversity credits inherently depend on commodifying biodiversity outcomes to allow for clear benefit attribution (to credit owners), commensurability (in units of currency), divisibility (between actions), tradability (between market actors) and storability (over time, e.g. mitigation banks) (Robertson 2004; White et al. 2021). These commodified features simultaneously constitute both opportunities and challenges.

Advocates for biodiversity credits suggest win-win outcomes can be achieved: enhanced biodiversity coupled with improved community livelihoods, and investor fulfilment of corporate social responsibility (CSR) objectives or successfully using credit to address companies' exposure to nature-related risk. However, an explicit theory of change (ToC) for biodiversity credits is still lacking. Generally, ToCs help laying out the stepwise requirements and assumptions needed for policy instruments to reach their intended goals – i.e., of "who will do what differently and why?" (Martius et al., 2018). In the past, empirically informed ToC frameworks have helped analysing innovative conservation tools such as environmental certification (Romero & Putz 2018), reduced emissions from deforestation and forest degradation (REDD) (Martius et al. 2018), payments for environmental services (PES) (Wunder et al. 2020a), and environmental impact bonds (Thompson 2023). A ToC is also helpful for stating relevant hypotheses and identifying confounders in rigorous impact evaluation. Here we will thus combine economic theory (how credits should work) with pilot experiences (how they have worked so far) to sequentially link inputs and treatments to intermediate outputs, outcomes, and final impacts (Qiu et al. 2018). This also allows us to classify different variants of biodiversity credits design, as manifested in current pilots, to be discussed further in our empirical assessment (Section 3).

A biodiversity-credit project developer typically seeks investment from a buyer or investor (*inputs*) to support conservation implementation, often aligned with standards and methodologies (Figure 1). Such customized on-the-ground actions may combine incentives (e.g., payments for environmental services [PES] to landowners), disincentives (e.g., resource-use restrictions, protected areas) and enabling actions (e.g., environmental education, land purchases) (Börner et al. 2020) (*treatments*). These influence local land stewards to either generate improvements in biodiversity through protection ('avoided loss') and/or from biodiversity restoration ('uplift'). Both avoided loss and uplift are defined, in theory, relative to a counterfactual of what would have happened without the biodiversity credits investment (Maron et al. 2013).

In practice we distinguish three different pathways along which credits are/ may be generated. Notably, when credits are issued based on *actions*, they will clearly depend less on verifiable biodiversity improvements than when moving to the right along the ToC, i.e. when they are *outcome*-, or even *impact-based* (Section 3):

❶ Monitoring management *actions* (allegedly additional, contributing to biodiversity outcomes)
❷ Monitoring biodiversity *outcomes* relative to a baseline defined ex-ante (static or projected)
❸ Ex-post evaluated biodiversity *impacts*, relative to a dynamically observed counterfactual

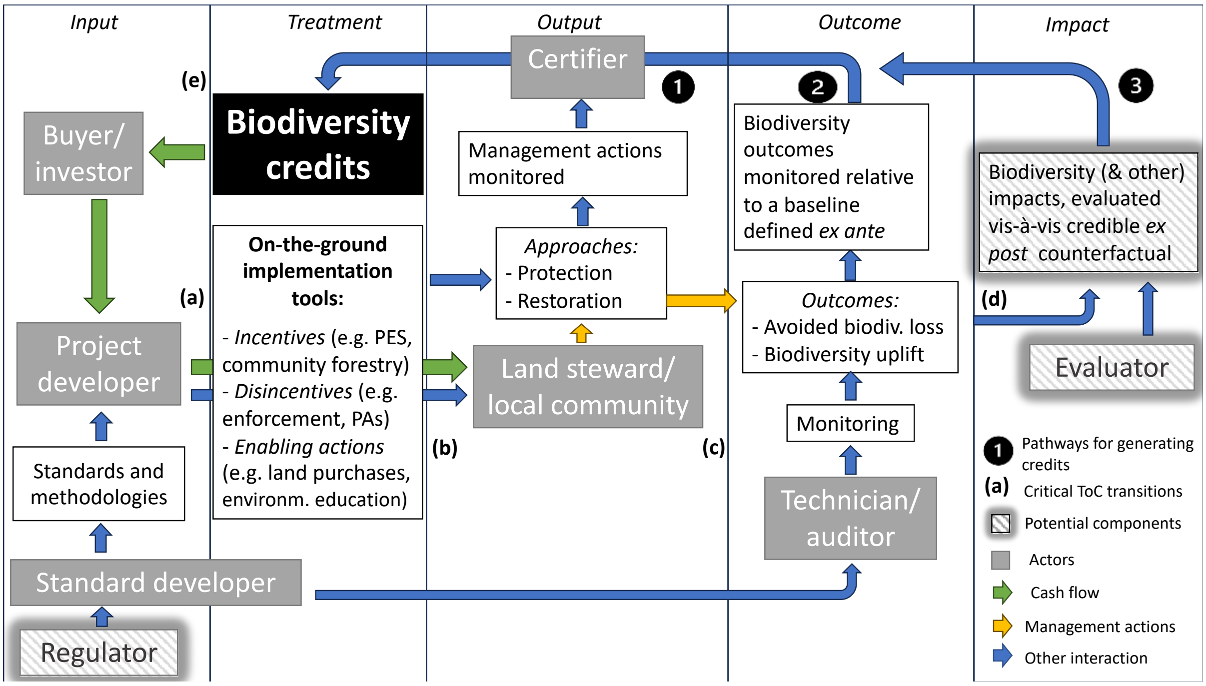


Figure 1. **Theory of change diagram for biodiversity credits: current and potential function**

For biodiversity credits to reach their intended impacts, mainly improving the state of biodiversity relative to a ‘no-credits’ counterfactual (verified by using rigorous methods with dynamics baselines, e.g., through monitored control areas), various critical ToC transmissions need to hold. Among the most important assumptions, we flag here (cf. letters in Figure 1):

(a) Upfront funding available (inputs => treatments)
(b) Action implementers locally are considered legitimate (treatments => outputs)
(c) Actions target biodiversity priority areas, use an adequate policy mix, and have substantive local participation (outputs => outcomes)
(d) Rigorous metrics, baselines and impact evaluation are used (outcomes => impacts)
(e) Credit demand sufficient for sustainable finance (credits => inputs feedback loop)

3. Lay of the land: currently ongoing initiatives

To describe the current state of biodiversity credits implementation, we compiled global data encompassing the rapidly proliferating initiatives, using peer-reviewed and grey-literature sources while also integrating pre-existing partial compilations (e.g., GEF 2023; Pollination et al. 2023; Carbone4 et al. 2023; Gradeckas 2023). Globally, our sample includes 37 ongoing initiatives developing and implementing standards (August 2023) (Figure 2; Table A3). For each credits initiative, we identified the methodologies and metrics used (e.g., biodiversity indicators, monitoring tools) and credits issued (e.g., outcomes, baseline, bundling, timing, price) (cf. Appendix A2/3, and discussion in Section 6).

Figure 2 maps standard developer locations and initiatives’ progress, scaled from preparational to operational. In 17 cases, projects were implemented also where standards are concurrently developed. Notably, advanced projects distribute in a geographically skewed manner, favouring countries with a tradition for market-based instruments. Of all single-country projects being operational/piloted in our sample (n=20), 6 are located in Australia/Oceania, 4 in Europe (Central, Northern, UK), 3 in South America (of which 2 are in Colombia); only 1 in Africa, and none in Asia. In turn, five standard developers are implementing projects cross-continentally, e.g. Savimbo in Oceania, South America and Africa, or InvestConservation in Ecuador and Borneo. Among government-led programmes, Gabon's, Niue's and New Zealand's are under consultation (Pollination, 2023; Ministry for the Environment, 2023), whilst Australia's was recently legislated. Notably, four project developers cater not only to voluntary markets (as per biodiversity credits inclusion criterion), but simultaneously also to biodiversity offset markets, indicating the supply-side fungibility of projects (cf. Section 2).

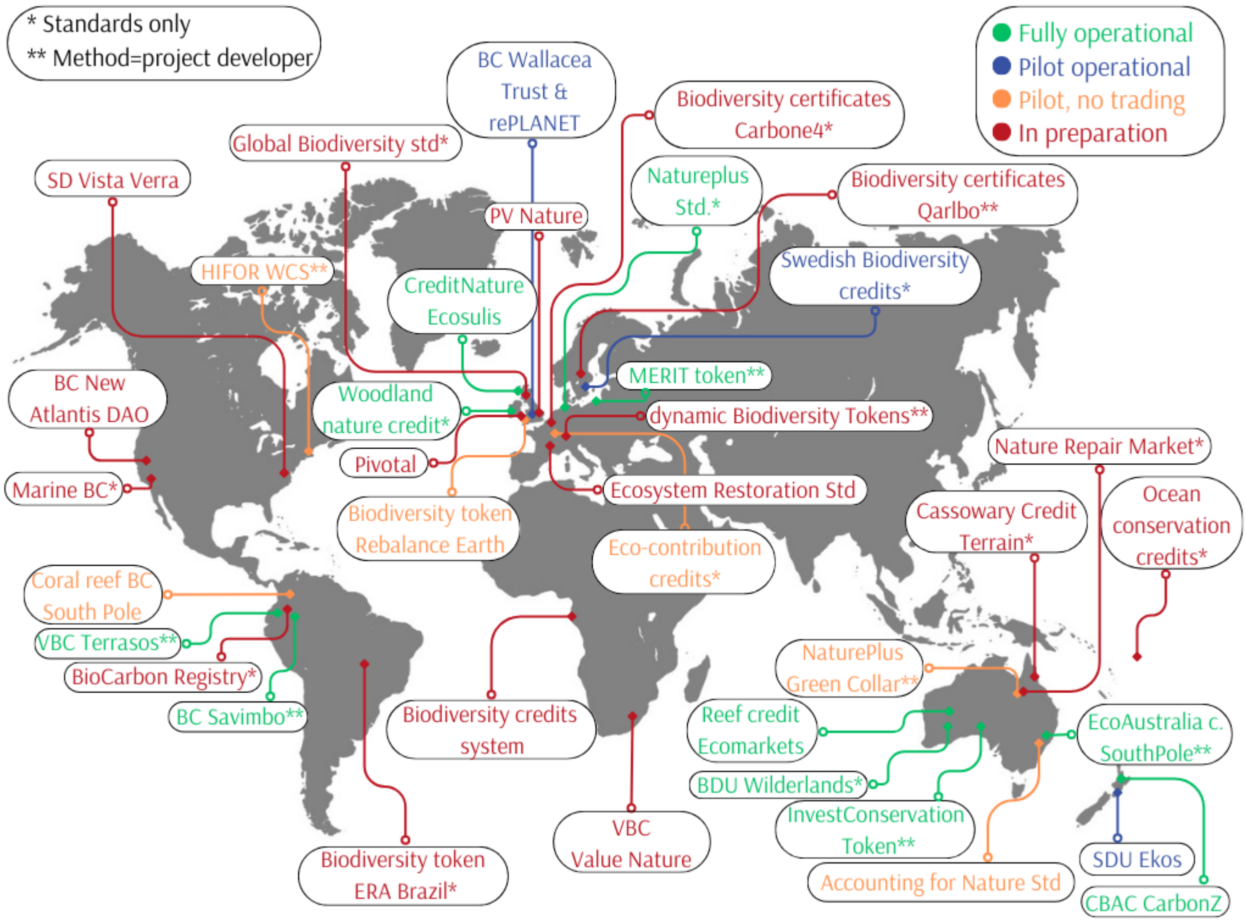


Figure 2. Global map of biodiversity credit initiatives: operational state and market function (n=37)

Notes:

- *Fully operational* (green): currently selling credits
- *Pilot, operational* (blue): methodology ready; credits from pilot projects sold
- *Pilot, testing* (orange): methodology released/launched; projects being tested without selling credits
- *In preparation* (red): methods being developed/consulted

Standard developers (*): develop methods for measuring and issuing credits
Project & standard developers (**): integrate credit and project functions
Residual without "*": integrating selectively methods, certifiers, verifiers, traders/ platform operators.
Acronyms: std.-standard; c.-credit; VBC-Voluntary biodiversity credits; BDU-Biodiversity Unit; SDU-Sustainable Development Unit; CBAC-CarbonZ biodiversity action credit
Sources: Consultations with standard developers, GEF (2023), Pollination (2023), Gradeckas (2023), Carbone4 et al. (2023)

Figure 3 further describes how the emerging market evolves. One third of initiatives develop methods; about another third also certify and trade under their own project registry (Fig.3a). For instance, Savimbo develops both methods and projects, using a direct interface with landowners to reduce transaction costs. As for implementation status, 38% are operational (10% as pilots), though most at small scales; almost half remain under development (Fig.3b). Most schemes focus on terrestrial (61%) or marine biodiversity (13%), while 18% cover multiple ecosystems. Some target agricultural land (Savimbo, Recelio, ReGeneration). Credits focus on averted loss (19%), biodiversity improvements (22%), while most combine both (Fig3c). Project horizons range 10-20+ years.

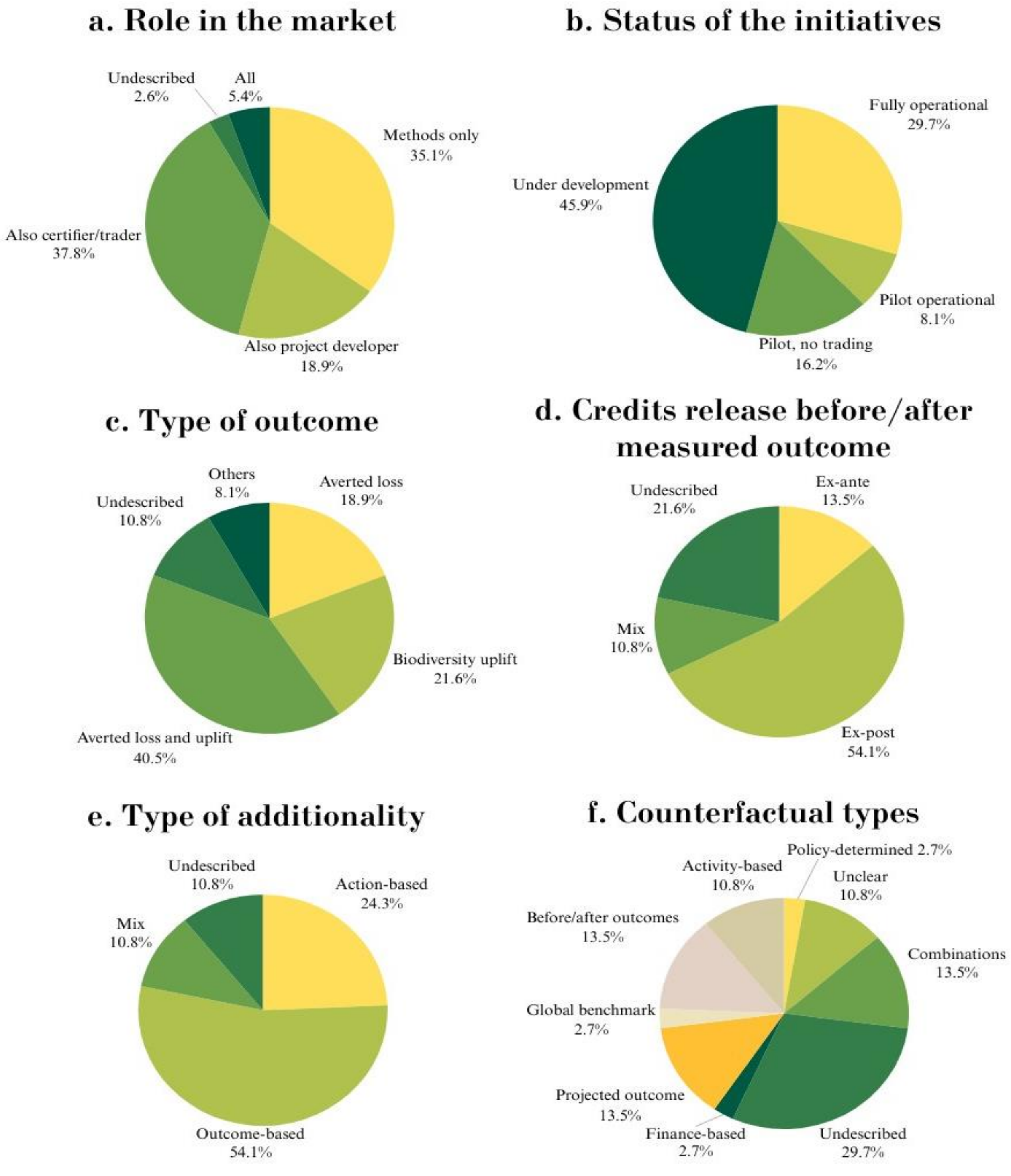


Figure 3. Key features of emerging biodiversity credit initiatives (n=37)
Note: For definitions, see Appendix Table A2

We can also trace our previous three crediting pathways from Figure 1. Nine cases in our sample adopt Pathway 1, monitoring actions and releasing credits based on those only (Fig.3e). Of these, one case represented additional inputs (more resources), while three newly implemented activities (or activity-based outcome projections) (Fig. 3f). For example, the Biological Diversity Unit by Wilderlands employed a policy-predetermined baseline, the InvestConservation token focused on additional financial inputs, while the Swedish Biodiversity Credits focused on actions against the existing management plan as a baseline.

With 14 cases, Pathway 2 is dominating: biodiversity outcomes were monitored relative to a baseline defined ex-ante. Unlike Pathway 1, this involved monitoring of some biodiversity metrics, whether as simple before-and-after comparisons (static baseline) or compared to an ex-ante assumed counterfactual (projected baseline) to determine credit issuance (Fig.3d). Examples of static baseline (n=5, Fig.3f) include credits issued against ecological milestones reached (e.g., Terrasos, GreenCollar) or gains vis-à-vis initial degraded ecosystem states (Coral Reef-South Pole in Colombia). Projected baselines (n=5, Fig.3f) may use remote-sensing baseline for at least five pre-project years (e.g., ValueNature monitoring habitat and wildlife populations). Alternatively, Cassowary Credits quantified rainforest habitat improvements and pressure reduction using ex-ante scenarios projecting biodiversity changes without the project. Currently, proponents use multiple counterfactual approaches to demonstrate projects allegedly make a difference. Some standards flexibly allow for posterior choice among several baseline scenarios to assess additional outcomes (e.g., Wallacea).

Pathway 3 features ex-post verification of outcomes against a data-driven dynamic counterfactual, thus attempting to eliminate confounding factors in a quasi-experimental attributive approach. Credits are only released ex-post following validated outcomes relative to a statistically-derived (i.e. not proponent-selected) counterfactual, representing a scientific ideal in credit schemes (Swinfield et al. 2023). Challenges include data for suitable control sites and considerable time lags between action and impact (Section 5). Currently only two cases approximate Pathway 3. First, the Marine Biodiversity Credit (Open Earth Foundation Ocean Program) uses a dynamic global benchmark index against which to quantify project-attributable impacts. Second, Wallacea's methodology also encourages, though does not require the use of monitored control sites (Wallacea 2023).

Unfortunately, the clearly biggest subgroup in our sample (41%) represents cases where the counterfactual remains either undescribed or unclear, leaving open the nature of crediting pathways (n=13).

Overall, our findings arguably do not convey an ideal picture. More than half of biodiversity credits in place or underway are either based on *actions* and their projected change, or remain unclear in conveying how they will generate credits. Result- or performance-based credits with properly evaluated *outcomes* or *impacts* against well-defined counterfactuals are clearly rarer. Furthermore, currently allowing often for flexible choices among multiple baselines may eventually reproduce key risks of opportunistic manipulations inflating baselines, credits and 'gaming' revenues as recognized in voluntary carbon markets (West et al. 2020, 2023; Calel et al. 2021; Stapp et al. 2023) and biodiversity offset markets (Maron et al., 2015). Rigorous ex-post impact evaluation elements, required to assess attributable performance, are practically absent. Jointly, these features can cast doubts about the prospects for biodiversity credits to achieve additionality under currently adopted baseline systems (Section 6).

4. Monitoring and commensurability of biodiversity change

4.1 What is measured for crediting?

A key crediting barrier is identifying suitable proxies to capture multidimensionality: biodiversity, characterised by the variability among living organisms (CBD 1992), encapsulates multiple scales of biological organisation (i.e., genetic diversity, species, ecosystems). This complexity also hinders the identification of a single currency for global biodiversity credits trading, equivalent to what carbon-dioxide equivalents (CO_2e) are for greenhouse-gas emissions (GHG). In addition, the values placed upon biodiversity are characteristically place-based (Jones et al. 2019), hence creating difficulties for comparisons across geographies. Measurement across scales involves functional, structural, and compositional indicators, necessitating a multi-faceted approach to assess the holistic state of nature. Various components can involve functional, structural and compositional indicators; necessitating a multi-faceted approach to assess the holistic state of nature.

Some innovative approaches towards providing comparative units at a global scale are noteworthy, such as quantifying extinction risk (e.g., Species Threat Abatement and Restoration (STAR) metric, Biodiversity Pressure Index by the LIFE Institute (Life Cycle Impact Assessment) and measuring the intactness of biodiversity relative to a reference state (de Palma et al., 2021, Mair et al 2021; Eyres et al. 2023, Milà i Canals et al., 2007). Other metrics may try to capture only partial components of biodiversity, be biome- or location-specific, and may thus be suitable only for application in particular ecological contexts (TNFD, 2023).

Most nascent biodiversity credit standards define how to measure, govern and trade credits, using baskets of outcome-based metrics with multiple biodiversity indicators and components (Taskforce on Nature Markets, 2023). For instance, the Swedish Biodiversity Credit provides specific metrics to compare within single biomes, boreal forests (Biodiversity Credits, 2022); EcoAustralia and Terrassos (Colombia) act within national domains (WEF, 2022). The Accounting for Nature Framework offers methods for various environmental asset classes, from faunal diversity accounted through a species richness indicator (which can be associated with the conservation status of native species) to waterways condition assessed through water quality, ecological flows, and riparian indicators. The framework targets meaningful components of ecosystem structure, function and composition in different contexts.

Some schemes develop(ed) metrics to compare biodiversity across ecosystems. For instance, Carbone4 assigned for each ecosystem an intactness-disturbance index ranging from zero (no biodiversity) to one (undisturbed ecosystem) type, based on expert-selected parameters (Carbone4, 2022). Wallacea's methodology uses a basket of metrics tailored to ecoregion and objectives, calculating the median percentage change in metrics values after five years to reflect the site's standardized biodiversity improvement (Wallacea, 2022).

Our review of existing schemes revealed a heterogeneous mix of metrics being used. Most captured higher level of biodiversity composition(i.e., species and ecosystems) and structural diversity (e.g., deadwood in Swedish forests), whereas genetic components and functional diversity are less common. *Species- and habitat*-based metrics are most often used, although monitoring species can be more expensive and time-consuming than measuring changes in habitat extent or ecological intactness. Methods *combining* species, genetic diversity and habitat are rare (5%).

Species- and *habitat*-based metrics are frequently used by emerging biodiversity credits, e.g. species richness, diversity, abundance, (14%), habitat with respect to extent, quality, or both (31%) (Fig.5a). Species metrics focus on changes in population sizes and/or diversity; species presence can often now feasibly be detected using technology. Well-studied taxonomic groups such as plants and vertebrates are often used as surrogates for wider biodiversity. Crediting metrics for species covers several taxonomic groups: ¾ of cases focused on at least three species groups, with birds, mammals and plants being the most popular (Fig.5b).

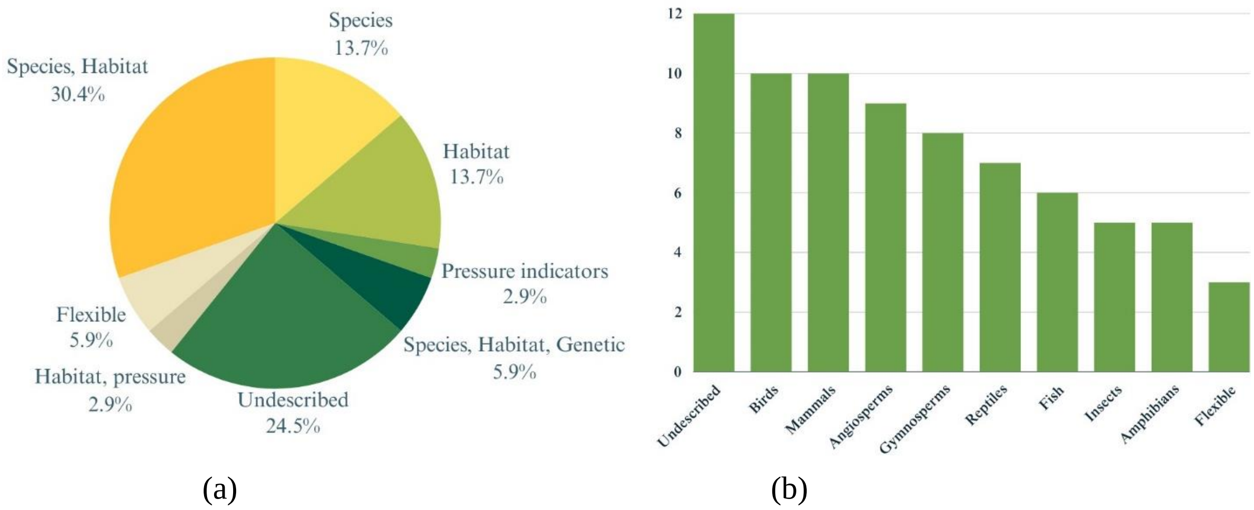


Figure 5. Biodiversity credit metrics. a) Type of indicator (n=36); b) Taxonomic groups monitored (n=32). Source: Own data

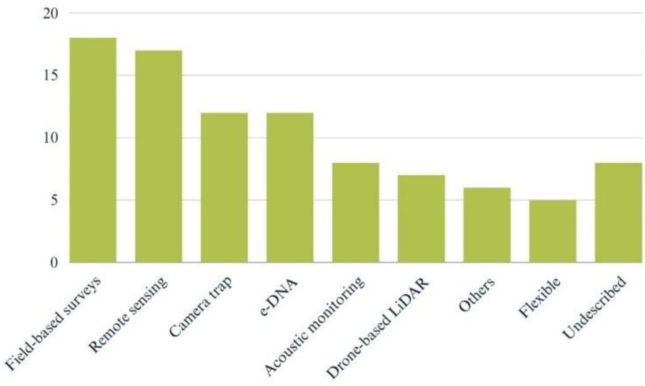
Habitat-focused metrics (mainly on quantity, quality) are sometimes more practically measurable, and are often used as a biodiversity proxy through global or local satellite-based remote sensing and geographical analyses. For example, each EcoAustralia credit relates to 1.5m^2 of habitat protection. However, these seldom consider landscape-scale effects such as habitat configuration or fragmentation beyond the project site.

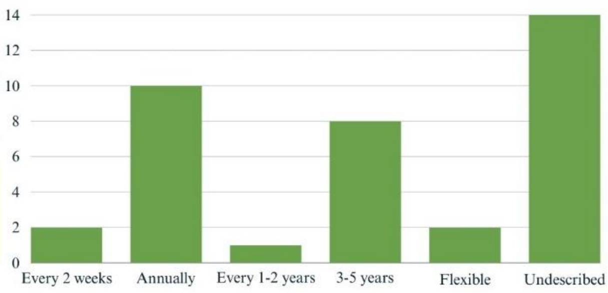
Biodiversity metrics can be customized to place-based values, but flexibility also has major drawbacks for credit systems. Obviously, spatially customized indicators make for hard-to-compare gains across projects globally, thus facilitating more segmented markets that would not be universally fungible (Section 5). Moreover, implementers could ex-post cherry-pick the indicators that had developed most favourably, introducing a gaming element that could weaken trustworthiness of credit systems. Finally, strong indicator customization will harden leakage assessments, i.e., new threats to adjacent non-intervention areas (cf. Section 6).

4.2 How is change measured?

Biodiversity credits monitoring approaches are just as variable as metrics, but two types prevail: ex-novo approaches (gathering new data) vs. desktop approaches (processing existing data).

Among *ex-novo approaches*, field-based surveys have long been the gold standard for biodiversity assessments, and also remain most popular in credits monitoring (n=18; Fig.6a). These feature high resolution of customized site-specific data, but are also time-consuming, technically demanding, and potentially expensive. New technologies helping to quantify biodiversity changes are becoming cheaper, and arguably more reliable as they mature, monitoring a wider range of biodiversity indicators (White et al 2021; Speaker et al 2022). For example, environmental DNA (n=12), passive acoustic monitoring (n=8), and drone-mounted lidar (n=7) are becoming widespread alternative tools to measure biodiversity, which credits initiatives are partly taking on board.





(a) (b)

Figure 6: Biodiversity monitoring: a) methods and b) frequency (n=37)
Source: Own data

Desktop approaches use generic (e.g., mid-point indicators in land-use impact assessments) or location-specific geodata (e.g., remote-sensing data or, other biodiversity observations databases such as the Global Biodiversity Information Facility (GBIF)). Remote sensing is widely used (n=17; Fig.6a). Moving forward, combining field surveys increasingly with these new ex-novo and desktop technologies will thus probably become the most cost-effective monitoring pathway, although universally-agreed ways of measuring biodiversity or ecosystem condition from space have not yet been developed.

As for *frequency* (Fig.6b), many schemes (n=10) used annual monitoring of outcomes, but with much variation, including some large intervals of 3-5 years (n=8). For almost half of the cases (n=16; 43%), frequency was explicitly left flexible, or information was lacking. Again, overly large or excessively flexible monitoring intervals may potentially introduce both insecurities and gaming options that could decrease the trustworthiness of credit schemes.

In Appendix Table A1, we provide a tentative taxonomy for biodiversity units, inspired by carbon credits, which potentially could further help classifying different biodiversity credits relevant accounting units, whether tradable or not.

5. Who will buy and sell biodiversity credits?

Demand

There is much hope that voluntary credits markets will contribute substantially to closing the aforementioned biodiversity financing gap of US$700-900bn/yr (Taskforce for Nature Markets, 2023). Yet, this challenge is daunting: even after decades of operation, voluntary carbon markets only reached 2 billion US$/year in 2022 (Shell & BCG, 2023). Indeed, industry predictions of biodiversity credit (and offset) market potential till 2030 are with US$162-68 billion still dwarfed by the potential US$268 billions saved by reducing harmful (especially agricultural) subsidies (Paulson Institute 2020:60). Overall, since potential credit buyers are highly diverse (Krause et al., 2021; Löfquist & Ghazoul 2019), a closer look at their attitudes and motivations is important. A central question is: why would the private sector voluntarily want to pay for global public goods?

A key driver of demand will be the *claims* that buyers are able to make from purchasing credits. One key organisational motivation is to fulfil voluntary *'nature-positive'* commitments (Pollination 2023). Similar concerns as for carbon credits apply, namely that purchasing credits could come to undermine action to reduce the drivers of biodiversity loss (cf. Section 2). For instance, Australia's planned legislative move to permit credit purchases over like-for-like offsetting transactions might stimulate credit demand – albeit in bypassing the mitigation hierarchy, to the likely detriment of threatened biodiversity (Maron et al., 2023).

Secondly, firms may use credits to manage exposure to nature-related risks, and to convey these efforts to others. When purchasing biodiversity credits from landscapes in which they are operationally reliant, and biodiversity loss is a material supply-chain risk, credits may address their exposure to nature-related risk under TNFD. More speculatively, purchasing credits might reduce their *future regulatory risks*. The voluntary purchase of credits shows evidence that firms are 'doing good' for biodiversity, which may delay, mitigate, or even reduce future regulation. Firms protecting nature voluntarily might thus not only make them more adaptive, but also wield *soft political power*. In addition, firms may increase their ESG scores (Nature Finance, 2023), which in turn may reduce costs of debt (Eliwa et al., 2021).

The literature points also to other potential motives to buy biodiversity credits (e.g. Krause et al., 2021; Löfqvist et al., 2023). *Corporate image-building* and *marketing benefits* potentially translate into enhanced market shares and price premiums, but also increase *employee job satisfaction*, reducing retention and recruitment costs. Still, price premiums may be small, as for instance shown for environmentally certified forest management (Cubbage and Sills, 2020). Yet, firms are also growing increasingly wary of greenwashing accusations and related emerging regulation, which in turn may raise demand for credits quality assurance.

Buying biodiversity credits in neighbouring areas could also improve firms' *Social License to Operate*. For example, toy giant LEGO engages in natural restoration, recently declaring intentions to reforest 10,000 hectares near its headquarters (Landbrugsavisen 2023). Kering committed to restore and regenerate one million hectares in its supply chain, protecting another million hectares of critical, irreplaceable habitat by 2025 (Kering, 2020). Several large EU companies have sustainability targets and progress reports due in 2024, as per the EU Corporate Sustainability Reporting Directive (CSRD), which could stimulate demand for easy-to-report measures of biodiversity protection, such as biodiversity credits (EU, 2022).

Supply

Another crucial question is where credit supplies would originate from, given conservation financiers cite the lack of profitably investable projects as the single largest upscaling barrier (CPIC 2021). Supply challenges vary geographically: cultural and rural land management obstacles are constraining in wealthier nations, while concerns over land tenure and corruption dominate in emerging economies (Löfqvist et al. 2023). A cross-cutting constraint is limited investor appetite for small projects where transaction costs abound.

As observed for voluntary carbon markets, transboundary market self-regulation may eventually fail to safeguard environmental integrity, e.g. when business models favour quantity over quality in credit supply (Greenfield 2023; Salzman & Ruhl, 2000). Permitting the protection of intact ecosystems under only incipient threat has intuitive appeal in increasing habitats managed for their valuable biodiversity, but due *inter alia* to poor threat predictability, the average additionality of these investments may be low (Maseyk et al. 2021). Thus, there is a risk of massive flows of 'hot-air' project supply, as observed for voluntary carbon markets and other private large-scale investments (Badgley et al. 2022; zu Ermgassen et al. 2023).

Conversely, an environmental impact-wise ideally designed ex-post crediting system – our Pathway 3, Section 2 – may constitute a challenging business case for potential suppliers: costs and risks will increase, with long time lags between investments and credit returns, especially for time-consuming biodiversity restoration efforts. This setup might eventually require substantial private and/or public financial intermediation and buffers to bridge time gaps and hedge against the added risks of credit non-performance.

Market size

In May 2023, the eight most developed biodiversity credits schemes reportedly covered 800,000 hectares collectively, with US$8 million pledged for funding (Carbon Pulse, 2023). The market is estimated to be currently between US$2-8 million (UNEP, 2023). In our dataset, per-credit prices range US$5-35 – maximum US$413 (Carbon Pulse, 2023c). Price expectations are for US$12/ha/yr by 2030 rising to 45$/ha/yr by 2050 (Carbon Pulse, 2023d). Future demand has been variously projected at US$2 billion in 2030 and US$69 billion by 2050 (WEF, 2023); a high-range alternative is US$160-200 billion by 2030 (BloombergNEF, 2023; GEF, 2023).

Yet, these inflated expectations are derived mostly from multilateral commitments (as under the Kunming-Montreal Global Biodiversity Framework), rather than transparently undertaken projections grounded in observed trends. Here we will not propose alternative guesstimates, but simply highlight the non-trivial limitations for both demand and supply, as discussed above. Moreover, the degree of market segregation among biodiversity credits will strongly influence tradability and scale.

Overall, some clear design tradeoffs between credit market quality and quantity have long been apparent (Salzman & Ruhl, 2000). Low-integrity, highly fungible biodiversity credits markets might potentially grow voluminous, that is, to the extent credits are ex-ante activity-based rather than ex-post impact-determined, that overly flexible baselines allow zero-additionality scenarios to get paid, and those low-integrity credits to continue to be issued against better knowledge (Macintosh and Butler, 2023). If recent initiatives to create higher-integrity carbon credits are successful (Twidale & Macfarlane, 2023), biodiversity credits markets could learn from them and avoid repeating decade-long carbon market mistakes (Section 6). This may initially imply slower-growing biodiversity credits niche markets, creating first the market confidence that is needed before sustainably scaling up.

6. Lessons from other conservation incentives

To become successful, biodiversity credits need to demonstrate environmental effectiveness, while respecting the human rights and improving the welfare of people in landscapes receiving investments. There are key lessons to learn from the last decades of experience with biodiversity offsetting, payments for environmental services, and forest carbon markets.

i. Develop and commit to high-integrity universal standards

Project proponents face challenging, yet not unfamiliar tradeoffs between ecological integrity and ease of market operation, as similarly found for regulatory-driven crediting mechanisms (e.g., Robertson, 2004; White et al 2021) and other nature-based markets (Salzmann & Ruhl 2000; Teytelboym 2019; Kedward et al. 2023). This inherent challenge has no single optimal solution. Ecologically robust measurement methods can act as a barrier to trading, by raising transaction costs and filtering out certain trades: in 'thin' illiquid markets, matching buyers to sellers is harder, and market-based resource allocation less effective (zu Ermgassen et al. 2020). Conversely, coarse and easily-measured biodiversity metrics may compromise on ecological robustness. A similar dilemma relates to price. Lower credit prices should in theory enable an efficient allocation of conservation funding to projects that promise to deliver biodiversity gains. Yet, if we see credits as an 'optional biodiversity tax', lower prices also reduce firms' initial incentives to reduce biodiversity losses (zu Ermgassen et al. 2020).

High current variability in credits methods is neatly mirrored by what has been seen in offsetting markets (Borges et al. 2023; Bracy-Knight et al 2020). After an experimental phase of testing out methods, credit developers need to commit to more stable, universal standards, if markets are to mature and show on-the-ground biodiversity impact. Without such consolidation, carbon markets and biodiversity offsets have shown that market forces increasingly translate high methodological flexibility into opportunistic over-crediting, or even gaming strategies (Swinfield et al. 2023; Badgley et al., 2022; Ruhl and Salzman 2011). While this might boost short-term private returns for some actors, it would pose a barrier to credit market integrity, confidence and upscaling, thus eroding options to effectively counter biodiversity loss.

ii. Robust baselines are needed to deliver additional biodiversity

Alongside needing appropriate metrics for measuring biodiversity (cf. Section 4), robust counterfactual approaches are arguably the single-most important matter for ensuring that credits are delivering biodiversity gains. Conservation impact evaluation is expanding rapidly, and its methods have advanced. Quasi-experimental study designs, such as difference-in-difference or synthetic controls, allow for robust evaluation of impacts from conservation interventions on forest-cover (Schelicher et al. 2020). Recent advances have shown how large-scale species time-series data can also be used for impact evaluation in certain cases (Wauchope et al 2022). Hence, solid evaluation methods are available to assess and attribute credibly the impacts of conservation interventions.

Unfortunately, evidence from robust impact evaluations of both biodiversity offsets and forest carbon credits suggests many are not delivering genuine additional positive outcomes. Gains associated with avoided losses are particularly problematic (zu Ermgassen et al. 2023, West et al. 2020, 2023). Avoided-loss offsets –whether for forest carbon or biodiversity—have suffered from over-crediting, caused by poor spatial targeting (selecting 'high-and-far' areas facing little real threat) – and as crux of the matter, adopting then opportunistic baselines that vastly exaggerated counterfactual threats, based on self-selected control scenarios under excessively flexible crediting standards (Calyx 2023; Haya et al. 2023).

Credits for active biodiversity restoration are typically more likely to achieve additionality as biodiversity improvements (Inkinen et al. 2022), although predictably also some *per se* profitable restoration projects will seek out biodiversity credit funding as a (non-essential) income supplement, making these projects de facto non-additional. Moreover, restoration-related efforts are typically time-consuming (>30yr), so that their alleged additionality can only be confirmed with large time lags.

As reviewed in Section 3, currently used credit counterfactual approaches should ring alarm bells vis-à-vis additionality concerns: for a large part of cases, baselines are either non-existent, unclear, extremely flexible (and thus ex-post manipulable), and/or are not based on monitored outcomes. Current biodiversity credit practice is thus repeating mistakes from the voluntary carbon credit market. Especially 'avoided-loss' biodiversity credits will predictably face similar baseline issues as forest carbon market (Greenfield 2023; Haya et al. 2023) and biodiversity offsetting (Maseyk et al. 2021). Notably, credits project proponents should not be permitted to self-select control sites (i.e., much more threatened ones than their project areas) – a practice that led to systemic over-crediting in certified avoided deforestation carbon credits (West et al. 2023; Calyx 2023).

Alternatives have been proposed which circumvent the ability to game the counterfactual, using a combination of impact evaluation techniques, e.g., matching paired with difference-in-difference analysis allows for estimating the before-and-after effects of an intervention (e.g. Swinfield & Balmford 2023). The best way to ensure biodiversity credits are truly additional would be to issue credits based on ex-post robustly evaluated impacts using satellite-data (Swinfield et al. 2023) – a method virtually absent in current biodiversity credits practice (Section 3). Conversely, when biodiversity credits are released to buyers before real-world biodiversity improvements are verified, it is essential to have contingencies in place to ensure remedial action is taken. This requires effective governance (see below); the sheer existence of compliance and enforcement powers does not alone guarantee these are exercised when needed, as England's biodiversity compensation system has shown (Rampling et al. 2023).

iii. Permanence of biodiversity credits poses particular challenges

Alongside additionality concerns, impermanence is a systemic threat to the outcomes delivered by a biodiversity credits market, and a concern raised in carbon credits and biodiversity regulatory credits and offset markets (e.g., Carreras Gamarra & Toombs, 2017; Bull et al 2013). Mechanisms to improve the longevity of regulatory biodiversity banking systems have included the requirement for long-term management plans, mechanisms for ensuring financing of management in perpetuity and placing formal land-use restrictions on the area being restored/protected (e.g., conservation easements) (Caroll et al., 2012).

Carbon credits also attempt to overcome impermanence issues through mechanisms which could apply to biodiversity credits. Temporary crediting offers an option, i.e., project implementers lose their revenues if the biodiversity outcomes are not retained for the duration of specific time-periods specified in their contracts. But this creates financial risks in the event of credit replacement, to either buyer or seller. Carbon markets have also used buffer pools of non-tradable buffer credits to insure against reversal risks, non-additionality and impermanence (Balmford et al., 2023). However, buffers are only as good as the average quality of the credits they contain, which would be problematic when credits are not commensurable or additional (see above). Further, buffer pools for permanent credits would require permanent monitoring systems both for the project and its control areas.

Among the biodiversity credits cases surveyed, Wallacea's methodology includes an "insurance buffer pool" of 20% for avoided-loss and 10% buffer for uplift-based credits (Wallacea, 2023). However, there are valid questions about whether these multipliers are sufficient in the context of recent evaluations of both avoided-loss carbon credits and biodiversity offsets, demonstrating underperformance of larger dimensions.

iv) Leakage can reduce overall biodiversity gains

Beyond satisfying additionality requirements within intervention areas, conservation interventions can also have *spillover* effects beyond the intervention area, sometimes strengthening but often weakening total conservation impacts (Meyfroidt et al., 2020). Interventions restricting opportunities to exploit natural resources can, for instance, partially displace those activities and their environmental effects to other areas. These spatial spillovers work through economic forces (e.g. moving production factors, changing prices), but also human learning, altered motivations, and ecological-physical links (Pfaff & Robalino, 2017). The most considered negative spillover effect is threat-displacing *leakage* (Filewod & McCarney, 2023). Its scope can be local (e.g. protected-area buffer zones), regional/national (e.g. emigration of settlers), or transnational (e.g. raising global commodity prices); the higher the price elasticity of the intervened output market, the farther leakage rings will likely spread (Murray, 2008).

How big a problem is leakage? Occurring outside the project boundaries, and requiring no-intervention counterfactuals, leakage is inherently difficult to directly monitor; typically, modelling is needed. Leakage is partial; it almost never triggers 1:1 threat displacement. When interventions replace high-profit rather than economically marginal activities, these are more likely to leak elsewhere (Atmadja & Verchot 2012; Wunder 2008). Quantitative assessments of forest-based climate-mitigation leakage show a large variation in estimates, from 10-20% nationally in large US government environmental programmes to a 42-95% range for smaller programmes worldwide including transnational leakage (Gan & McCarl 2007; Atmadja & Verchot 2012). For large-scale, long-term policy of creating 525 new protected areas in the Brazilian Amazon during 2004-17 was found to produce little regional leakage – sometimes even triggering its negative twin "blockage" of reducing biodiversity loss 'outside', due to lost local development momentum (Barros et al., 2022).

For biodiversity conservation, restoration may be more susceptible to leakage than preservation action, when spatial redistributing pre-established economic activities (Filewod & McCarney 2023). However, land characteristics inside vs. outside also matter: if the credits-related preselection of conservation intervention sites has effectively prioritized biodiversity hotspots and other priority areas, then a one-unit habitat loss 'outside' is likely less damaging than the same 'inside'. For biodiversity, the per-hectare leakage loss may thus be less than for carbon: in the tropics, ecosystem service densities tend to be more concentrated for biodiversity conservation than for carbon (e.g., Locatelli et al., 2014, for Costa Rica); elsewhere this ranking may be reversed (e.g., Anderson et al., 2009, for the UK).

In summary, for credits implementers leakage observed in forest carbon projects should illustrate how interventions restricting land use in one location may partially displace threats elsewhere. Nevertheless, there is no consensus on how leakage is best addressed. One school of thought advocates additional productive-sphere actions to reduce commodity demand and/or increase local supply in the restricted activity (e.g., by boosting productivity) (Filewod & McCarney, 2023). But this just addresses output, not factor markets as leakage-transmitting channels. Alternatively, leakage may be viewed as a result of seldom-avoidable market forces, the effect of which should be measured, and sometimes ex-ante predicted, but not necessarily micro-managed (Pfaff & Robalino, 2017). Since projects are often assumed to have larger leakage than national policies, this was one motive for scaling up REDD+ from project to jurisdictional scales (Boyd et al., 2018; Wunder et al., 2020) – a scaling matter that could also become relevant for biodiversity credits.

iv) Bundling and especially stacking of ecosystem services often disappoint

For biodiversity conservation to gain competitiveness, getting paid for more than one ES is appealing (Wunder & Kanounnikoff, 2009), either with one buyer paying for ecological improvements encompassing multiple ES (e.g., both biodiversity and forest carbon) (*bundling*), or by selling them separately to multiple ES buyers (*stacking*) (von Hase & Cassin, 2018; Cooley & Olander, 2011).

Among our biodiversity credits cases, eight have already developed carbon-bundled credits, accounting explicitly for carbon gains (e.g. ValueNature BC), including in high-integrity tropical forests or conservation hotspots (InvestConservation token). Almost half (42%) allow for bundling/stacking in principle, indicating hopes for generating synergetic revenue streams. Conversely, some voluntary carbon market standards already bundle in biodiversity and social co-benefits, including Gold Standard (https://www.goldstandard.org/) and Climate, Community and Biodiversity Standard (https://www.climate-standards.org/ccb-standards/).

Nevertheless, the extensive experience with bundling/stacking from implementing PES-type land-use conditional contractual payments offers mixed lessons (von Hase & Cassin, 2018): practical market and policy constraints often apply (Torabi & Bekessy, 2015; Robertson et al. 2014). Notably, stacking can reduce separate buyers' perceived additionality: the same environmental outcome is sold more than once, with hence a risk of asymmetrical accounting, or double-counting of benefits (Cooley & Olander, 2011; Robertson et al. 2014). Dealing with two different buyers simultaneously is also ecologically and institutionally complex, especially in the face of multiple natural and socioeconomic risks, and thus likely time-consuming and transaction-cost heavy (von Hase & Cassin, 2018).

Whilst bundling and stacking are elegant in theory (Cooley & Olander, 2011; Torabi & Bekessy, 2015), their practice is somewhat sobering: von Hase & Cassin (2018) identified globally only 19 PES and PES-like real-world schemes applying bundling, and notably just two stacking cases. In other words, bundling has sometimes been feasible, whereas stacking has failed from an ecological and additionality perspective almost wherever it has been tried (Hase & Cassin, 2018): buyer additionality concerns, ecological complexities and transaction costs have proved insurmountable obstacles.

v) Social safeguards and equity are central to success

Social equity considerations have proved key to increasing the acceptability and efficacy of on-the-ground conservation strategies worldwide (Klein et al., 2015). Moreover, biodiversity richness remains highest in the Global South, where much exploitation of natural resources is undertaken for consumption elsewhere. These stylized facts also underscore the vision that credit design and implementation need to contribute to social equity and global justice, in both a North-South perspective and for indigenous peoples and local communities (IPLC) (Löfqvist et al., 2023). Initially, globally derived priorities for biodiversity conservation need to also be made compatible with IPLC's own biodiversity values (Sheil & Wunder, 2002).

Drawing on key lessons from PES and forest carbon markets (Pascual et al., 2014), several approaches aim to incorporate equity and benefit-sharing elements into biodiversity offsetting (Jones et al. 2019), and recently credits markets. Incentive payments may provide a motivation for initially establishing improved governance mechanisms, e.g. land-tenure clarification (Zadek & Herr 2023). Credits may offer a potential avenue for meaningfully involving IPLC in the design and implementation of more equitable markets from the very beginning, rather than *ex post facto* (Tupala et al., 2022). Implementers have also proposed market-wide price floors and minimum benefit-sharing percentages reserved for IPLC, especially to counteract a trend observed with 'carbon cowboys': voluntary markets with poor institutions and deficient social safeguards marginalising benefits and disregarding costs on behalf of local people (Luttrell et al., 2013). Among the biodiversity credits currently targeted to the Global South, we observe at least considerable stated attention towards benefit-sharing objectives: in our biodiversity credits sample, designs specifically includes benefit-sharing targets of 60-70% (n=3), 70-80% (n=3), or even 90% (n=1), with the remainder not systematically investigated. Obviously, these stated targets would need to be reached also in implementation. In implementing them, predictably the biodiversity credits concerned may also become costlier.

Finally, global biodiversity credits markets could also help transfer some financial flows from wealthier economies to poorer countries with high yet threatened biodiversity (TBC 2022). But for that purpose, other global economic reforms addressing historic injustices and unequal historical destruction of biodiversity might be more effective (Dempsey et al., 2022).

vi) Institutional architecture is critical

In thinking through how biodiversity credits markets could or should function, concerns from voluntary carbon markets remain highly pertinent. In ongoing carbon-market reforms, vesting baseline-setting tasks with independent third-party institutions, instead of with project proponents, has been a recent proposed alteration (O'Sullivan et al., 2023) – one that would appear highly relevant also to the credits architecture. But this would be just a first humble step. Certifying bodies should arguably also not be industry-paid on a per-credit volume base, which for carbon gives them own incentives to push for over-crediting (Greenfield, 2023). Executing such fundamental reforms will likely encounter harsh resistance, given the vested interests concerned. Undoubtedly though, more incentive-compatible systemic architectures with broader sectoral participation are urgently needed for environmental markets in general, and biodiversity credits markets in particular (cf. Section 7).

Furthermore, the local impacts of biodiversity credits investments need to be institutionally contextualized. Credits must not lead to a 'land rush' where IPLCs are dispossessed, nor should informal land tenure conversely exclude IPLCs from the market, thus widening pre-existing inequalities (Monterroso & Sills, 2022). Various institutional factors act as strong obstacles to implementing effective conservation incentives - in particular for IPLCs with insecure, informal, partial, or resource-specific land tenure (Robinson et al., 2018). PES schemes, for instance, cannot be implemented when local communities lack effective rights of excluding third land-intruding parties (Wunder, 2013). Generally, geographies with weak institutions, e.g., in open agricultural settlement frontiers, or with a history of frequent political reversals, will struggle to attract credits investments. The World Bank/GEF-introduced Rhino Bond demonstrated recently that perceived high-risk countries with biodiversity hotspots were excluded as too risky receiver sites for investors (Medina and Scales, 2023).

Integrating socio-ecological concerns into functional governance setups across space and time may further long-term effectiveness (Griffiths et al., 2019). Nevertheless, reforming institutional contexts is challenging, and equity perceptions differ widely within and across communities (Bidaud et al., 2017; Griffiths et al., 2019). Changing institutional setups explicitly to enable conservation concession incentives and related policies may therefore easily come to fail, as shows a case study from Kalimantan (Wunder et al., 2008). Hence, credit project proponents will often need to adaptively try out which on-the-ground interventions would be contextually compatible, a trial-and-error process that adds complexity (and cost) to market-based approaches but is necessary for their success (Milne & Niesten, 2009).

7. Conclusion and discussion

This paper has reviewed the underlying theory of change and emerging design features of biodiversity credits, as developed globally in 37 documented cases at different stages of progress. From assessing the status quo, we have sought to evaluate their likely prospects, based on lessons from other market-based interventions, such as biodiversity offsets, PES, and carbon markets/REDD. But given the many identified parallels to similar financial incentives, readers may also legitimately ask: how much conceptual novelty vs. 'old wine in new bottles' is there fundamentally in biodiversity credits?

Redford et al. (2013) argued that conservation fads are characterised by the process of "an absolute abnegation of the previous approach or fad; second, an insistence that the next approach is totally new, usually signalled by a snappy new name; and third, not uncommonly, incorporation into the "new" approach of strong elements of the approach it is replacing" (p.3). Current biodiversity credits discourses would likely test positive under several of these 'conservation fad' criteria: many proposed schemes appear to replicate problems which particularly carbon and biodiversity offsets have faced. There are conceptual distinctions and similarities between the current emerging voluntary markets previous approaches to assessing biodiversity gains, offsets and credit generation based on regulatory markets (Section 2). Many design and implementation concerns are shared with voluntary carbon markets and experiences with biodiversity offsets (sections 4,6). All this is accompanied by apparently substantial credits market enthusiasm and lofty expectations for evolving market size (Section 5), which seems widely reminiscent of the early years of voluntary carbon markets.

The fundamental concepts underpinning the biodiversity credits concept are thus not novel, drawing heavily on previous instruments. Biodiversity credits pilot applications have also not yet demonstrated substantial departures from previous constraints. As a financing umbrella with open-ended on-the-ground implementation options, biodiversity credits implementers will face similar non-trivial challenges to previous umbrellas like integrated conservation and development projects (ICDP) or REDD: trying to put resources meaningfully to work by designing locally well-customized and effective intervention mixes. Notably, both ICDP and REDD interventions have so far disappointed expectations, for REDD explained by a chicken-and-egg mix of disappointing financing streams and ineffective on-the-ground interventions (Section 6; Wunder et al., 2020).

Rather than conceptual, the novelty with biodiversity credits may instead lie in the momentum and support for biodiversity that the idea has garnered in the private sector and policy circles. Much will depend on to what extent credits proponents will take on board critical lessons from the past: only by understanding more tangibly what previous elements worked or not, can more resilient instruments be developed. What would it take, then, for biodiversity credits to avoid becoming the next predictable conservation fad in line?

Ideally, voluntary credits would stimulate private conservation investments and allocate them towards global priority areas of conservation, fighting real but addressable biodiversity threats—rather than picking the lowest-hanging fruit of high-and-far de facto unthreatened areas. They would employ high-integrity biodiversity measures, adopt realistic baselines, and monitor progress using comprehensive metrics and tested approaches in intervention areas compared to control sites. Credits would be used in contexts where they become nature-positive complements, not undercutting existing offsetting systems aiming to reduce harm to threatened ecosystems, and not substitutes for stringent regulation to address biodiversity loss – and therefore ideally sold only to organisations with credible strategies for scaling down their own biodiversity impacts complementary to purchasing credits. Proponents would select, design and implement adaptive conservation strategies of both avoiding threats and restoring biodiversity, which performance-wise do well in checking the traditional environmental impact boxes: high additionality, permanence, limited leakage, attention to equity and sharing benefits locally. Scheduled-in rigorous impact evaluations would create confidence that the credits, including environmental and socioeconomic benefits, were for real, demonstrating that credits interventions would reach their objectives, as outlined in their ToC.

How does current biodiversity credits practice compare to this idealized wish list? At this early stage, certainly some elements look more constructive than others. Regarding biodiversity commensurability, a delicate prerequisite for tradability, new methods have been established, supported also by new, promising technologies (Section 4). For benefit-sharing, a thorny issue for many past conservation incentives, in our sample several emerging credits in the tropics aim to reserve considerable percentages of revenues for local communities (Section 6). Only when implementation progresses, will we see more results. Many interesting methodologies are being examined: heterogeneity abounds; the biodiversity credits market is letting many flowers bloom. Some experimental vagueness and inclusiveness is desirable when new concepts are put to test. But as over time concepts mature, clearer delimitations, methodological choices and solid standards are needed (Strunz, 2012) – a phase biodiversity credits arguably should embark on now.

Conversely though, on issues at the heart of carbon market failure—the perverse incentives for project proponents to over-credit by exaggerating business-as-usual baselines– the current biodiversity credits outlook is sobering. First, many credits schemes currently rely in their crediting pathway only on ex-ante indicators from the left-hand side of the theory of change (financing, activities, threats), all far detached from biodiversity outcomes/*endpoints*: buying these credits will essentially amount to a leap of faith. Second, the genuinely outcome-based credit pathways predominantly use either simple before-and-after comparisons, or what may eventually be worse, vaguely defined baseline constructions leaving ample room for future opportunistic gaming. Third, current credits schemes clearly make insufficient efforts to integrate rigorous impact evaluation into their operation: making ex-post impact assessment in comparative control sites would allow us to measure attributable effects from the underlying field actions at hand: simple before-and-after designs without appropriate no-intervention counterfactuals will say little about credits effectiveness (Wauchope et al., 2021; zu Ermgassen et al., 2023). Credits buyers would need to insist on this to happen, so we can learn what actions in biodiversity credits initiatives work, and which do not. Finally, only 41% of cases included third-party auditing of their biodiversity outcomes, the rest having either decided against (18%) or still being unavailable (41%). On aggregate, this picture should ring strong alarm bells vis-à-vis additionality concerns: for most biodiversity credits cases, baselines are either non-existent, unclear, extremely flexible (and thus ex-post manipulable), and/or are not based on monitored outcomes.

Much thus also comes down to which biodiversity credits governance architecture would enable robust implementation. Market-based environmental governance often relies on private self-organized governance, with a small group of international companies acting as standards bodies or third-party accreditors. These private actors rarely have credible enforcement power, nor may they be fully independent. Credits governance would thus likely need to rely on a network of actors and incentives including accreditation bodies, third-party auditors, differentiated buyer demand for expensive high-quality vs. cheaper low-quality credits, and civil society for transparency to enable oversight.

Public environmental regulators can also play a role, although for biodiversity offsets, they have often been understaffed (Evans, 2023) vis-à-vis their counterparts in regulated industries (Walker et al., 2009). In practice, checks and balances in offset systems have been minimal, with regulators usually accepting by default the offset assessments provided by project proponents and their consultants, without site visits and third-party verification: there are strong political-economy incentives for non-compliance to remain undetected.

If unchecked, many such governance shortcomings from other environmental markets would likely self-replicate in biodiversity credits systems. Hence, high integrity credits require robust calculation methodologies and independent third-party oversight, including without certifiers deriving revenue tied to the number of credits approved —a systemic perverse incentive inherent to voluntary carbon markets. Also, responsible buyers must accept that genuinely impactful credits will eventually become more expensive (Kedward et al., 2023).

In summary, the core challenge with many environmental markets to date has been that they are overly focused on tradability, and insufficiently on the environment itself. Buyers, providers, intermediaries, product consumers and government officials can all synergistically benefit from commercial 'green' transactions and governance structures— that in the end fail to make positive impacts on biodiversity. A key question is therefore what alternative credits architecture would be needed to bring environmental interests effectively to the forefront. Environmental NGOs, multilaterals and national environmental agencies, IPLCs, are all candidates for places at the table of organizations providing the better oversight these markets require.

In terms of recommended actions, various stakeholders should thus participate more actively in the framing, design and supervision of environmental markets. If *international* *organizations* and *negotiating parties* were able to advance further towards a legal international framework for biodiversity, this regulatory prospect/threat would greatly stimulate further market development. *Public regulators* could in a forthcoming more consolidated phase of credits development play a role in setting the rules of the game (e.g., what can be claimed or not, by whom?), supporting monitoring and enforcement systems, including social safeguards. *Donors* can provide co-funding for systemic investments and public-good provision, incl. de-risking of selected innovative approaches which exhibit a plausible pathway to scaling that would not rely on public or philanthropic support. *Civil society* should support both social safeguards and ecological integrity: in many contexts, environmental NGOs or multilaterals may be the best bet for representing environmental interests. If ex-post, impact-evaluated credits were to be developed further, *bankers* may be needed to bridge financing gaps and raise credit buffers held for insurance. Finally, the *research community* is called for both to help manage well commensurability tradeoffs and significantly improve credits baselines and impact evaluation.

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Appendix figures and tables

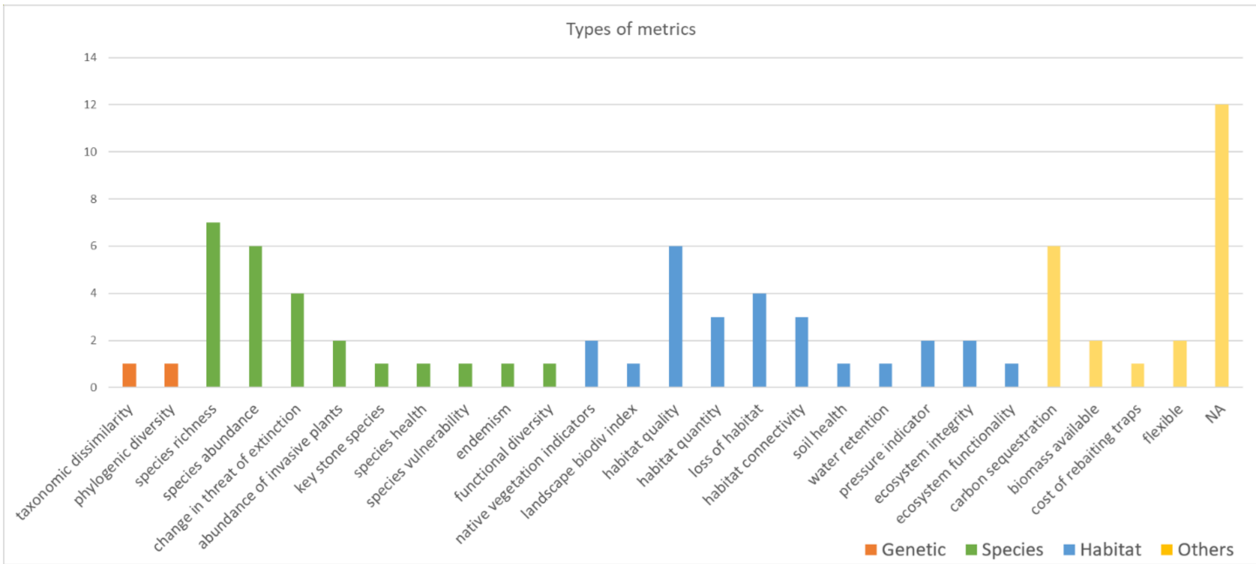

Figure A1: Composition of metrics in biodiversity credits (cases: n=37; 75 entries)
Source: Own data

Table A1: Tentative taxonomy for biodiversity units

<table>
<tr><td colspan="3"></td><td colspan="7">End-user situation and approach. End user = provider of result-based finance for activity</td></tr>
<tr><td colspan="3" rowspan="3">All impacts (delta) assumed quantified with fungible quantified metrics at Land Management Unit Level.</td><td colspan="4">Not traded/Not commodity (=certificate)</td><td colspan="3">Traded/Commodity (=unit)</td></tr>
<tr><td rowspan="2">LM Scope 1 only</td><td colspan="4">In scope (LM Scope 1 <u>and</u> Company Scope 3)</td><td colspan="2">Out of scope</td></tr>
<tr><td>Avoid</td><td>Minimize</td><td>Restore</td><td>Insetting</td><td>Offset</td><td>Above & beyond</td></tr>
<tr><td></td><td colspan="2">Application</td><td>Certified and verified LM self-claim</td><td colspan="3">Traceable and Verified LM + CoC certificates (connecting LM to End User of BU)</td><td>As in-scope where traceability is not possible</td><td colspan="2">In spot market and over-the-counter (OTC) trading of units</td></tr>
<tr><td rowspan="4">Land Manager Theory of Change</td><td rowspan="2">Protect</td><td>Avoid loss</td><td rowspan="2">Conservation certificate with counterfactual</td><td>Conservation certificate with counterfactual ToC</td><td>Reduction/mitigation certificate based on footprint/impact and counterfactual</td><td>N/R</td><td>Conservation unit, with ecological equivalence criterion (EEC) and counterfactual</td><td>Offset Unit/Credit with EEC and counterfactual</td><td>Conservation Unit without ecological equivalence criterion (EEC) and counterfactual</td></tr>
<tr><td>Main-tain</td><td colspan="6">N/R - Only possible to monetise if standards develop methodologies for gross ES pricing without counterfactual/baseline</td></tr>
<tr><td rowspan="2">Uplift</td><td>Exis-ting</td><td>Improvement certificate</td><td>N/R</td><td colspan="2">Reduction/mitigation certificate based on footprint/impact and base year value (gross net accounting)</td><td>Insetting Unit/Credit with further unit naming similar to in-scope use though with EEC and additionality =baseline</td><td>Offset Unit/Credit with EEC and additionality =baseline</td><td>Compensation unit without EEC and additionality =baseline</td></tr>
<tr><td>New- (Green-field)</td><td>Restoration certificate</td><td>N/R</td><td>N/A</td><td>Restoration Certificate with EEC and additionality relative to = 0. On land already in scope</td><td>Insetting Unit/Credit with further unit naming similar to in-scope use though with EEC and additionality = 0</td><td>Offset Unit/Credit with EEC and additionality = 0</td><td>Compensation unit without EEC and additionality = 0</td></tr>
</table>

Table A2: Definition of variables used in our Biodiversity Credit Dataset

Stakeholder functions

1. **Method developer:** organisations elaborating standards and methods for measuring and issuing credits.
2. **Certifier/trader:** organisations responsible for verifying and certifying the biodiversity credits generated by projects, and/or involved in issuing and trading of credits (e.g. managing a platform to trade credits). It is out of this paper´s scope to distinguish certifiers clearly from traders.
3. **Project developer:** facilitator connecting land stewards with standards, investors and other stakeholders supporting and benefiting from conservation efforts. It identifies, plans, and executes conservation projects that generate biodiversity credits.
4. **Data provider:** collects data to quantify the effect of restoration or conservation projects on biodiversity.

Status

1. **Under development/in preparation**: methods in progress or under consultation.
2. **Pilot**: methodology released/launched, and projects being tried out without selling credits.
3. **Pilot, operational**: readymade methods being trialled, including credit sales.
4. **Fully operational**: selling credits on markets at scale.

Ecosystem

1. **Terrestrial** (some subcategories examples – Forest, Tropical Forest, Boreal Forest).
2. **Marine**
3. **River**
4. **Diverse**

Main Outcome/Output

1. **Averted loss**: protective effort to mitigate existing or predicted harm to biodiversity.
2. **Biodiversity improvement (‘uplift’)**: active generation/restoration of existing (or non) habitat, species lost, or other biodiversity elements.
3. **Combined**: credits aim at both averted losses and biodiversity improvements.
4. **Others**: residual category including threat reductions (e.g. pollutant reduction, pest control) as outputs

Type of credit

1. **Outcome-based**: credits issued based on measured environmental change allegedly attributable to biodiversity credits-underlying conservation actions.
2. **Action-based**: credits issued based on efforts made/specific activities implemented to e.g., allegedly reduce risks for/ pressures on biodiversity, without quantifying the targeted environmental outcomes.
3. **Outcome- and action-based**: combining both.

Counterfactual type

Category	**Definition**	
Before/after outcome	Monitored changes in indicators over time	
Projected baseline	Counterfactual ex-ante scenario estimated from historical data in project area, and/or matching control area	
Projected & before/after	Ex-ante projections combined with monitored changes in indicators over time	
Policy-determined	Administratively mandated additionality targeted	

Reference benchmark	Use of wider-scale indicator as yardstick	
Input-based	Considering increased conservation funding (*input*) as additionality (financial additionality)	
Treatment-based	Considering incremental project activities as additionality (activity additionality)	
Unclear	Ambiguous information given	
NA	Information not available	

Issuance period: maximum length of projects during which credits can be issued – expressed in years

Credit claim

1. **Ex-ante**: credits issued before conservation outcome/action is being measured, likely at project start.
2. **Ex-post (regularly)**: credits issued after outcome is measured monthly, bi-monthly, annually, or 1-5 years (with a credit release schedule).
3. **Ex-post (ecological milestones)**: credits issued after tangible outcomes have been measured.
4. **Ex-post (NA)**: credits are issued after the outcome is measured, whether regularly or at project end, using ecological or management milestones (criteria unclear).
5. **Mix**: combining ex-ante and ex-post outcome measurement; following a schedule of ecological and management milestones.
6. **NA**: not available.

Bundling and stacking

1. **YES**: bundling and/or stacking are possible
2. **NO**: bundling and/or stacking are not possible

Table A3: General information on emerging biodiversity credits

Name	Geographical coverage	Developer of	Status	Ecosystem	Main Outcome	Type of credit	Baseline type	Issuance period	Credit claim b/a monitoring	Bund/ Stack
Wallacea Trust and rePLANET biodiversity credit methodology	International	Wallacea trust: Methods, Certifier; (rePLANET) Project	Pilot operational	Terrestrial and Marine	Averted loss & biodiv uplift	Outcome-based	Financial additionality & projected outcome	25 years	Ex-post	NO
PV Nature - Plan Vivo Foundation	International	Methods, Certifier	Under development	Terrestrial and Marine	Averted loss & biodiv uplift	Action-based	Financial/Activity additionality	>20 years	Ex-post (yearly)	NO
Protocol for the Issuing Voluntary Biodiversity Credits - Terrasos	Colombia	Methods, Projects	Operational	Terrestrial	Averted loss & biodiv uplift	Action-based	Before/after outcomes & Activity additionality	>20 years	Mix (ecological and management milestones)	YES
Voluntary Biodiversity Credit - ValueNature	International	Methods, Certifier	Under development	Terrestrial	Averted loss & biodiv uplift	Outcome-based	Projected outcome	5-10 years	Mix (any time)	YES
Sustainable Development Units Programme - Ekos	International	Methods, Certifier	Pilot operational	Terrestrial	Averted loss & biodiv uplift	Outcome and Action-based	Unclear	4-20 years	Ex-post (yearly)	YES
EcoAustralia credits - South Pole	Australia	Methods, Projects	Operational	Terrestrial	Averted loss & biodiv uplift	Outcome-based	Unclear	<5 years	Ex-ante	YES
Restoration of coral reefs for biodiversity recovery - South Pole (Colombia)	Ecosystem specific	Methods, Certifier	Pilot	Marine	Biodiversity uplift	Outcome-based	Before/after outcomes	10-20 years	Ex-post	YES
CreditNature - Ecosulis	International	Methods, Certifier	Operational	Terrestrial	Biodiversity uplift	Outcome-based	Projected & Before/after outcomes	NA	NA	NA
Biodiversity certificates - OBC, NHN, Carbone4	International	Methods	Under development	Terrestrial	Biodiversity uplift	Outcome-based	Projected & Before/after outcomes	NA	Ex-post	NO
Biodiversity token - Rebalance Earth	International	Methods, Certifier	Pilot	Terrestrial	Averted loss	Outcome-based	Unclear	NA	Ex-post	NA
SD VISta - Verra	International	Methods, Certifier	Under development	Terrestrial and Marine	Averted loss & biodiv uplift	Outcome-based	NA	NA	NA	NA

Accounting for Nature Standards	Australia	Methods, Certifier	Pilot	Terrestrial and Marine	Averted loss & biodiv uplift	Outcome-based	NA	No issuance	No issuance	NO
NaturePlus - Greencollar	International	Methods, Projects	Pilot	Terrestrial and Marine (farm)	Averted loss & biodiv uplift	Outcome-based	Before/after outcomes	NA	Ex-post (yearly)	NA
Cassowary Credits - Terrain NRM	Australia	Methods	Under development	Terrestrial (forest)	Biodiversity uplift	Outcome-based	Projected outcome	25 years	Ex-post (every 3-5 years)	YES
Biological Diversity Units - Wilderlands	Australia	Methods	Operational	Terrestrial	Averted loss & biodiv uplift	Action-based	Policy determined	20 years	Ex-ante	NA
Reef Credit scheme - Ecomarkets Australia	Australia	Methods, Certifier	Operational	Marine	Pollutant reduction	Outcome and Action-based	Projected outcome	25 years	Ex-post (max 25 y)	NA
Swedish Biodiversity credit	Ecosystem specific (Boreal forests)	Methods	Pilot operational	Terrestrial (forest)	Averted loss & biodiv uplift, management improvement	Action-based	Activity additionality	>20 years	Ex-post (yearly)	NA
Biodiversity Credit system - Governmental	Gabon	NA	Under development	NA	NA	NA	NA	NA	NA	NA
Ocean Conservation Credits	Niue	Methods	Under development	Marine	NA	Action-based	NA	20 years	NA	NA
Nature Repair Market	Australia	Methods	Under development	Terrestrial	NA	NA	NA	NA	NA	NA
Eco-contribution credits - ReGeneration	Ecosystem specific	Methods	Pilot	Terrestrial (farm)	Biodiversity uplift	Outcome-based	Before/after outcomes	5-10 years	Mix	YES
Woodland Nature Credit - Bank of Ireland, Coillte, Forestry partners	Ireland	Methods (Coillte - proj. Developer)	Operational	Forest	Tree planting	Action-based	NA	25 year	Ex-ante	YES
Biodiversity certificates - Qarlbo Natural asset company	NA	Methods, Projects	Under development	NA	NA	NA	NA	NA	NA	NA
dynamic Biodiversity Tokens - Recelio	Switzerland	Methods, Certifier, Projects	Under development	Terrestrial (farm)	Biodiversity uplift	Outcome and Action-based	Before/after outcomes	TBD	Mix	YES

Ecosystem Restoration Standard	International	Methods, Certifier	Under development	Terrestrial	Biodiversity uplift	TBD	TBD	>20 years	Ex-post (every 1-5 years)	YES
Pivotal	International	Methods, data provider	Under development	Terrestrial	Averted loss & biodiv uplift	Outcome-based	TBD	>20 years	Ex-post	NO
Methodological Document for Biodiversity Conservation - BioCarbon Registry	International	Methods	Under development	Terrestrial	Biodiversity uplift	Outcome-based	Before/after outcomes	10-20 years	Ex-post (ecological milestones)	YES
Global Biodiversity Standard - Botanic Gardens Conservation International	International	Methods	Under development	Terrestrial	Averted loss & biodiv uplift	Outcome-based	NA	N/A	NA	NA
CarbonZ biodiversity action credit (CBAC)	Ecosystem specific	Methods, Certifier	Operational	River	Pest control	Action-based	Activity additionality	1 year	Ex-ante	NO
Biodiversity token ERA Brazil	Brazil	Methods	Under development	Terrestrial	Averted loss	Outcome-based	Unclear	>10 years	Ex-post (annually or biannually)	NA
InvestConservation Token	Ecosystem specific	Methods, Projects	Operational	Terrestrial (tropical forest)	Averted loss & biodiv uplift	Outcome and Action-based	Financial additionality	>20 years	Ex-post (annually)	YES
Biodiversity credit - New Atlantis DAO	International	Methods, Certifier	Under development	Marine	Averted loss	Outcome-based	NA	NA	NA	YES
Marine Biodiversity Credit - Open Earth Foundation Ocean Program	International	Methods	Under development	Marine	Averted loss	Outcome-based	Reference benchmark	5-10 years	Ex-post (annually)	YES
Biodiversity credits - Savimbo	South America	Methods, Projects	Operational	Diverse	Averted loss	Action-based	Activity additionality	2 months	Ex-post (bimonthly)	YES
MERIT token - Single Earth	International	Methods, Certifier, Projects	Operational	Terrestrial (forest)	Averted loss	Outcome-based	Projected outcome	NA	Ex-post (monthly)	YES
High Integrity Forest Investment Intiative (HIFOR) – WCS	International	Methods, Projects	Pilot	Terrestrial (forest)	Averted loss	Action-based	Activity additionality	NA	Ex-post	NA
Nature plus standard	Germany	Methods; (AgoraNatura: Certifier)	Operational	Diverse	Averted loss & biodiv. uplift	Outcome-based	Projected outcome	NA	Ex-ante	NA