Title page

Article title: Reversing biodiversity loss requires a World Biodiversity Organisation that can bridge finance and nature

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Acknowledgements: We are grateful to XXX reviewers, the editorial board, S. Pawaar, D. Moreno-Mateos, and K. O'Donoghue for their help improving this manuscript. All authors gratefully acknowledge funding support from the Singapore Green Finance Centre ("Nature-Related Financial Risks in Southeast Asia") for this project. The Pearse lab and WDP are supported by the Alan Turing Institute (FA.04), and UKRI BB/Y008766/1, NE/X00547X/1, and NE/X013022/1. LS is supported by the Natural Environment Research Council [NE/S007415/1], and the Hitachi-Imperial Centre for Decarbonisation and Natural Climate Solutions, a collaboration between Hitachi Ltd, Hitachi Europe and Imperial College London. NP is funded by Imperial College London President's PhD Scholarship. EMS is supported by the Ministry of Education, Singapore, under its MOE AcRF Tier 3 Award MOE-MOET32022-0006. Axis icons in figure 1 are taken from Canva.

Abstract

Decades of research and politics have led to a coherent set of biodiversity metrics and strong evidence that biodiversity supports human well-being. So why do we not have a financial system that encourages conservation and restoration of nature? We argue that a central reason is that the financing used has not been aligned with the spatial and temporal structure of biodiversity. Ecosystems are 'local': strongly shaped by the propagating consequences of interactions through time and across space, such that measuring or predicting biodiversity in any one region requires context from nearby regions and prior ecological processes. Not all financing methods are local, and joint biodiversity-finance approaches that do not account for ecosystems' locality cannot succeed. This mismatch helps explain why biodiversity crediting markets face persistent design problems, and why advances in monitoring or AI, while valuable, cannot by themselves resolve the challenge. We therefore argue for a World Biodiversity Organisation that would act as a bridge between ecological and financial systems, ensuring that biodiversity's locality, non-fungibility, and process time-horizons are respected. Drawing on case studies of finance-based interventions, we outline the modifications to existing frameworks that would be required to couple financial and ecological systems.

Impact statement

Despite the well-established financial and societal impacts of global biodiversity loss, we have yet to develop financial architectures capable of prioritising nature conservation and recovery at scale. We argue that an important reason is a mismatch between the spatial and temporal structure of ecological systems and the way biodiversity finance is often structured. This means that any one approach, such as biodiversity crediting, is unlikely to be sufficient unless it is embedded in frameworks that preserve ecological context. We outline a new, global organisation—a World Biodiversity Organisation—that would address these challenges and unlock the potential of financial systems to address the biodiversity crisis.

Main text

Biodiversity is essential for people and economies, with strong evidence that it underpins key ecosystem services that we rely on, providing food, water, and health (Dasgupta, 2021; Díaz et al., 2019; IPBES, 2024; Kumar, 2012; Pimentel et al., 1997). This makes the ongoing loss of biodiversity a global crisis (Díaz et al., 2019). In response, the creation of organisations and frameworks to address the challenge of biodiversity loss (*e.g.*, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES); see Díaz et al., 2015) has led to the development of targeted road-maps and plans (*e.g.*, the Kunming-Montreal Global Biodiversity Framework (KM-GBF), reviewed by Hughes & Grumbine, 2023) and a coherent set of biodiversity metrics that can be applied in almost any ecosystem (*e.g.*, Pereira et al., 2013). These impressive efforts have achieved a great deal, but there are still concerns that the pace of change is insufficient to stop, yet alone reverse, current biodiversity loss (Leclère et al., 2020).

Governments have been quick to identify the importance of biodiversity (and in particular 'natural capital'; Dasgupta, 2021), but many countries, particularly those with large regions of intact ecosystems, lack the resources to preserve nature in the short-term. Given current national budget deficits and debts (International Monetary Fund, 2024), ongoing external stressors such as wars, and growing impacts from climate change (Pörtner et al., 2023), it seems unlikely that governments will have greater resources to spend on biodiversity in the near-term. Financial frameworks, by leveraging private resources, are seen as a potential solution to these issues (Flammer et al., 2025; Karolyi & Tobin-de la Puente, 2023; but they are not a silver bullet; see Kedward et al., 2023). Financial instruments (summarised in table 1) and institutions offer complementary, potentially faster-paced, ways to preserve biodiversity in comparison with traditional, governmental conservation actions alone.

To incorporate biodiversity into financial decision-making, frameworks such as the Taskforce on Nature-related Financial Disclosures (TNFD; reviewed by Irvine-Broque & Dempsey, 2023) have been developed to provide guidance on assessing and reporting nature-related dependencies and impacts. The uptake and enforcement of these frameworks is beginning to be recognised but remains limited (Guo et al., 2026; Nedopil, 2023). This is partly because, unlike carbon, biodiversity lacks established markets and universal pricing strategies or regulations, restricting financial incentives for its protection (Tedersoo et al., 2024). A key barrier has been the question of how to measure biodiversity: on the one hand, biodiversity researchers have long argued that there is no one metric of biodiversity (Magurran, 2021) and so there should never be a single policy metric (Purvis, 2025). As a result, they have instead provided a suite of potential metrics to be used in concert (Pereira et al., 2013). On the other hand, financial actors need a universal, reliable, and trusted method of biodiversity measurement to form the backbone of a market (Lucey et al., 2025).

Here, we argue that current approaches to integrating ecology and finance have a fundamental, conceptual flaw: they do not recognise that they operate across distinct spatio-temporal scales. There are, already, excellent reviews of biodiversity theory (*e.g.*, Purvis & Hector, 2000), and excellent reviews of biodiversity finance for the non-specialist (*e.g.*, Carter et al., 2026). Yet, despite this, we have not achieved meaningful integration across biodiversity and finance; for example, it has been known for decades that biodiversity is not fungible, but this has not stopped financial practitioners and academics acting as if it were (Wunder et al., 2025). Here we move beyond reviewing historical trends and instead frame the fundamental concepts of biodiversity and finance in a way that makes sense to members of both disciplines, in order to outline an approach to address the biodiversity crisis. We begin by describing the unifying, conceptual framing that ecological systems are 'local' in a way that financial systems must recognise. Having established this, we argue for the existence of a World Biodiversity Organisation whose structure is designed to overcome this conceptual barrier of locality and so bridge financial and ecological systems.

A biodiversity framework that supports financial theory and practice

We begin by reviewing fundamental biodiversity theory, providing a shared framework that enables everyone (including non-specialists, such as financiers) to understand core issues with defining and measuring biodiversity. Biodiversity scientists are rarely interested in the absolute value of an observed biodiversity sample at a single place and time. Rather, they are interested in how biodiversity varies across time and space, and how that variation can be used to understand underlying ecosystem processes and states (Chave, 2013; Levin, 1992). Different biological processes—interactions among individuals, environmental forcing factors, and evolution—are expected to be detectable at different spatio-temporal scales (figure 1; Cavender-Bares et al., 2009; Weiher & Keddy, 1995). Importantly, this spatio-temporal mapping is not controversial in biodiversity science, and it is expected that processes that operate across broader spatial scales will also operate across broader temporal ones. Entire sub-fields, such as eco-evolutionary dynamics, have been created for the fascinating edge cases of this relationship, such as when evolutionary processes traditionally thought of as operating across broad spatio-temporal scales are detected at finer ones (Pelletier et al., 2009). Similarly, while ecologists seek out cases where processes seem to operate similarly across spatial or temporal scales, these cases are exceptions and have serious conceptual and empirical caveats that represent the frontiers of current research (Newman et al., 2019). Mismatches between the scale at which ecosystem services are delivered or studied, and the scale at which social science is conducted, are known to induce difficulties in planning, and are also a major focus of empirical and theoretical study (Scholes et al., 2013). Thus biodiversity is inherently *local*: it operates and exists across well-defined spatial and temporal scales.

Recognising this spatio-temporal framework allows the biodiversity researcher to make intuitive decisions about the data required to understand their study system. To forecast the biodiversity of a $1m^2$ patch of grass at Silwood Park (UK) in a year's time, we would hope to have data on nearby (within $100m$) sites from which seeds could disperse, the biodiversity and climate of the last two years (to establish a baseline), and climate forecasts for next year (to inform prediction). It is perhaps intuitive that to forecast a million years into the future would require data from greater distances away (as there is more time for dispersal of distant species), from further in the past (to establish a greater baseline of expected variation), and of different kinds (*e.g.*, genetic data, to account for possible evolution). What is less intuitive to the non-specialist, and that this framework shows us, is that modelling biodiversity across broader spatial scales also requires broader temporal scales. As we move across space, we move across lineages (species) that have been isolated for longer periods of time and so have evolved for longer and so differ in ways for which we must account.

A significant part of the current paradigm of coupled financial-biodiversity systems based on widely accessible markets depends on the development of a *global* crediting framework. This is challenging because a global financial market requires a universal measure of value. The local nature of biodiversity means that there are, in essence, multiple markets that have been expanding, contracting, and exchanging across millions of years, each with separate value systems. Biologists call the richness of an ecosystem 'α-diversity' and the differences among ecosystems 'β-diversity' (Magurran, 2021); both of these components induce different challenges for financial markets. α-diversity is measured in different ways in different ecosystems, and there are not even rules of thumb for what an appropriate value is (*e.g.*, more species is often better, but degraded systems are often hyper-diverse; Pearse et al., 2018). There are also no short-cuts to assessing ecosystem state: it is rare for the presence of a particular species (*e.g.*, an ecosystem engineer) to reliably indicate an ecosystem's health but, even where such species do exist, they must laboriously be found for each ecosystem and each region (Lindenmayer & Westgate, 2020). β-diversity means that financial systems cannot treat the loss of one habitat (*e.g.*, a forest in Borneo) as equivalent to the gain of another (*e.g.*, a forest in England): distinct ecosystems are not fungible (exchangeable; Wauchope et al., 2024; Wunder et al., 2025).

Markets that do not account for the local context of ecological systems will generate financial 'persistent mispricing'. We use 'ecological arbitrage' as shorthand for this: ecologically non-equivalent assets are forced into exchangeable accounting categories, allowing financial gains but ensuring ecological losses are local, under-valued, or entirely external to the market. Unlike standard financial arbitrage, where price discrepancies are traded away, price correction cannot occur in ecological arbitrage because the claims being compared are not ecologically equivalent (not fungible). In the financial world, arbitrage is normal and part of a healthy financial system, but because biodiversity is not fungible, reliance on arbitrage causes difficulty. Unless checked, this process will shift benefits elsewhere within the market while leaving ecological losses concentrated locally, reinforcing both biodiversity decline and social inequality. In that sense, it is a telecoupled commons problem, with cross-border spillovers, unpriced externalities, and weak collective governance (Hardin, 1968; Liu et al., 2015; Perrings et al., 1992).

Ecological arbitrage is a problem of market price formation, and is therefore distinct from, though informed by, the large and well-established literature on environmental valuation. For decades, environmental economists have estimated nature's welfare value using theoretical 'shadow prices' for policy appraisal and natural-capital accounting (Costanza et al., 1997; Dasgupta, 2021; Freeman III et al., 2014; Kumar, 2012). Biodiversity finance, however, addresses a different issue: how financial markets actually price, structure, and trade ecological risks and assets (Flammer et al., 2025; Karolyi & Tobin-de la Puente, 2023). This distinction is critical because shadow prices are calculated on paper, not traded on exchanges; they lack a market mechanism to prevent real-world financial mispricing. Even advanced natural-capital asset pricing models (Fenichel & Abbott, 2014; Fenichel et al., 2016) yield accounting figures tied to local regimes rather than market-enforced prices. This economic literature provides independent support for our argument, in that the well-documented difficulty of 'benefit transfer' (applying a value estimated at one site to another; Johnston et al., 2015) is simply environmental economics discovering that nature's value is strictly local and non-fungible.

In our experience it is common for the non-specialist to be certain that there is a technological solution to the problem of defining, and so measuring, biodiversity. Yet the need for spatio-temporal context reveals that, even if AI and other technological advances deliver on their promise of near-constant, global biodiversity monitoring (Allan et al., 2018; Besson et al., 2022; Perry et al., 2022), such monitoring will be insufficient to address the challenges of biodiversity loss. We do not doubt that biodiversity monitoring and assessment are undergoing transformative improvement, particularly in remote sensing (Converse et al., 2024; Willis, 2026) and high-throughput measurement (Lawson et al., 2025), despite practical challenges (Besson et al., 2022; Keitt & Abelson, 2021; Stephenson, 2020). We are optimistic that blockchain technology will make it easier to verify, track, and so reward progress towards many sustainable development goals, including the restoration of biodiversity (Thanasi-Boçe & Hoxha, 2025). But faith in technology should not be allowed to create a false sense of security by importing assumptions from finance, where short-term predictability is possible, into local ecosystems defined by complexity, uncertainty, and a dependency on historical context. New technologies will give even more robust forecasts of ecosystem health when they are grounded in the context provided by historic long-term datasets, natural history collections, or deep-time evolutionary information (Barak et al., 2016; Pyke & Ehrlich, 2010; Rick & Lockwood, 2013; Willis & Birks, 2006; Willis et al., 2007).

A World Biodiversity Organisation would integrate biodiversity and finance

Biodiversity finance needs to take into account the locality of ecological systems by appropriately structuring contracts and information transmission. Many financing methods are, of course, local in the sense that they rely on local information and context (see Allen & Gale, 2000). The first formal institutions for finance were banks, which have been around for thousands of years and were initially very local. Banks raised money through deposits and lent money to businesses and families; depositors did (and still do) have little knowledge about loans that were made. Over time, banks have become larger and more spread out geographically, but most loan decisions remain based on local information. Institutions would later develop into what today would be called over-the-counter (OTC) markets (reviewed by Duffie et al., 2005). These were physical gathering places, such as the Rialto Bridge in Venice or the coffee houses of London, where dealers bought and sold financial securities (*e.g.*, bonds and shares) at price markups sufficient to allow them to hold inventories and make a living.

Many bond markets, particularly for corporate bonds, still essentially trade as OTC markets, but later, institutions such as exchanges developed, an early example of which is the Amsterdam Bourse (c. 1602). Crucial to the development of global exchanges was standardisation: prices were posted across markets and so processes such as financial arbitrage could operate effectively. Markets' dependencies on standardisation and potential for instantaneous trading are what drive the disconnect between financial and ecological systems (figure 1). Financial systems such as these that do not share this spatio-temporal scaling are essentially 'non-local' (*sensu* Amico et al., 2008): they are highly networked and capable of propagating valuation effects across space on incredibly rapid timescales (Schwarcz, 2008), much faster and further than ecological processes. A transaction executed in one market can affect prices, funding conditions, collateral values, and balance-sheet constraints elsewhere. In our everyday lives, we all rely on local institutions such as banks, using them to save, hold, and invest money on our behalf; such institutions are the bridges between our local lives and non-local global markets. Ecosystems do not, at present, have such a bridge.

Because ecosystems are inherently local, there will be many different kinds of biodiversity problems to be solved, and the costs of assessing and addressing them will be large. Yet there are cases where financial markets have driven successful, local, low-cost interventions (table 1). One example is the World Bank's outcome-contingent Rhino Bond, where investor returns are linked to verified population outcomes over a multi-year horizon (reviewed by Medina & Scales, 2024). Some insurance policies have also been successful; The Nature Conservancy (an NGO) worked with the Mexican state of Quintana Roo to fund rapid reef and beach repair after events such as Hurricane Delta (The Nature Conservancy, 2021). These cases do not show that biodiversity can be standardised into a deep universal market, but rather that bespoke (local) financial instruments can work when the ecological objective is clear and can be monitored, and that an intermediary can connect non-local finance to local implementation. Because such instruments are thinly traded, bespoke, and information-intensive, they are more naturally organised as OTC markets. The growth of the carbon market, despite ongoing issues with its auditing, has often been seen as a model that biodiversity crediting could follow (García & Moros, 2025; Sasaki, 2025; Swinfield & Scott, 2025). Indeed, the last decades have seen periods of progress and decline in crediting approaches such as REDD+ (Reducing Emissions from Deforestation and forest Degradation; Duchelle et al., 2018) and the EU's Carbon Removals and Carbon Farming framework (CRCF; Günther et al., 2024; Laktuka et al., 2025; Vidal Morant et al., 2025). It is notable that, while there has been great progress in standardising carbon credits and measurable units, for *voluntary* carbon markets where much more information is required, OTC markets are used rather than global, centralised exchanges (Berg et al., 2025). This is despite the fact that it is possible to make fungible units of CO_2-equivalents for carbon-credits, unlikely biodiversity which is not fungible.

These examples show that instruments in biodiversity finance are highly variable, but this variation is not random. The diversity of instruments in table 1 is driven by how easily ecological information can be verified by outside investors. Where ecological outcomes are easily verified within a contract's timeframe, tradeable outcome-based bonds or parametric insurance are viable (*e.g.*, the Rhino Bond). Where outcomes are harder for outsiders to verify, funding shifts toward paying for specific land-use practices (*e.g.*, payments for ecosystem services) or regulatory frameworks (*e.g.*, mitigation banking). When biodiversity data are complex and unobservable from afar, finance requires a trusted middleman (a 'delegated monitor') to conduct assessments on behalf of investors (Allen & Gale, 2000; Diamond, 1984). Differences among the tools in table 1 in terms of risk profile, suitability, and investor base are therefore not loose variation, but the predictable consequence of how much local ecological information each structure must carry and how credibly that information can be transmitted. This explains why effective biodiversity structures are currently bespoke and intermediated rather than standardised on global exchanges, and it directly supports our central proposal for a global institution that can serve as a delegated monitor for local ecosystems.

To date, the scale at which market-based financial interventions have been applied is limited in comparison to the scale of the global biodiversity crisis (see table 1 and Waterford et al., 2024). It is therefore useful to ask how finance is normally supplied when projects are variable and costly, as is true of biodiversity. In most economies, capital is not raised through markets, but through intermediaries such as banks and other financial institutions. These institutions exist precisely because many investment opportunities are bespoke and information-intensive, and so not easily reducible to standardised securities. Small and medium-sized enterprise lending depends on banks: loans are typically bespoke and rely on decentralised judgements of borrower quality, local conditions, and risk. Biodiversity opportunities are essentially the same: assessing the likelihood of success and the return on investment requires detailed, expert understanding of the local ecosystem. If financial institutions have, historically and successfully, acted as the intermediaries between non-local financial markets and local ecosystems, it seems reasonable that they should again be used to act as intermediaries among global capital and local expertise.

Biodiversity finance requires an intermediary architecture beyond today's mix of disclosure frameworks, fragmented project finance, and voluntary crediting. A World Biodiversity Organisation (WBO) is one possible model, particularly if understood not as a replacement for existing institutions but as a coordinating and capacity-building layer. This model has been successfully followed in other settings, such as The World Bank (World Bank Group, 2025), which successfully deals with development issues, and the World Health Organisation (WHO; WHO, 2025), that focuses on health in all countries (table 2). A WBO could be funded in a variety of ways much like the World Bank, where there is a private sector arm, as well as philanthropic and government funding. Just as the World Bank and WHO have a wide range of experts among their staff, the WBO would also have broad capabilities, covering biodiversity, socio-economic systems, finance, and the interplay between them. Critically, just as banks act to manage the complexities of complying with financial policy, investment decisions for stored wealth, and the safety of assets, the WBO would manage the complexities of local ecosystem processes. By acting as a trusted intermediary, the WBO would work with partners on-the-ground to ensure broader improvement in biodiversity, similarly to how the WHO works with on-the-ground partners to share knowledge, expertise, and support public-health policy. A WBO would not replace or overlap with the roles of organisations like the IPBES (Díaz et al., 2015, 2019) or conventions such as the Convention on Biological Diversity (CBD; Chandra & Idrisova, 2011): it would act as a trusted intermediary to facilitate financial transactions.

How a World Biodiversity Organisation would operate

The WBO would raise money through debt and other forms of financial leverage, just as the World Bank does today (table 2). Investment from developed nations would then use these funds to support biodiversity bonds and structures (of the kind described in table 1). As an example of the kinds of financial instruments that could be used, the WBO could seek to organise, align, regulate, and manage biodiversity crediting markets, to the extent these are possible (*e.g.*, tradeable only within designated regions) or desired. By acting as a broker, the problem of ecological arbitrage might be entirely avoided by regulating of the distribution of biodiversity credits across ecosystems. The WBO could leverage global capital and apply it within a series of local, ecosystem-centric markets. Instruments like this would, in part, help raise funds to pay back bonds issued to fund the WBO. This degree of oversight could support, rather than hinder, innovation and entrepreneurship by providing an environment within which new approaches, such as tokenised tracking of ownership and improvement in biodiversity (Thanasi-Boçe & Hoxha, 2025), could be trialled and promoted.

The WBO could act as a technical body, supporting the efforts of conservation organisations and playing a leading role in data collection and research (akin to the WHO; table 2) to support its role. Biodiversity researchers are already calling for coordination of research (Urban et al., 2026) and data collection (Gonzalez et al., 2026); the Global Environment Facility's (GEF) Global Biodiversity Framework Fund (GBFF; see below also) already exists to raise and distribute private funds internationally. It would be difficult to argue that the missions of these ongoing or proposed organisations would be more effective without careful communication and planning. The WBO could not, and should not, attempt to oversee every aspect of biodiversity, but in carrying out its finance functions it would necessarily house technical expertise, and could share that expertise similarly to the WHO's role. The story of the eradication of smallpox is the story of the WHO's targeted, coordinated deployment of resources to surveil, contain, and then roll-out vaccination programs against the disease (Henderson, 2011). Most would argue the scale of the biodiversity crisis dwarfs the dangers of smallpox, and so to tackle the biodiversity crisis we need, at a minimum, a similarly empowered organisation.

The WBO would delegate and co-ordinate, not supplant existing structures. The World Bank is not the only major development organisation in the financial sector, and we do not propose that a WBO would supplant or replace existing conservation groups. Economic development problems are often regional in nature, and so there are many regional development banks. These include the African Development Bank (AfDB), the Asian Development Bank (ADB), the Asian Infrastructure Investment Bank (AIIB), the European Bank for Reconstruction and Development (EBRD), and the Inter-American Development Bank (IDB). These examples highlight that financial institutions are typically local: just like ecosystems, they have a defined spatio-temporal scope, allowing them to act as a bridge between financial and natural systems. A similar structure of multiple biodiversity organisations would be desirable because biodiversity challenges vary in different parts of the world. This hierarchical nesting of inter-connected organisations would match well to the local structure and functioning of ecosystems and, notably, would match approaches recommended for biodiversity measurement (Gonzalez et al., 2026). It would also allow for efficient and balanced commitments of resources across ecosystems. As initiatives such as the Tropical Forests Forever Facility (reviewed in Mendham et al., 2026) continue to gain traction, there is a danger that a new constellation of funds and initiatives will have to re-learn hard lessons from past conservation programs. Funding is often easier to gain for charismatic 'flagship' species (McGowan et al., 2020), and care has to be taken to ensure that resources are allocated according to urgency, long-term priorities, and efficacy (Bottrill et al., 2008) and not solely where flagship species are found. The WBO would coordinate to ensure such an effective allocation of funds.

The WBO would carry out work and distribute funds, but it would not be the GEF or the GBFF. The GEF, first established in 1991 as part efforts related to the 1992 Rio Earth Summit, is a "financial mechanism for six multilateral conventions" (Global Environment Facility, 2026). One of those conventions is the GBFF, which has raised over $386 million since its inception in 2023. The effort and achievement of the GBFF has been enormous, impressive, and extremely important, but we still have some way to go before reaching the KM-GBF Target 19 goal of mobilising at least $30 billion per year for biodiversity by 2030 (to put us on a path to recovery by 2050). The fundraising model of the GBFF is based around direct investment, not loans and oversight as in our WBO model, and as such the GBFF and the WBO could easily coexist. Perhaps most importantly, both the GEF and GBFF are embedded within the World Bank, highlighting the clear and immediate need for a financial institution that is devoted to biodiversity. The biodiversity crisis is so large and important that an existing financial institution has stepped in to fill the breach, but clearly this is not enough because the problem has not been solved. If we are serious about biodiversity and its recovery, we need a financial institution dedicated to biodiversity rather than being forced to retrofit the needs of biodiversity into existing financial structures.

A World Biodiversity Organisation could harmonise reporting standards with ecological theory

The standards and frameworks that regulate how firms should measure, manage, and report their impacts on ecosystems (*e.g.*, TNFD) are at an early stage and are still open to refinement. When framed in terms of local ecosystems and non-local financial markets, the problems with existing frameworks are not necessarily their proposed metrics, but that many metrics are reported at levels of temporal and spatial aggregation that are poorly aligned with the mechanisms by which ecological harm propagates and recovery occurs (Levin et al., 2013). This makes it difficult to connect financial disclosures to ecological processes, and therefore difficult to interpret reported values or to forecast using ecological theory.

From the perspective of an ecosystem, many economic activities (*e.g.*, felling a forest for timber) are exogenous shocks. Reporting frameworks should therefore place greater emphasis on how ecological systems absorb, propagate, and recover from such perturbations (Scheffer et al., 2009). At a minimum, this requires attention to: (a) ecosystem condition before and after the perturbation, (b) the duration and temporal pattern of the perturbation, and (c) the spatial scale over which the effect propagates. Annualised reporting can still be useful for some purposes, but where perturbations are local, pulsed, or state-dependent, annual averages can materially weaken inference and in some cases become misleading. This is different from climate reporting, where the externality is comparatively more global and cumulative. Even there, however, aggregation into CO_2-equivalent units can generate distortions when gases differ in persistence, warming profiles, or reporting standards are not harmonised (Biagini et al., 2026; Cenci & Biffis, 2025). If aggregation is already imperfect in climate, the case for caution is stronger still in biodiversity.

We therefore argue that regulators in biodiversity finance should focus less on proposing new biodiversity metrics and more on how existing ecologically meaningful metrics are collected, time-stamped, spatially located, and reported. A World Biodiversity Organisation would be able to carry out this important work as a delegated monitor. For example, the Essential Biodiversity Variables (EBVs; Pereira et al., 2013) provide a plausible starting point. The deeper difficulty is often not the variable itself, but the reporting convention applied to it. Aggregated disclosure across time, geography, or business segments can wash out precisely the local ecological context needed for interpretation. Consider wastewater discharge. Volume and pollutant concentration are intuitive metrics, but the same measured discharge can generate very different ecological consequences depending on whether it is released as a short pulse or continuously, whether it enters a resilient or already degraded ecosystem, and whether downstream effects propagate only nearby or across a wider hydrological system. The problem is not the metric in isolation: it is the loss of ecological information induced by aggregation.

A World Biodiversity Organisation could solve the 'dynamic inconsistency' problem of changing biodiversity priorities over time

A central difficulty in biodiversity conservation and restoration is dynamic inconsistency: the changing of policy over time such that earlier, optimal plans are abandoned in favour of shorter-term rewards. This problem is especially acute for biodiversity because ecological systems are slow-moving, state-dependent, and partly irreversible, whereas political and financial decision cycles are short. As a result, governments may commit to long-horizon conservation or restoration, only to weaken standards later when fiscal pressure intensifies, political leadership changes, or the distribution of costs and benefits becomes politically inconvenient. Private actors face a related commitment problem: investors and firms may support nature-positive strategies in principle, yet retrench when short-term performance pressures tighten, biodiversity outcomes remain difficult to verify at the pace demanded by markets, or the returns to ecological stewardship accrue too slowly to sustain private incentives (Levin et al., 2013; Levin, 1998).

Incomplete contracting makes this problem more severe. Neither public regulation nor private agreements can specify all future ecological contingencies, all relevant states of ecosystem degradation, or all shifts in political, technological, and macro-financial conditions. Critically, delays that seem modest in political or market time could push ecosystems toward states from which recovery is slow, costly, or impossible. Biodiversity finance faces the challenges that complex adaptive systems theory warns against: policy designed under linear, reductionist, or static assumptions will tend to omit the very features that matter most for long-term management (Levin et al., 2013). In practice, biodiversity finance is therefore exposed to a two-level commitment problem: within jurisdictions, policymakers face electoral turnover and fiscal constraints; across jurisdictions, countries and firms can defer effort, free-ride, or relocate ecological pressure elsewhere (*sensu* Putnam, 1988).

A WBO needs to be designed to maximise the planning horizon of the institution, and so its funding should be long-term and very difficult to reduce. If possible, the WBO should have an endowment that allows it to operate independently of the funding institutions, at least to some extent. The head of the institution should have a term that is longer than that of most of the sponsoring governments and other institutions. Critically, by being grounded in Ostrom's polycentric governance framework (Ostrom, 1990, 2009), a WBO would not act as a top-down monolith, but as a coordinating layer connecting nested regional development institutions with community stewardship.

Conclusion

The scale of the biodiversity crisis has never been greater, but never before have we had such financial and political resources available to address it. Our goal here is not to suggest that the ongoing and planned efforts to reverse biodiversity decline should be slowed, abandoned, or have been poorly conceived. Instead, we highlight ways to diversify and increase the financial resources we might use to address this crisis based upon careful, interdisciplinary assessment of opportunities and challenges at the intersections of biodiversity and finance. There is clearly capacity within the global community of researchers and market participants to consider more than one approach, and we see no risk that considering complementary alternatives will somehow dilute efforts. As a species, we have overcome global challenges such as smallpox and the hole in the ozone-layer, but we have never done so through the actions of market forces alone. Perhaps now is the time to extend our aim beyond markets towards a global, financial institution such as the World Biodiversity Organisation.

Table 1: **Candidate instruments for 'investable biodiversity'**. The table lists illustrative financial structures that can be tailored to biodiversity projects with different process horizons and uncertainty profiles. For each instruments we list (a) market size, (b) typical tenor (essentially the duration of the contract), (b) dominant risk profile (ecological, measurement, and policy risks), suitability for biodiversity outcomes (including whether outcomes can be credibly measured within the contract window and, where feasible, tied to performance-contingent payments rather than inputs or proxies), (e) typical investors, and (f) examples. We *do not* cover voluntary carbon offsets marketed with biodiversity co-benefits as the carbon market is too large and varied, and we address it instead in the main text. We note that Zhou and Almond (2026) reported market size of c. \$2bn for such credits in 2021, projecting c. \$50bn by 2030, but found no systematic evidence of improved ecological quality across the credits. Other reviews of financial instruments that could be used for biodiversity exist (*e.g.*, Carter et al., 2026; Sravan & Mishra, 2024; Young & Castro, 2021); ours differs most by focusing on risks as identified by the spatio-temporal framework we present here (*i.e.*, related to ecosystems being local) and their time-horizon (as is also relevant for our argument here relating to ecosystems' locality in terms of temporal processes).

Instrument	**Size**	**Tenor (yrs)**	**Risk profile**	**Suitability**	**Investors**	**Example**
Biodiversity credits	Nascent. Allen et al. (2026) report <\$2m sold by 2024 but note that some estimate up to \$5.9m; Waterford et al. (2024) estimate \$0.33–1.85m.	1–30	High for measurement, permanence and policy. Potential low liquidity. Reviewed by Croci et al. (2025b) and Holmlund et al. (2026)	High only with credible integrity rules; weak fit for a fungible global market.	Corporates, impact funds, specialised buyers	Various; reviewed by Croci et al. (2025a).
Offsets / mitigation banking	OECD (2024) records 17 programmes in 9 countries, Vaissière and Levrel (2015) estimate c. \$6.3–9.2 bn/year	5–30	Equivalence, location, restoration, and regulatory risk; liquidity low/moderate & program-specific (Levrel et al., 2017)	Medium where equivalence rules are strict	Developers, mitigation banks, regulated entities	Wetland mitigation banking (Robertson & Hayden, 2008)
Payment for Ecosystem Services (PES)	c. \$10.1 bn/year. OECD (2024) records 51 schemes in 28 countries; earlier (Perry & Karousakis, 2020) work identified 153 programmes in 37 countries.	1–20	Contracting, targeting, monitoring, and slippage risk; illiquid by design (Engel et al., 2008; Jack et al., 2008)	High for repeated local incentives; weak fit for capital-markets scaling	Governments, donors, NGOs, DFIs	Various, many in Costa Rica & Mexico (Engel et al., 2008; Sims & Alix-Garcia, 2017)
Outcome-based conservation bonds	Pilot-scale. Rhino Bond issued at \$150m in 2022 (World Bank, 2022)	3–10	Outcome, verification, and model risk; bespoke structures with limited secondary liquidity (Thompson, 2023)	High if ecological outcomes are independently verifiable during contract	Impact investors, foundations, DFIs	Rhino Bond (reviewed by Medina & Scales, 2024)

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Table 1 – continued from previous page

Instrument	Size	Tenor (years)	Risk profile	Suitability	Investors	Example
Parametric insurance	No robust biodiversity-only total; parent-market comparator is global Insurance-Linked Securities (ILS), c. $48bn outstanding at end-2024 (Reguero et al., 2020; Swiss Re, 2026)	1–5	Tail-event, basis, trigger, and counterparty risk; liquidity varies with ILS conditions but is only moderate (Bill-Weilandt et al., 2026; Reguero et al., 2020)	High for rapid post-shock funding; indirect for long-run biodiversity recovery	ILS funds, institutional investors, re-insurers, donors	The Mesoamerican Reef Insurance Policy (Wharton, 2024)
Use-of-proceeds green / blue bonds and loans	OECD (2025b) report $639 bn in 2024, but biodiversity is a subset of broader labelled debt	3–15	Credit, execution, and reporting risk; public formats can be liquid, but biodiversity linkage is indirect (Karolyi & Tobin-de la Puente, 2023)	Medium–high, weaker with strict biodiversity attribution.	Pension funds, insurers, mutual funds, banks, MDBs	Seychelles sovereign blue bond (March et al., 2024)
Sustainability-Linked Bonds & Loans (SLBs/SLLs)	OECD (2025b) reports $35bn global corporate SLBs in 2024, of which biodiversity are a small portion	2–10	KPI calibration and verification risk; issuer credit risk; publicly tradeable but biodiversity link is often weak (Anderson & Kish, 2024; De Mariz et al., 2024; Feldhütter et al., 2024)	Medium–high if robustly linked to biodiversity	Public credit investors, banks	Suzano sustainability-linked securities (Suzano, 2021)
Debt-for-nature swaps	Large but infrequent; average deal c. $700m in 2020–24 (OECD, 2025a)	10–30	Sovereign, FX, political, legal, and governance risk; structured and episodic, with low secondary liquidity (Cassimon et al., 2011; Nedopil & Sun, 2025)	High for long-horizon funding with governance covenants	DFIs, sovereign investors, guarantors, NGOs	Belize ($364m; The Nature Conservancy, 2022) & Ecuador's Galápagos Islands (c. $1.6bn; Inter-American Development Bank, 2023)
Blended-finance vehicles	Convergence (2024) records $1,123$ transactions totalling $213bn; biodiversity vehicles are a small subset	7–15	Asset, pipeline, governance, and exit risk; illiquid, dependent on patient and concessional capital (Flammer et al., 2024, 2025)	High if vehicle internalises monitoring and management	DFIs, endowments, family offices, impact funds	The Fund for Nature (Climate Policy Initiative, 2022)

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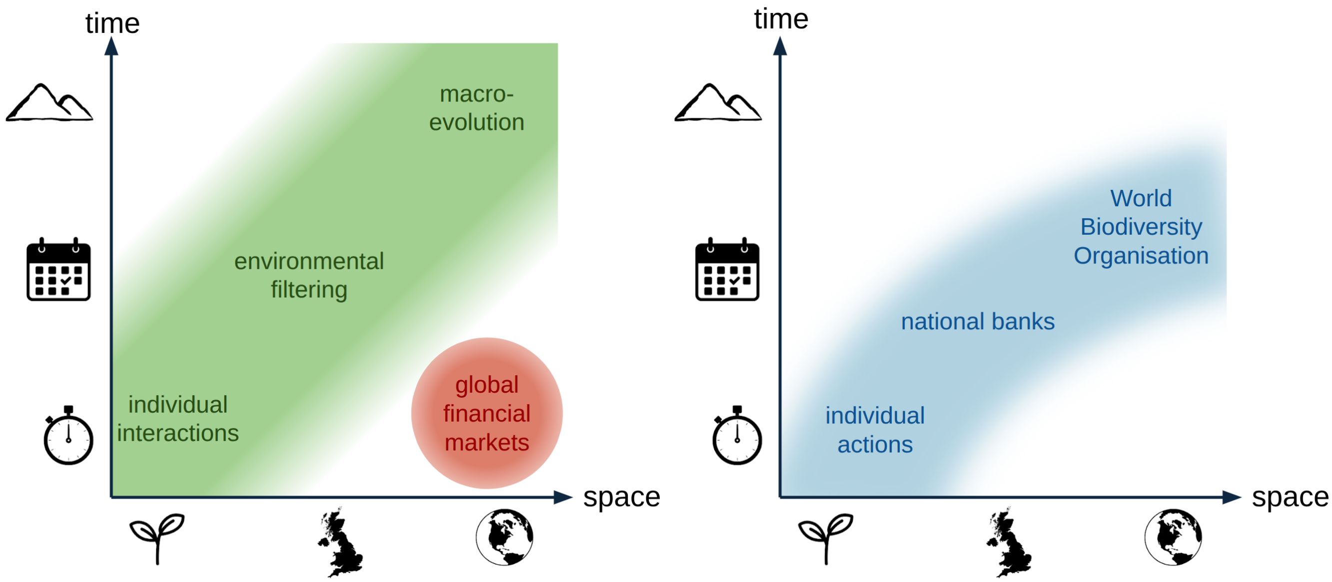
Table 1 – continued from previous page

Instrument	**Size**	**Tenor (years)**	**Risk profile**	**Suitability**	**Investors**	**Example**
Biodiversity-themed listed funds	MSCI (2023) identifies 149 funds with c. $60bn of assets as of Sep. 2023, including 15 pure-play funds with c. $1bn of assets. Goldman Sachs Asset Management (2025) described a narrower c. $3.4 bn set in 2025.	Open-ended / perpetual	Thematic concentration, taxonomy drift, and greenwashing risk; listed wrappers may be liquid, but outcome linkage is weak and indirect (Flammer et al., 2025; Goldman Sachs Asset Management, 2024)	Low–medium for direct additionality; stronger as allocation wrappers than as local biodiversity contracts	Asset managers, wealth platforms, retail and institutional allocators	Goldman Sachs Biodiversity Bond Fund (Goldman Sachs Asset Management, 2025)

Institutional Feature	**GBFF**	**IMF**	**WHO**	**World Bank**	**WBO**
Mandate	Grant funding for KM-GBF targets	International monetary and financial stability	Establish global public health norms & resolve emergencies	Capital investment & poverty reduction	Bridge financial and natural systems
Operational Model	Grants from partners	Surveillance, policy coordination, and conditional financing	Technical standard-setting	Capital-market AAA bond issuance & loans	Capital-market bond leverage, OTC credit oversight, & technical standard-setting
Financing Structure	Voluntary donor contributions	Member quotas and lending facilities	Member dues & earmarked donor funds	Global bond market issuance	Leveraged AAA green bonds & sovereign endowments
Local Intermediary Role	Low: relies on country submissions	Medium: through member-country authorities and central banks	Medium: national public health authorities	High: country offices & regional development banks	High: nested regional biodiversity institutions & OTC markets

Table 2: **Comparison of the models of existing organisations and a putative World Biodiversity Organisation (WBO).** Here we contrast the WBO with the Global Biodiversity Framework Fund (GBFF), International Monetaray Fund (IMF), World Health Organization (WHO), World Bank, and the proposed World Biodiversity Organisation (WBO). The WBO's operations would seek to minimise friction at the interface between non-local finance and local ecosystems, in order to efficiently spend as much resource as possible to reverse biodiversity decline and so safeguard human wellbeing.



(a) Current biodiversity-finance (b) Proposed biodiversity-finance

Figure 1: **Biodiversity processes operate across a local spatio-temporal scale, while current global financial systems are non-local**. In (a), ecologists and evolutionary biologists have long-recognised that biodiversity is structured by processes (green) that operate across different scales of space (horizontal axis, measured in centimetres, kilometres, and hundreds of kilometres) and time (vertical axis, measured in seconds, months, and (millions) of years; Cavender-Bares et al., 2009; Weiher & Keddy, 1995). Current global financial systems (red), on the other hand, are non-local: they can operate near-instantaneously across the entire planet. Our central argument is that no coupled financial-ecological systems can be successful without acknowledging and accounting for this difference. In (b), we show our proposal: a nested hierarchy of interventions that are operating at the appropriate spatial and temporal scales of biodiversity.

References

Allan, B. M., Nimmo, D. G., Ierodiaconou, D., VanDerWal, J., Koh, L. P., & Ritchie, E. G. (2018). Futurecasting ecological research: The rise of technoecology. *Ecosphere*, *9*(5), e02163.

Allen, F., Behr, P., Cosenza, R., & Nowak, E. (2026). Do investors care about the rainforest? evidence from voluntary carbon offsets around the world. *Review of Finance*, *30*(1), 321–349.

Allen, F., & Gale, D. (2000). *Comparing financial systems*. MIT press.

Amico, L., Fazio, R., Osterloh, A., & Vedral, V. (2008). Entanglement in many-body systems. *Reviews of modern physics*, *80*(2), 517–576.

Anderson, A.-M., & Kish, R. (2024). Rewarding performance through sustainability-linked bonds. *Economic Affairs*, *44*(2), 294–319.

Barak, R. S., Hipp, A. L., Cavender-Bares, J., Pearse, W. D., Hotchkiss, S. C., Lynch, E. A., Callaway, J. C., Calcote, R., & Larkin, D. J. (2016). Taking the long view: Integrating recorded, archeological, paleoecological, and evolutionary data into ecological restoration. *International Journal of Plant Sciences*, *177*(1), 90–102.

Berg, F., Ceccarelli, M., Heeb, F., Ivashchenko, A., Rigobón, R., & Zwinkels, R. C. (2025). *The market for voluntary carbon offsets* (tech. rep.). SAFE Working Paper.

Besson, M., Alison, J., Bjerge, K., Gorochowski, T. E., Høye, T. T., Jucker, T., Mann, H. M. R., & Clements, C. F. (2022). Towards the fully automated monitoring of ecological communities. *Ecology Letters*, *25*(12), 2753–2775.

Biagini, S., Biffis, E., & Nobari, K. (2026). Short-lived gases, carbon markets, and climate risk mitigation. *Available at SSRN 4997380*.

Bill-Weilandt, L., et al. (2026). A systematic review of nature-positive climate risk transfer and financing instruments. *Communications Earth & Environment*.

Bottrill, M. C., Joseph, L. N., Carwardine, J., Bode, M., Cook, C., Game, E. T., Grantham, H., Kark, S., Linke, S., McDonald-Madden, E., et al. (2008). Is conservation triage just smart decision making? *Trends in ecology & evolution*, *23*(12), 649–654.

Carter, H., Thompson, B. S., Bull, J. W., Dickman, A., Jones, J. P., Shrikanth, S., & zu Ermgassen, S. O. (2026). Demystifying biodiversity finance. *Nature Reviews Biodiversity*, 1–14.

Cassimon, D., Prowse, M., & Essers, D. (2011). The pitfalls and potential of debt-for-nature swaps: A us–indonesian case study. *Global Environmental Change*, *21*(1), 93–102.

Cavender-Bares, J., Kozak, K. H., Fine, P. V., & Kembel, S. W. (2009). The merging of community ecology and phylogenetic biology. *Ecology letters*, *12*(7), 693–715.

Cenci, S., & Biffis, E. (2025). Lack of harmonisation of greenhouse gases reporting standards and the methane emissions gap. *Nature Communications*, *16*(1), 1537.

Chandra, A., & Idrisova, A. (2011). Convention on biological diversity: A review of national challenges and opportunities for implementation. *Biodiversity and Conservation*, *20*(14), 3295–3316.

Chave, J. (2013). The problem of pattern and scale in ecology: What have we learned in 20 years? *Ecology Letters*, *16*, 4–16.

Climate Policy Initiative. (2022). *The fund for nature – instrument analysis*. Climate Policy Initiative.

Convergence. (2024). *The state of blended finance 2024*. Convergence.

Converse, R. L., Lippitt, C. D., Koneff, M. D., White, T. P., Weinstein, B. G., Gibbons, R., Stewart, D. R., Fleishman, A. B., Butler, M. J., Sesnie, S. E., & Harris, G. M. (2024). Remote sensing and machine learning to improve aerial wildlife population surveys. *Frontiers in Conservation Science*, *5*.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R. V., Paruelo, J., et al. (1997). The value of the world's ecosystem services and natural capital. *nature*, *387*(6630), 253–260.

Croci, E., Lucchitta, B., & Cusa, M. (2025a). Biodiversity credits schemes: A comparative analysis. *Journal of Cleaner Production*, *523*, 146382.

Croci, E., Lucchitta, B., & Cusa, M. (2025b). Biodiversity credit schemes: A comparative analysis. *Journal of Cleaner Production*, *523*, 146382.

Dasgupta, P. (2021). *The economics of biodiversity: The dasgupta review*. Hm Treasury.

De Mariz, F., Bosmans, P., Leal, D., & Bisaria, S. (2024). Reforming sustainability-linked bonds by strengthening investor trust. *Journal of Risk and Financial Management*, *17*(7), 290.

Diamond, D. W. (1984). Financial intermediation and delegated monitoring. *The review of economic studies*, *51*(3), 393–414.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J. R., Arico, S., Báldi, A., et al. (2015). The ipbes conceptual framework—connecting nature and people. *Current opinion in environmental sustainability*, *14*, 1–16.

Díaz, S., Settele, J., Brondízio, E. S., Ngo, H. T., Agard, J., Arneth, A., Balvanera, P., Brauman, K. A., Butchart, S. H., Chan, K. M., et al. (2019). Pervasive human-driven decline of life on earth points to the need for transformative change. *Science*, *366*(6471), eaax3100.

Duchelle, A. E., Simonet, G., Sunderlin, W. D., & Wunder, S. (2018). What is redd+ achieving on the ground? *Current Opinion in Environmental Sustainability*, *32*, 134–140.

Duffie, D., Gârleanu, N., & Pedersen, L. H. (2005). Over-the-counter markets. *Econometrica*, *73*(6), 1815–1847.

Engel, S., Pagiola, S., & Wunder, S. (2008). Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological Economics*, *65*(4), 663–674.

Feldhütter, P., Halskov, K., & Krebbers, A. (2024). Pricing of sustainability-linked bonds. *Journal of Financial Economics*, *162*, 103944.

Fenichel, E. P., & Abbott, J. K. (2014). Natural capital: From metaphor to measurement. *Journal of the Association of Environmental and Resource Economists*, *1*(1/2), 1–27.

Fenichel, E. P., Abbott, J. K., Bayham, J., Boone, W., Haacker, E. M., & Pfeiffer, L. (2016). Measuring the value of groundwater and other forms of natural capital. *Proceedings of the National Academy of Sciences*, *113*(9), 2382–2387.

Flammer, C., Giroux, T., & Heal, G. (2024). *Blended finance* (tech. rep. No. 32287). NBER.

Flammer, C., Giroux, T., & Heal, G. (2025). Biodiversity finance. *Journal of Financial Economics*, *164*, 103987.

Freeman III, A. M., Herriges, J. A., & Kling, C. L. (2014). *The measurement of environmental and resource values: Theory and methods*. Routledge.

García, J. H., & Moros, L. M. (2025). Key issues in carbon markets and lessons for biodiversity conservation and financing. *Current Opinion in Environmental Sustainability*, *77*, 101586.

Global Environment Facility. (2026, January). *The GEF at a glance* (Fact Sheet). Global Environment Facility (GEF).

Goldman Sachs Asset Management. (2024). *Making biodiversity investing actionable*. Goldman Sachs Asset Management.

Goldman Sachs Asset Management. (2025). *Goldman sachs asset management launches biodiversity bond fund*. Goldman Sachs Asset Management.

Gonzalez, A., August, T., Bailey, S., Bobiwash, K., Boersch-Supan, P. H., Burgess, N. D., Daru, B. H., Elphick, C. S., Freckleton, R. P., Frick, W. F., et al. (2026). From data to decisions: Toward a biodiversity monitoring standards framework. *Proceedings of the National Academy of Sciences*, *123*(10), e2519347123.

Günther, P., Garske, B., Heyl, K., & Ekardt, F. (2024). Carbon farming, overestimated negative emissions and the limits to emissions trading in land-use governance: The eu carbon removal certification proposal. *Environmental Sciences Europe*, *36*(1), 72.

Guo, C., Agarwala, M., Freeman, M., Groom, B., & McKenzie, E. (2026). Introduction to the special issue:'biodiversity and finance: Risk, disclosure and double materiality'.

Hardin, G. (1968). The tragedy of the commons: The population problem has no technical solution; it requires a fundamental extension in morality. *science*, *162*(3859), 1243–1248.

Henderson, D. A. (2011). The eradication of smallpox–an overview of the past, present, and future. *Vaccine*, *29*, D7–D9.

Holmlund, M., et al. (2026). Voluntary biodiversity credits: A review of concepts and a perspective on their application in european production forests. *Ecosystem Services*, *78*, 101828.

Hughes, A. C., & Grumbine, R. E. (2023). The kunming-montreal global biodiversity framework: What it does and does not do, and how to improve it. *Frontiers in Environmental Science*, *11*, 1281536.

Inter-American Development Bank. (2023). *Ecuador completes world's largest debt-for-nature conversion with idb and dfc support*. IDB.

International Monetary Fund. (2024, October). *Fiscal monitor: Putting a lid on public debt* (tech. rep.) (Accessed: 2026-04-03). International Monetary Fund. Washington, DC.

IPBES. (2024). *Thematic assessment report on the interlinkages among biodiversity, water, food and health of the intergovernmental science-policy platform on biodiversity and ecosystem services* (P. A. Harrison, P. D. McElwee, & T. L. van Huysen, Eds.). IPBES Secretariat. Bonn, Germany.

Irvine-Broque, A., & Dempsey, J. (2023). Risky business: Protecting nature, protecting wealth? *Conservation Letters*, *16*(4), e12969.

Jack, B. K., Kousky, C., & Sims, K. R. E. (2008). Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. *Proceedings of the National Academy of Sciences*, *105*(28), 9465–9470.

Johnston, R. J., Rolfe, J., Rosenberger, R. S., & Brouwer, R. (2015). Benefit transfer of environmental and resource values. *The economics of non-market goods and resources*, *14*.

Karolyi, G. A., & Tobin-de la Puente, J. (2023). Biodiversity finance: A call for research into financing nature. *Financial Management*, *52*(2), 231–251.

Kedward, K., Zu Ermgassen, S., Ryan-Collins, J., & Wunder, S. (2023). Heavy reliance on private finance alone will not deliver conservation goals. *Nature Ecology & Evolution*, *7*(9), 1339–1342.

Keitt, T. H., & Abelson, E. S. (2021). Ecology in the age of automation. *Science*, *373*(6557), 858–859.

Kumar, P. (2012). *The economics of ecosystems and biodiversity: Ecological and economic foundations*. Routledge.
Laktuka, K., Luksta, I., & Blumberga, D. (2025). Policy coherence of the eu carbon removal certification framework: Integration of carbon farming in climate and agricultural policy. *Environmental and Climate Technologies*, *29*(1), 658–684.
Lawson, J., Lee-Grant, C., O'Neill, A., Forey, E., de Ruig, L., Weeks, T., Yang, J., Ewers, R., Rosindell, J., & Pearse, W. D. (2025). Systematic review of biodiversity monitoring shows gradual rise of scaleable and automated methods and inherent spatial and taxonomic biases. *bioRxiv*, 2025–10.
Leclère, D., Obersteiner, M., Barrett, M., Butchart, S. H., Chaudhary, A., De Palma, A., DeClerck, F. A., Di Marco, M., Doelman, J. C., Dürauer, M., et al. (2020). Bending the curve of terrestrial biodiversity needs an integrated strategy. *Nature*, *585*(7826), 551–556.
Levin, S., Xepapadeas, T., Crépin, A.-S., Norberg, J., De Zeeuw, A., Folke, C., Hughes, T., Arrow, K., Barrett, S., Daily, G., et al. (2013). Social-ecological systems as complex adaptive systems: Modeling and policy implications. *Environment and development economics*, *18*(2), 111–132.
Levin, S. A. (1992). The problem of pattern and scale in ecology: The robert h. macarthur award lecture. *Ecology*, *73*(6), 1943–1967.
Levin, S. A. (1998). Ecosystems and the biosphere as complex adaptive systems. *Ecosystems*, *1*(5), 431–436.
Levrel, H., et al. (2017). Should we be wary of mitigation banking? evidence regarding the risks associated with ecological equivalence in wetland offset policies from florida in the united states. *Ecological Economics*, *135*, 136–149.
Lindenmayer, D. B., & Westgate, M. J. (2020). Are flagship, umbrella and keystone species useful surrogates to understand the consequences of landscape change? *Current Landscape Ecology Reports*, *5*(3), 76–84.
Liu, J., Mooney, H., Hull, V., Davis, S. J., Gaskell, J., Hertel, T., Lubchenco, J., Seto, K. C., Gleick, P., Kremen, C., et al. (2015). Systems integration for global sustainability. *Science*, *347*(6225), 1258832.
Lucey, B. M., Urquhart, A., & Vigne, S. (2025). Biodiversity, financial markets, and systemic risk: A synthesizing review. *Journal of Climate Finance*, *13*, 100078.
Magurran, A. E. (2021). Measuring biological diversity. *Current Biology*, *31*(19), R1174–R1177.
March, A., Evans, T., Laing, S., & Raguain, J. (2024). Evaluating the world's first sovereign blue bond: Lessons for operationalising blue finance. *Commodities*, *3*(2), 151–167.
McGowan, J., Beaumont, L. J., Smith, R. J., Chauvenet, A. L., Harcourt, R., Atkinson, S. C., Mittermeier, J. C., Esperon-Rodriguez, M., Baumgartner, J. B., Beattie, A., et al. (2020). Conservation prioritization can resolve the flagship species conundrum. *Nature Communications*, *11*(1), 994.
Medina, C., & Scales, I. R. (2024). Finance and biodiversity conservation: Insights from rhinoceros conservation and the first wildlife conservation bond. *Oryx*, *58*(1), 90–99.
Mendham, D. S., Langston, J. D., Resosudarmo, I. A. P., Supriatna, J., Abdurrahim, A. Y., & O'Grady, A. (2026). Strengthen the tropical forests forever facility to safeguard forests and people. *Nature Ecology & Evolution*, 1–3.
MSCI. (2023). *Biodiversity funds: Welcome to the jungle*. MSCI.
Nedopil, C. (2023). Integrating biodiversity into financial decision-making: Challenges and four principles. *Business Strategy and the Environment*, *32*(4), 1619–1633.

Nedopil, C., & Sun, Z. (2025). Current perspectives on debt-for-nature swaps: Moving from exploratory to empirical research. *Current Opinion in Environmental Sustainability*, *79*, 101538.

Newman, E. A., Kennedy, M. C., Falk, D. A., & McKenzie, D. (2019). Scaling and complexity in landscape ecology. *Frontiers in Ecology and Evolution*, *7*, 293.

OECD. (2024). *Tracking economic instruments and finance for biodiversity 2024*. OECD. Paris.

OECD. (2025a). *Global debt report 2025*. OECD. Paris.

OECD. (2025b). *Sustainable bonds: Trends and policy recommendations*. OECD. Paris.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge university press.

Ostrom, E. (2009). A polycentric approach for coping with climate change. *Available at SSRN 1934353*.

Pearse, W. D., Cavender-Bares, J., Hobbie, S. E., Avolio, M. L., Bettez, N., Roy Chowdhury, R., Darling, L. E., Groffman, P. M., Grove, J. M., Hall, S. J., et al. (2018). Homogenization of plant diversity, composition, and structure in north american urban yards. *Ecosphere*, *9*(2), e02105.

Pelletier, F., Garant, D., & Hendry, A. P. (2009). Eco-evolutionary dynamics.

Pereira, H. M., Ferrier, S., Walters, M., Geller, G. N., Jongman, R. H., Scholes, R. J., Bruford, M. W., Brummitt, N., Butchart, S. H., Cardoso, A., et al. (2013). Essential biodiversity variables. *Science*, *339*(6117), 277–278.

Perrings, C., Folke, C., & Mäler, K.-G. (1992). The ecology and economics of biodiversity loss: The research agenda. *Ambio*, 201–211.

Perry, E., & Karousakis, K. (2020). *A comprehensive overview of global biodiversity finance*. OECD. Paris.

Perry, G. L. W., Seidl, R., Bellvé, A. M., & Rammer, W. (2022). An outlook for deep learning in ecosystem science. *Ecosystems*, *25*, 1700–1718.

Pimentel, D., Wilson, C., McCullum, C., Huang, R., Dwen, P., Flack, J., Tran, Q., Saltman, T., & Cliff, B. (1997). Economic and environmental benefits of biodiversity. *BioScience*, *47*(11), 747–757.

Pörtner, H.-O., Scholes, R., Arneth, A., Barnes, D., Burrows, M. T., Diamond, S., Duarte, C. M., Kiessling, W., Leadley, P., Managi, S., et al. (2023). Overcoming the coupled climate and biodiversity crises and their societal impacts. *Science*, *380*(6642), eabl4881.

Purvis, A. (2025). Bending the curve of biodiversity loss requires a 'satnav'for nature. *Philosophical Transactions B*, *380*(1917), 20230210.

Purvis, A., & Hector, A. (2000). Getting the measure of biodiversity. *Nature*, *405*(6783), 212–219.

Putnam, R. D. (1988). Diplomacy and domestic politics: The logic of two-level games. *International Organization*, *42*(3), 427–460.

Pyke, G. H., & Ehrlich, P. R. (2010). Biological collections and ecological/environmental research: A review, some observations and a look to the future. *Biological reviews*, *85*(2), 247–266.

Reguero, B. G., et al. (2020). Financing coastal resilience by combining nature-based solutions and insurance. *Ecological Economics*, *169*, 106487.

Rick, T. C., & Lockwood, R. (2013). Integrating paleobiology, archeology, and history to inform biological conservation. *Conservation Biology*, *27*(1), 45–54.

Robertson, M. M., & Hayden, N. (2008). Evaluation of a market in wetland credits: Entrepreneurial wetland banking in chicago. *Conservation Biology*, *22*(3), 636–646.

Sasaki, N. (2025). Addressing scandals and greenwashing in carbon offset markets: A framework for reform. *Global Transitions*, *7*, 375–382.

Scheffer, M., Bascompte, J., Brock, W. A., Brovkin, V., Carpenter, S. R., Dakos, V., Held, H., Van Nes, E. H., Rietkerk, M., & Sugihara, G. (2009). Early-warning signals for critical transitions. *Nature*, *461*(7260), 53–59.

Scholes, R. J., Reyers, B., Biggs, R., Spierenburg, M., & Duriappah, A. (2013). Multi-scale and cross-scale assessments of social-ecological systems and their ecosystem services. *Current Opinion in Environmental Sustainability*, *5*(1), 16–25.

Schwarcz, S. L. (2008). Systemic risk. *Georgetown Law Journal*, *97*, 193.

Sims, K. R. E., & Alix-Garcia, J. M. (2017). Parks versus pes: Evaluating direct and incentive-based land conservation in mexico. *Journal of Environmental Economics and Management*, *86*, 8–28.

Sravan, C., & Mishra, P. P. (2024). Bridging the gap between finance and conservation biology: How derivatives can help in conservation. *Journal for Nature Conservation*, *78*, 126550.

Stephenson, P. J. (2020). Technological advances in biodiversity monitoring: Applicability, opportunities and challenges [Open Issue 2020 Part A: Technology Innovations and Environmental Sustainability in the Anthropocene]. *Current Opinion in Environmental Sustainability*, *45*, 36–41.

Suzano. (2021). Sustainability-linked securities framework [Issuer framework].

Swinfield, T., & Scott, E. T. (2025). *Scientific credibility for high-integrity voluntary carbon markets*.

Swiss Re. (2026). *Insurance-linked securities market update*. Swiss Re.

Tedersoo, L., Sepping, J., Morgunov, A. S., Kiik, M., Esop, K., Rosenvald, R., Hardwick, K., Breman, E., Purdon, R., Groom, B., et al. (2024). Towards a co-crediting system for carbon and biodiversity. *Plants, People, Planet*, *6*(1), 18–28.

Thanasi-Boçe, M., & Hoxha, J. (2025). Blockchain for sustainable development: A systematic review. *Sustainability*, *17*(11), 4848.

The Nature Conservancy. (2021). *A post-storm response and reef insurance primer* (tech. rep.) (Accessed: 2026-04-07). The Nature Conservancy.

The Nature Conservancy. (2022). *Belize debt conversion case study*. The Nature Conservancy.

Thompson, E. (2023). Impact investing in biodiversity conservation with bonds: An analysis of financial and environmental risk. *Business Strategy and the Environment*, *32*(1), 353–368.

Urban, M. C., Zurell, D., Bocedi, G., Gonzalez, A., Velazco, S. J., Bezeng, B. S., Briscoe, N. J., Brotons, L., Buckley, L. B., de Oliveira Junior, A. C., et al. (2026). A global research co-ordination programme is urgently needed for biodiversity. *Nature Ecology & Evolution*, 1–3.

Vaissière, A.-C., & Levrel, H. (2015). Biodiversity offset markets: What are they really? an empirical approach to wetland mitigation banking. *Ecological Economics*, *110*, 81–88.

Vidal Morant, M., Eagle, A. J., van de Ven, G., Lavallee, J. M., Zahra, J., de Wit, A., & Hijbeek, R. (2025). Carbon farming in europe, policies of symbolic reassurance. *Outlook on Agriculture*, *54*(4), 336–345.

Waterford, L., FitzSimons, V., Back, O., Crowley, H., Gianferrara, E., Bucher-Melcer, S., Young, A., Williams, G., Hutchinson, J., & Gorring, A. (2024). State of voluntary biodiversity credit markets: A global review of biodiversity credit schemes. *Edited by H. Crowley, E. Gianferrara, and S. Bucher-Melcer. Pollination Group: London*.

Wauchope, H. S., Zu Ermgassen, S. O., Jones, J. P., Carter, H., to Bühne, H. S., & Milner-Gulland, E. (2024). What is a unit of nature? measurement challenges in the emerging biodiversity credit market. *Proceedings of the Royal Society B: Biological Sciences*, *291*(2036), 20242353.

Weiher, E., & Keddy, P. A. (1995). Assembly rules, null models, and trait dispersion: New questions from old patterns. *Oikos*, 159–164.

Wharton, J. (2024). *The MAR insurance programme: A nature-based solution to enhance resilience* (tech. rep.) (Accessed: 2026-04-09). MAR Fund.

WHO. (2025). *World health statistics 2025: Monitoring health for the sdgs, sustainable development goals* (tech. rep.) (Accessed: 2026-04-09). World Health Organization. Geneva, Switzerland.

Willis, J. (2026). Biodiversity finance: What has been achieved and where is it heading. *Ecological Economics*, *240*, 108713.

Willis, K. J., & Birks, H. J. B. (2006). What is natural? The need for a long-term perspective in biodiversity conservation. *Science*, *314*(5803), 1261–1265.

Willis, K. J., Araujo, M. B., Bennett, K. D., Figueroa-Rangel, B., Froyd, C. A., & Myers, N. (2007). How can a knowledge of the past help to conserve the future? biodiversity conservation and the relevance of long-term ecological studies. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *362*(1478), 175–187.

World Bank. (2022). *Investors join landmark wildlife conservation bond to support black rhinos and local communities in south africa*. World Bank.

World Bank Group. (2025). *The world bank group annual report 2025* (tech. rep.) (Accessed: 2026-04-09). World Bank. Washington, DC.

Wunder, S., et al. (2025). Biodiversity credits: An overview of the current state, future opportunities, and potential pitfalls. *Business Strategy and the Environment*.

Young, C. E. F., & Castro, B. S. (2021). Financing mechanisms to bridge the resource gap to conserve biodiversity and ecosystem services in brazil. *Ecosystem Services*, *50*, 101321.

Zhou, Z. Y., & Almond, D. (2026). Biodiversity co-benefits in carbon markets? evidence from voluntary offset projects. *Review of Finance*, *30*(2), 537–570.