Why nature cannot be replaced: the limits of substitution in biodiversity conservation

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Abstract

Contemporary conservation governance increasingly relies on biodiversity offsetting and related instruments that seek to compensate ecological losses from development projects through metric-based equivalence and No Net Loss accounting. In their dominant policy form, these approaches treat biodiversity as substitutable: damage at one site is rendered acceptable if equivalent gains are generated elsewhere. This paper examines the limits of this substitution logic. Drawing on literature on biodiversity offsetting, value pluralism and conservation governance, it argues that metric equivalence cannot by itself establish the substitutability of nature. Biodiversity embodies not only instrumental benefits but also intrinsic and relational values that resist fungibility. These values are difficult to represent within exchangeable metrics. Substitution therefore depends on two reductions: plural values are narrowed to measurable benefits, and complex ecological systems are simplified into indicators that can be compared across sites and over time. To clarify the governance implications of these limits, the paper develops an Ethical Impact Assessment framework centred on a plural-value scaffold linking ecosystem structure, functions, services and value dimensions. This scaffold shows why compensatory responses vary in ethical reach depending on the level of ecological organisation at which they intervene. Where compensatory equivalence cannot plausibly justify harm, the framework introduces a justificatory exit: a decision point at which projects threatening non-substitutable ecological values should be reconsidered rather than balanced through offsets. Recognising these limits reorients conservation governance toward stronger avoidance, restraint and forms of ethical repair that acknowledge irreversible loss without presuming replacement.

1. Introduction

Infrastructure development, urban and industrial expansion, and agricultural conversion remain major drivers of habitat loss and biodiversity decline (Richardson et al., 2023). In response, conservation governance increasingly relies on instruments that seek to reconcile development with biodiversity protection by compensating ecological losses through gains elsewhere. Biodiversity offsets and related crediting mechanisms are central examples, usually operating under the policy goals of biodiversity No Net Loss or Gain (Bull et al., 2016; Marshall et al., 2026). Their practical appeal lies in the promise that residual losses can be translated into measurable units and balanced against future or off-site ecological improvements.

This promise depends on a demanding assumption: that biodiversity losses and gains can be made sufficiently equivalent to justify substitution across places and over time. In practice, this assumption is operationalised through metrics, baselines, multipliers and offset rules that convert heterogeneous ecological realities into comparable units (Wauchope et al., 2024). Such tools can make compensation administratively tractable, but they also shape what is recognised as loss, what counts as gain, and which values are left outside the calculation. Biodiversity is not valued only for ecosystem services, but also for intrinsic and relational dimensions associated with organisms, species lineages, ecological histories, and place-based human–nature relationships (Ives & Bekessy, 2015; Spash, 2015; Björnberg, 2020).

The problem is intensified by the institutional role of the mitigation hierarchy. In principle, impacts should first be avoided, then minimised and restored, with compensation used only as a last resort (Maron et al., 2025). Yet empirical studies indicate that this sequencing is often imperfectly implemented, with avoidance insufficiently explored and residual impacts displaced towards compensatory stages (Moilanen & Kotiaho, 2018; Jones et al., 2022). Compensation may therefore become more central to development decision-making than its last-resort status suggests (Maron et al., 2025). This raises a central conservation question: when, if ever, can compensatory gains justify biodiversity losses?

This paper argues that metric equivalence cannot, by itself, establish the substitutability of nature. Substitution becomes problematic where biodiversity embodies plural values and ecological complexity that resist reduction to exchangeable indicators. In such cases, compensation may respond to loss, but it cannot function as a full moral or ecological counterbalance. The central task for governance is therefore not simply to improve offset metrics, but to identify the limits of offsetability and to specify when avoidance, redesign, refusal, or non-compensatory forms of repair are required.

To develop this argument, the paper synthesises literature on biodiversity offsetting, environmental values, ecological complexity and conservation governance. It proposes an Ethical Impact Assessment framework, centred on a plural-value scaffold linking ecosystem structure, functions, services and human wellbeing to different value dimensions. This framework clarifies why compensation directed at one level of ecological organisation may fail to address losses occurring at another, and why increasingly complex, historically constituted or place-bound ecological values become harder to substitute. The paper introduces the concept of a justificatory exit: a governance threshold at which compensatory equivalence can no longer plausibly justify harm and decision-makers must reconsider the underlying project or require forms of response that acknowledge rather than erase residual loss.

The paper proceeds as follows. Section 2 examines how instrumental, intrinsic and relational values bear on assumptions of fungibility in biodiversity compensation. Section 3 develops the Ethical Impact Assessment framework and identifies limits to substitution within conservation decision-making. Section 4 considers the governance implications, arguing that where substitution fails as justification, conservation must shift towards restraint and ethical repair under conditions of irreversibility.

2. Value pluralism and the limits of fungibility

Fungibility is the condition under which distinct natural entities may be treated as interchangeable for compensatory purposes (Salzman & Ruhl, 2019). In biodiversity offsetting, metrics, baselines, and equivalence rules construct this interchangeability by making selected dimensions of ecological loss and gain commensurable. Because ecological systems are multidimensional and context-dependent, such commensuration necessarily involves normative choices about which values are recognised, simplified or excluded (Wauchope et al., 2024).

Whether substitution is conceptually coherent or normatively defensible therefore depends on which kinds of value are at stake (Ives & Bekessy, 2015). If biodiversity is valued solely for its instrumental contributions, fungibility may appear relatively plausible: goods valued as means can, in principle, be replaced by functionally similar alternatives. However, where organisms, ecosystems or places embody non-instrumental values that are not reducible to utility or functional similarity, the assumption of interchangeability becomes contested (Himes & Muraca, 2018). In such cases, conservation decisions involve genuine trade-offs between plural values rather than straightforward substitutions between equivalent units.

For this reason, the analysis distinguishes between instrumental, intrinsic and relational values (Table 1). These categories are not mutually exclusive and often co-occur: a forest may simultaneously provide flood regulation or timber, support organisms and species lineages, embody ecological continuity, and carry cultural or personal significance (Anderson et al., 2022). Distinguishing these value dimensions clarifies how each bears on fungibility and the limits of compensation.

2.1 Instrumental value

Instrumental value refers to cases where nature is valued as a means to human ends, including provisioning services such as food, timber or medicinal resources, and regulating services such as climate regulation, water purification or pollination (Díaz et al., 2018). Because instrumental value is defined in relation to benefits or outcomes, a wetland valued primarily for flood regulation, for example, may appear compensable if another wetland or engineered system can provide the same level of flood protection (Bull et al., 2015).

This does not make instrumental value illegitimate. It remains indispensable in conservation and environmental decision-making. The problem arises when instrumental value becomes the dominant or exclusive basis for assessing biodiversity loss (Díaz et al., 2018; Ghijselinck, 2023). In that case, ecological entities are framed as interchangeable so long as aggregate benefits are maintained, thereby providing the conceptual foundation for metric-based compensation.

Table 1:

Principal environmental value dimensions and their implications for fungibility and substitution in conservation governance.

Value dimension	**What matters?**	**Implication for fungibility?**
Instrumental	Ecosystem services and functional outcomes contributing to human wellbeing	More compatible with substitution where equivalent functions or benefits can be provided
Intrinsic (organisms)	The flourishing or good of individual living beings	Strict substitution is problematic because individual beings are not replaceable as such
Intrinsic (species and ecological systems)	Species lineages, ecological integrity, and the systemic relations that sustain life	Substitution is strongly constrained where loss disrupts lineages, ecological organisation or integrity
Intrinsic (historical)	Ecological trajectories, accumulated legacies, and historically constituted habitats	Generally non-substitutable once continuity is interrupted
Relational	Place attachment, identity, stewardship, care, memory and situated human–nature relationships	Context-dependent, but often resistant to substitution because relationships are tied to particular places

2.2 Intrinsic value

Intrinsic value refers to the value of nature in its own right. The present argument need not resolve debates about its metaphysical status; it is enough to recognise that conservation discourse frequently invokes non-instrumental concern for organisms, species, ecosystems and ecological integrity (McShane, 2007).

Intrinsic value may be attributed to individual living beings understood as entities with their own good (Taylor, 1986). Conservation practice, however, often engages intrinsic value at broader levels of ecological organisation, including populations, species lineages and ecosystems. Species embody historically continuous evolutionary trajectories, such that extinction is not simply the loss of individual organisms but the termination of a lineage (Leopold, 1949; Rolston, 1988). Ecosystems, in turn, are organised systems of co-evolved interactions, trophic relations and ecological processes whose integrity may be disrupted even where some functional outputs remain replaceable (Woodley & Kay, 2020).

Intrinsic value may also be grounded in historical continuity. Long-established forests, wetlands or grasslands often embody ecological legacies, such as accumulated species assemblages, soil structures and slow-forming biotic interactions, that arise over long periods of relatively uninterrupted development (Read & Perez-Moreno, 2003; Naaf & Kolk, 2015). Their value is not exhausted by present condition or function, but includes the trajectory through which they have come to exist (Rolston, 1988). This concern mirrors the distinction developed in the preceding chapter between present-day habitat condition and long-term ecological continuity. A tool may record structural or compositional quality while still failing to represent the accumulated ecological legacies that make historically continuous habitats difficult or impossible to replace. From the standpoint of fungibility, such values resist straightforward substitution because they attach to entities and relations that cannot be fully counterbalanced by comparable instrumental benefits or a spatially displaced analogue.

2.3 Relational values

Relational values concern meaningful human–nature relationships, including place attachment, identity, memory, stewardship, care and responsibility (Jax et al., 2018; Deplazes-Zemp & Chapman, 2021). They are often place-based, reflecting the significance of *this* forest, *this* river or *this* landscape within a lived and situated context (Knippenberg et al., 2018). This particularity matters for compensation. The loss of places embedded in personal or communal meaning cannot be fully compensated by creating another site that is merely functionally or structurally similar.

Relational values therefore highlight a further limit of fungibility. Even when ecological metrics indicate equivalence between an impact site and an offset site, the affected relationships may not be transferable. Aesthetic appreciation illustrates the point. The beauty of a landscape may be treated instrumentally when valued as a source of recreation or tourism, but it may also become relational when aesthetic experience deepens attachment, care or identity. In such cases, value is not reducible to generic enjoyment and cannot simply be relocated without loss (Tribot et al., 2018; Ghijselinck, 2023).

2.4 From value pluralism to substitution-based conservation

These limits become especially consequential when fungibility is institutionalised through biodiversity offsetting and No Net Loss.

2.4.1 Fungibility institutionalised: offsetting and No Net Loss

Offsetting and No Net Loss policies do not merely assume fungibility; they institutionalise it through systems of measurement, aggregation and exchange (Moreno-Mateos et al., 2015). Losses and gains are translated into standardised metrics - such as habitat hectares, vegetation integrity scores, species credits or biodiversity units - rendering heterogeneous ecological realities comparable across sites and over time (Bull et al., 2016; Damiens et al., 2021). These metrics often combine multiple ecological criteria, such as species richness, abundance, habitat condition or structural complexity, through processes of normalisation, weighting and aggregation (Gamarra et al., 2018). Metric equivalence is therefore not simply discovered; it is constructed through decisions about what is measured, how different attributes are weighted, and which forms of difference are treated as acceptable.

This matters because the values most readily represented in such frameworks are those that can be translated into measurable outputs. Instrumental values - such as flood regulation, carbon storage or habitat provision - can often be compared in terms of functional performance (Moreno-Mateos et al., 2015). Intrinsic and relational values, by contrast, are more difficult to express as exchangeable units. As a result, substitution-based conservation tends to privilege dimensions of biodiversity that can be quantified, while values tied to organisms, lineages, ecological histories or place-based relationships remain only partially represented, or outside the metric altogether (Moreno-Mateos et al., 2015; Gelot & Bigard, 2021).

No Net Loss claims are therefore vulnerable to a form of normative incompleteness. The issue is not merely whether measurement can be improved, but whether what is measured exhausts what matters. Where plural values exceed what can be rendered commensurable, translating biodiversity into a single compensatory currency risks flattening ecological and normative differences into functional equivalence (McCauley, 2006; Bull et al., 2015; Spash, 2015).

The mitigation hierarchy reveals this problem particularly clearly. By placing avoidance and minimisation before restoration and offsetting, it recognises that compensation should be a last resort rather than a default response (Bergès et al., 2020; Ghijselinck et al., 2026). This ordering is partly grounded in practical concerns, including uncertainty, temporal lag and limits to ecological replicability (Bull et al., 2015; Rampling et al., 2024). Yet it also has a justificatory role: if metric equivalence fully captured what is at stake, prioritising avoidance over offsetting would be difficult to explain. The hierarchy thus implicitly recognises that some losses are not reducible to calculable exchange.

However, this ethical basis is rarely made explicit. Without a principled account of why certain losses should resist substitution, the hierarchy risks becoming a procedural sequence rather than a substantive constraint. As Ives and Bekessy (2015) argue, when the rationale for the “last resort” status of offsetting remains under-theorised, compensatory gains may normalise impacts that conservation governance should instead avoid.

3. Governing the limits of substitution

Under value pluralism, governance must specify which values are treated as compensable and the thresholds beyond which loss can no longer be permissibly offset.

3.1 From value pluralism to governance: a plural-value scaffold

This section develops an Ethical Impact Assessment framework that makes plural environmental values explicit within decision-making. The framework does not resolve the ethical problems of substitution, but provides a structured way to assess when compensatory equivalence is more or less defensible, and when governance should constrain substitution.

At the heart of this proposal is a plural-value scaffold, which traces pathways from ecosystem structure to functions, services and human wellbeing (Fig. 1). The scaffold functions both as an ecological model and as a value map: it links levels of ecological organisation to different value dimensions and shows how different forms of loss engage different substitutability constraints. Ecosystem structure refers to the spatial arrangement and composition of biotic and abiotic components, including habitat types, vegetation strata, patch configuration and other forms of heterogeneity. It reflects ecological interactions and historical development, and provides the organisational basis on which ecosystem functions depend (Chapin et al., 2011; Farley et al., 2024).

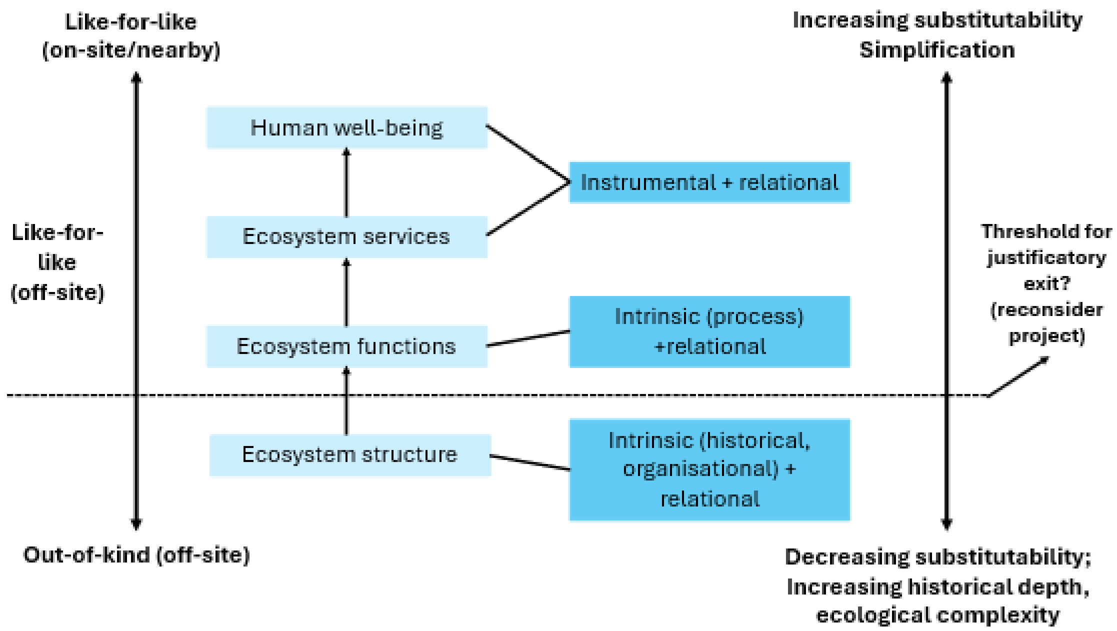

Figure 1: Plural-value scaffold linking ecological organisation, plural values of nature, and substitutability limits in biodiversity governance. The scaffold links ecosystem structure, functions, services and human wellbeing to different value dimensions. Intrinsic values attach primarily to organisms, species lineages, ecological integrity and historically constituted ecological systems; instrumental values are most closely associated with ecosystem services; and relational values may arise across the scaffold through situated human–nature relationships. The right-hand axis represents a complexity–substitutability gradient: as ecological organisation, historical continuity and place-based relations are more fully considered, credible substitution becomes more difficult. The left-hand axis represents a simplified hierarchy of compensatory responses, from like-for-like compensation on-site or nearby, to like-for-like compensation off-site, and finally to out-of-kind compensation. Moving down this hierarchy increases ecological and spatial distance between impact and compensation, thereby increasing the justificatory burden. The horizontal threshold marks the justificatory exit: a decision point at which compensatory equivalence can no longer plausibly justify harm and governance must shift from compensatory balancing toward avoidance, redesign, restraint or ethical repair.

Ecosystem functions refer to ecological processes and interactions - such as nutrient cycling, primary production, predator–prey dynamics or habitat provision - that sustain ecosystem dynamics over time (Chapin et al., 2011). These functions connect ecosystem structure to ecosystem services, but are not reducible to human-derived benefits and may also generate what Lliso et al. (2022) call “disvalues”, as in the case of zoonotic pathogens. Ecosystem services, such as food production, timber supply or climate regulation, are most readily captured through instrumental valuation. Importantly, ecosystem structure, functions, and services do not always change together: development or management may alter ecosystem structure or degrade ecological functions without immediately reducing services, while some services may be restored without recreating the original ecosystem structure (Moilanen & Kotiaho, 2018).

These distinctions matter because impacts and compensatory gains may be assessed at different levels of the scaffold. Losses evaluated at the level of ecosystem services may appear substitutable even when underlying structures, functions or ecological histories are altered. Fungibility therefore becomes an institutional decision rather than an ecological fact: governance determines whether instrumental values are treated as decisive, or whether non-instrumental values constrain substitution (Spash, 2015). Measures targeting ecosystem structure can potentially address multiple ecological and value losses, whereas interventions targeting services or wellbeing operate further removed from the ecological relations originally affected. The scaffold thus foregrounds a central question for biodiversity compensation: not only whether compensation occurs, but what exactly is being compensated, and at which level of ecological organisation equivalence is being claimed. In this sense, the plural-value scaffold can be read as a response to the reductionist framing of offsetting. Where offsetting tends to translate ecological relations into comparable units, the scaffold asks which level of ecological organisation is affected, which value dimensions are implicated, and whether the proposed compensatory response addresses the same kind of loss. It therefore resists the move from ecological complexity to exchangeable accounting units.

The scaffold also reflects a complexity–substitutability gradient that extends the trade-off identified in the preceding chapter between ecological realism and methodological tractability. As biodiversity is represented through simplified functional or service indicators, losses appear more readily exchangeable, but such representations capture only part of the ecological relations at stake (Wauchope et al., 2024). As governance incorporates higher levels of ecological organisation - including multiple interactions, emergent processes, historical continuity and non-linear dynamics - substitutability declines (Calvet et al., 2015). This creates a structural tension for No Net Loss governance: the more comprehensively biodiversity is represented, the harder it becomes to identify credible equivalents for loss, and the less defensible substitution claims become (Droste et al., 2022).

3.2 Governing compensation under value pluralism

The scaffold can be operationalised through two analytical steps. The first assesses how impacts propagate across ecological organisation. This depends on how ecological loss is defined in practice, including the level of organisation recognised in baseline descriptions (Aide, 2024). Pressures affecting ecosystem structure - such as habitat deterioration, degradation or loss - can propagate through connected ecological functions and, in some cases, ecosystem services, because they alter the substrate on which ecological relations depend. Even where services do not decline immediately, such impacts may erode the ecological conditions on which future functions and services depend, and become especially difficult to substitute where they involve historically continuous systems, ecological integrity, species lineages or ecological communities whose continuity is disrupted. Potential responses can likewise intervene at different levels, from service-oriented or engineered measures to structure-oriented restoration, connectivity enhancement or ecological reconstruction (Lee & Nepf, 2024).

The second step concerns the selection and ordering of compensatory responses under substitutability constraints. Responses can be arranged along a gradient from like-for-like measures implemented on-site or nearby, to like-for-like measures implemented off-site, and finally to out-of-kind measures that permit substitution across different ecological attributes. This gradient matters because increasing spatial or ecological distance places greater justificatory weight on assumptions of substitutability.

Where non-instrumental values are implicated, like-for-like, structure-oriented measures come closest among compensatory responses to addressing the kind of loss incurred. Even then, they do not restore moral equivalence: the destruction of particular organisms, ecological constellations or historically continuous systems remains irreversible. Such measures are therefore better understood as forms of repair and re-enablement under conditions of irreversibility than as full replacement.

Where like-for-like measures cannot be implemented at or near the affected site, spatially flexible compensation may sometimes improve ecological outcomes, for example through landscape-scale planning or connectivity (Kiesecker et al., 2010; Habib et al., 2013). Yet spatial displacement can increase the justificatory burden where relational values are involved, because ecological meanings, place attachment and human–nature relationships may not be transferable between locations (Hanski, 1998). It may also separate those who bear the loss from those who receive the benefits of compensation (Bull et al., 2015; Tupala et al., 2022). Participation is essential, but cannot by itself justify treating intrinsic or historically grounded values as fungible.

Out-of-kind measures intensify these difficulties. Because they provide different ecological attributes, often higher in the scaffold, they rely on stronger assumptions of substitutability and cannot plausibly answer for non-instrumental losses. Compensation type should therefore be understood as an ethical indicator of the extent to which governance relies on substitution: the more spatially displaced or ecologically dissimilar the response, the more it departs from the values originally affected.

Governance may seek to reduce these problems through supporting measures such as habitat multipliers, expanded restoration obligations, financial contributions or combinations of compensatory actions (Wauchope et al., 2024; Ghijselinck et al., 2026). Such measures may reduce ecological shortfall, but they remain embedded within a substitutive logic and cannot establish replacement where the values at stake are non-substitutable.

4. Ethical restraint beyond substitution

4.1 Restraint and the limits of substitution in practice

The analysis in Section 3 places a limit on compensatory reasoning: as ecological complexity and plural values are more fully recognised, credible substitution becomes increasingly difficult to establish. Beyond this point, No Net Loss may remain a useful accounting objective, yet compensatory equivalence becomes an increasingly fragile basis for justifying biodiversity loss. The governance question therefore shifts from how compensation should be designed to when avoidance, redesign, refusal, or other forms of restraint are required. The argument developed here therefore asks a further question: when should governance refuse to construct fungibility at all? The justificatory exit gives institutional expression to that question by identifying cases in which even a well-designed compensatory arrangement cannot provide an adequate basis for authorising loss.

This need for restraint is reinforced in practice by weaknesses in substitution-based governance. Empirical literature repeatedly documents uncertainty, implementation failure, weak enforcement, temporal delays and incomplete recovery in offsetting systems (Ghijselinck et al., 2026). These shortcomings reveal a tension between the conditions required for defensible substitution and the simplified metrics, flexible exchange rules and limited scrutiny that often make offsetting operationally feasible (Walker et al., 2009; Salzman & Ruhl, 2019). In practice, this can privilege fungibility over ecological integrity, allowing development to proceed under the appearance of equivalence while residual loss persists (Ghijselinck et al., 2026).

From a plural-value perspective, this tension is normative as well as administrative. Improved metrics, stricter multipliers or stronger monitoring may reduce some ecological risks, but they cannot by themselves establish moral equivalence where the values at stake are non-substitutable. In such contexts, reliance on compensatory equivalence risks obscuring residual loss and weakening the basis for more precautionary responses (Ives & Bekessy, 2015).

Recognising these limits requires governance to articulate substitutability constraints and to prioritise restraint where equivalence cannot be meaningfully sustained (Landres, 2004). Governance should not merely rank compensation options; it should also define thresholds of non-substitutability and institutional triggers for avoidance, refusal or project redesign. At these limits, the mitigation hierarchy cannot coherently culminate in compensation. It instead requires a justificatory exit from substitution, through which decision-makers reconsider the underlying project rather than treating offsetting as the default response to residual loss.

This does not eliminate trade-offs from conservation governance. Many situations remain constrained, involving conflicts between legitimate moral and practical considerations (Marcus, 1980; Gowans, 1987; Batavia et al., 2020). The point is rather that trade-offs should be made with conceptual clarity about what cannot be replaced and with institutional restraint proportionate to that recognition. Restraint should therefore be understood not as an absolute prohibition, but as a condition of responsible action where ecological harm risks foreclosing irreplaceable values (Kelly & Landres, 2023). It also signals an attitudinal shift away from treating nature as a set of compensable units and toward care, humility and attentiveness to the goods of other beings (O'Neill, 1992).

4.2 Ethical repair under conditions of irreversibility

Even where governance recognises the justificatory limits of substitution, ecological harm cannot always be avoided. Legitimate human development, including objectives such as the transition to renewable energy, may itself entail adverse biodiversity impacts (Maron et al., 2025). The question is therefore how post-impact action should be understood once substitution is ethically hard to defend.

Post-impact responses are best understood not as compensation, but as forms of ethical repair. Such repair acknowledges that harm has occurred and affirms an ongoing responsibility to address that harm as far as ecologically and practically possible, without claiming equivalence between loss and gain (Almassi, 2017). Recognition of non-substitutability therefore does not weaken the responsibility to pursue recovery where recovery remains possible. Rather, it distinguishes that responsibility from the stronger claim that subsequent gains can counterbalance, replace, or erase what has been lost. Where ecological complexity and plural values are at stake, ecological loss may remain only partially reparable even where substantial restoration is possible. Ethical repair instead begins from recognition of this non-substitutability and asks what responsibilities remain once harm has occurred.

Restoration can constitute one important form of such repair (Oksanen, 2008; Basl, 2010). Rather than being understood as replacing what has been destroyed, it seeks to repair or re-establish the conditions under which ecological processes, relationships, and forms of self-organisation can develop (Callicott, 2002; Carver et al., 2021; Jørgensen, 2015). Within a plural-value perspective, this may involve not only restoring ecological functions or associated benefits, but also supporting the recovery, where possible, of ecologically and morally significant relationships and conditions in which organisms and ecological communities can flourish (Sylvan, 1998). Repair may also need to remain attentive to the histories and relationships through which places have acquired ecological and relational significance, responding to their trajectories rather than treating damaged places as blank canvases (O'Neill, Holland & Light, 2008; Hourdequin, 2013). Attention to ecological history need not imply attempting to recreate a fixed historical state; rather, historical trajectories can provide context for determining what forms of recovery are fitting without prescribing a fixed endpoint for future ecological change (Sylvan, 1998; Almassi, 2017; May, 2019).

The ethical significance of restoration lies not only in the ecological improvements it may achieve, but also in sustaining responsibility towards damaged ecological systems even where complete recovery is impossible. In this sense, repair calls for care and humility[1], supporting renewed ecological possibilities without presuming complete control over ecological trajectories (Hargrove, 1989; Almassi, 2017). Ethical repair is therefore better understood as an ongoing process than as an endpoint at which ecological harm has been made good (Basl, 2010).

Ethical repair does not displace avoidance. The same orientation of responsibility, care and humility that calls for repair after harm also supports restraint where anticipated losses are irreversible or their substitutability doubtful (Mills, 1996; Sylvan, 1998).

Ethical repair also requires institutional expression. Developers may discharge formal compensatory obligations without thereby adopting an orientation of acknowledgement, care or humility, and governance cannot depend on individual actors possessing particular environmental virtues. Responsibilities must instead be translated into enforceable rules, obligations, monitoring and other forms of control (Primmer et al., 2019). Such arrangements should preserve the priority of avoidance, recognise limits to substitution, and ensure that restorative obligations respond meaningfully to harm without presuming that their fulfilment makes that harm good.

Contribution-based approaches provide one possible analogue to this distinction because they support conservation or restoration without claiming that gains offset a

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[1] Throop (2012), for example, characterises humility, self-restraint, sensitivity, and respect as virtues of good restoration. Drawing on the metaphor of healing, he emphasises attentiveness to the particularities of the damaged ecological system and its relationships with surrounding systems.

corresponding loss (Blanchard et al., 2024; Wauchope et al., 2024). Decoupling ecological improvement from an offsetting claim avoids presenting that improvement as replacement, although it must not weaken the relationship between the magnitude of harm and the responsibility incurred (Maron et al., 2024, 2025). Rejecting substitution therefore does not entail abandoning ecological assessment or quantification: ecological gains can remain rigorously assessed while more modest claims are made about what those gains accomplish.

From the perspective of ethical repair, this distinction is crucial. Quantification may help specify and enforce responsibilities arising from ecological harm without thereby justifying the harm itself. Where compensation is required, demanding equivalence requirements can retain an important accountability function by helping to calibrate the required response to the magnitude and character of the harm (Maron et al., 2025). This does not mean that satisfying those requirements establishes legitimate substitution.

The appropriate response to the limits of substitution is therefore neither to abandon efforts to improve ecological representation nor to assume that better representation can resolve those limits. Rather, demanding ecological assessment must be combined with stronger safeguards around avoidance and acceptable loss (Pope et al., 2021), while post-impact obligations are understood as responsibilities for repair rather than as proof that the original loss has been made good (Sylvan, 1998; Basl, 2010).

5. Beyond substitution

This paper has argued that substitution-based conservation encounters fundamental limits under value pluralism and ecological complexity. The plural-value scaffold shows why substitution becomes less defensible as historically constituted, ecologically complex and place-bound values are more fully recognised.

Recognising these limits requires thresholds beyond which substitution no longer provides adequate justification. The justificatory exit marks such a threshold, requiring decision-makers to reconsider projects whose impacts threaten non-substitutable ecological values.

A central implication is that residual loss is not merely an implementation failure within substitution-based systems, but often a structural outcome. Substitution depends on two reductions: plural environmental values are narrowed to measurable benefits, and complex ecological systems are simplified into exchangeable indicators. What is balanced is therefore not biodiversity loss in its full ecological and normative significance, but a simplified proxy of what has been selected for measurement.

Conservation governance therefore requires more than better metrics. It requires stronger avoidance and restraint where loss cannot be justified, alongside responsibility for repair where harm nevertheless occurs. Such repair should respond meaningfully to ecological loss without presuming that subsequent gains replace what was lost. A conservation framework attentive to value pluralism must therefore recognise both the limits of substitution and the responsibilities that remain beyond them.

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Conflicts of interest

None

Ethical standards

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Data availability

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