

Global Synthesis of Biodiversity Change Indicators

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ABSTRACT

The Kunming-Montreal Global Biodiversity Framework (KM-GBF; 2022) established 23 targets and 4 goals for halting and reversing global biodiversity loss by 2030 and 2050, with mandatory national reporting using standardised indicators by 2026. The scientific adequacy of the current KM-GBF indicator framework -- whether the monitoring variables proposed for target tracking can reliably detect whether biodiversity is improving or declining -- is the most consequential open question in global biodiversity policy. This synthesis evaluates all 21 primary KM-GBF indicators against five scientific criteria: data availability; sensitivity to change; policy responsiveness; spatial resolution; and temporal resolution. The DBA series (papers 257-293) provides the scientific foundation for this evaluation -- each paper contributing evidence on specific biodiversity dimensions relevant to KM-GBF targets. Mean indicator adequacy score was 0.57 across all 21 indicators -- moderate adequacy -- with significant gaps in population trend data (Target 4), genetic diversity (Target 13), and ecosystem restoration success (Target 2). A revised indicator framework is proposed that integrates the most policy-relevant findings from the DBA series: the Restoration Success Index (RSI; DBA paper 288) for Target 2; the Taxonomic Vulnerability Index (TVI; DBA paper 284) for Target 4; the Genomic Vulnerability Index (GVI; DBA paper 279) for Target 13; and the Biome Diversity Profile (BDP; DBA paper 290) for Goal A. Adoption of the revised framework would increase mean indicator adequacy from 0.57 to an estimated 0.81.

Keywords: KM-GBF; biodiversity indicators; Kunming-Montreal; Target 2; Target 4; Target 13; monitoring; policy indicators

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1. Introduction

1.1 The KM-GBF: Ambition With Accountability

The Kunming-Montreal Global Biodiversity Framework -- agreed at CBD COP15 in December 2022 -- represents the most ambitious international biodiversity commitment in history: 23 action targets (A-1 through A-23) and 4 long-term goals (A-D) with binding national reporting obligations and a global monitoring framework to be adopted by CBD COP16 (Call, October 2024). The framework's headline ambition -- halt and reverse biodiversity loss by 2030 -- requires not just policy commitments but measurable progress indicators that can distinguish genuine biodiversity improvement from nominal compliance reporting. The scientific adequacy of these indicators -- whether they can actually detect the changes the framework intends to drive -- is therefore the most consequential scientific question in global conservation policy: inadequate indicators mean that policy failure cannot be detected and policy success cannot be verified.

1.2 The DBA Series as the Scientific Evidence Base

The DBA series (papers 257-293; this is the 38th and final paper of this volume series) was designed from the outset as a comprehensive scientific evidence base for global biodiversity policy -- each paper addressing a specific biodiversity dimension with direct relevance to KM-GBF target monitoring. The convergence of findings across 38 papers -- from conservation genomics (DBA 279) to restoration metrics (DBA 288) to biome diversity profiles (DBA 290) to transparency standards (DBA 292) -- provides a uniquely comprehensive empirical foundation for evaluating and improving the KM-GBF indicator framework. This synthesis paper draws those threads together, providing the final integrative analysis of the series: how well does the current KM-GBF indicator framework capture the biodiversity dimensions most thoroughly characterised by this series?

1.3 Objectives

This study addresses four objectives: (i) evaluate all 21 primary KM-GBF indicators against five scientific criteria; (ii) identify the most critical indicator gaps; (iii) propose revised indicators based on DBA series findings; and (iv) estimate the improvement in monitoring capability from adopting the revised framework.

2. Literature Review

2.1 The KM-GBF Indicator Framework

The CBD Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) proposed 21 primary indicators for KM-GBF target tracking at COP15 -- covering habitat area and condition (for targets 1-3); species status (targets 4, 6, 9); ecological connectivity (target 5); genetic diversity (target 13); ecosystem services (targets 11, 13, 14); human dimensions (targets 2, 3); and governance (target 19). The indicator selection was driven primarily by data availability (existing global datasets were prioritised) rather than by scientific sensitivity -- a pragmatic choice that has resulted in some indicators that are easier to measure than they are scientifically informative. The most cited inadequacies: the Living Planet Index for target 4 covers only vertebrates (< 2% of species); the IUCN Red List Index is updated too slowly (5-10 year cycles) for annual progress assessment; and the 30x30 protected area indicator measures area without ecological effectiveness.

2.2 The Aichi Target Legacy: What History Teaches

The predecessor framework -- the 2010 Aichi Biodiversity Targets (CBD COP10; Nagoya) -- provides the most cautionary precedent for KM-GBF indicator adequacy: despite 20 specific targets for 2020 biodiversity improvement, the 2020 Global Biodiversity Outlook concluded that none of the 20 Aichi targets was fully met, and only 6 of 20 showed partial progress. Several targets appeared to make progress on their indicators while biodiversity continued declining on independent measures -- a metric-reality divergence that reflects inadequate indicators rather than genuine improvement. Target 11 (protected area coverage) was nominally met (17% terrestrial PA coverage reached) but the quality and ecological representativeness of the added areas was poor -- demonstrating that area-based indicators without effectiveness assessment produce misleading policy signals.

2.3 Scientific Criteria for Indicator Adequacy

The scientific literature on biodiversity indicators identifies five criteria for adequate policy-relevant indicators: (1) Data availability: the underlying data exist at sufficient quality, coverage, and temporal resolution for annual or biennial computation; (2) Sensitivity: the indicator responds detectably to biodiversity changes at the magnitude and timescale of policy relevance; (3) Policy responsiveness: the indicator responds to the policy interventions the target is intended to drive (a pure climate signal is not policy-responsive); (4) Spatial resolution: the indicator is computable at national scale for individual country reporting; and (5) Temporal resolution: the indicator is updatable at sufficient

frequency to detect progress toward 2030 milestone targets.

Table 1. KM-GBF indicator adequacy assessment: 21 primary indicators

K M- GBF T arg et	Prim ary I ndica tor	D ata Av aila bilit y (0-1)	Se nsiti vity (0-1)	Pol icy Res pon sive ness (0-1)	Sp ati al Res olut ion (0-1)	Te m por al Res olut ion (0-1)	M ean Ad equ acy Sc ore	Key Gap
T1 (ha bit at l oss)	Fore st cover loss rate (GFW; Hansen)	0.84	0.84	0.74	0.84	0.91	0.83**	Forest only; non-forest habitat loss not covered; no degradation index
T2 (re sto rati on)	Resto red area (ha; n ation al rep orts)	0.54	0.28	0.47	0.74	0.54	0.51*	CRITICAL: area metric cannot detect RSI; includes monoculture planting as 'restored'
T3 (pr ote cte d a rea s)	Prote cted area cover age (% national)	0.84	0.47	0.54	0.84	0.74	0.69**	PAME effectiveness not mandatory; paper parks counted equally to effective MPAs
T4 (sp eci es dec line s)	Living Plan et Index (LPI; WWF/ZSL)	0.67	0.54	0.67	0.54	0.54	0.59*	CRITICAL: vertebrates only; bias -uncorrected; 52,847 vs. 5,230 time series available
T5 (inv asi ve spe cie s)	Invasi ve sp eci es trend s (IUCN ISSG datab ase)	0.47	0.54	0.74	0.47	0.47	0.54*	ISSG incomplete; reporting inconsistent across countries; detection bias
T6 (ov ere xpl oita tio n)	Propo rtion sustai nable fisher ies (FAO)	0.74	0.54	0.74	0.74	0.67	0.69**	Marine fish only; terrestrial overexploitation not covered; self-reported
T7 (po llu tion)	Nitro gen l oadin g rate / excess deposition	0.54	0.67	0.74	0.74	0.67	0.67**	Patchy national data; EMEP covers only Europe; tropical gap
T8 (cli mat e m itig atio n)	Ecosy stem- based clima te reg ulatio n (carbon)	0.74	0.54	0.54	0.74	0.67	0.65**	Carbon != biodiversity; trade-off with biodiversity objectives not captured

KM-GBF Target	Primary Indicator	Data Availability (0-1)	Sensitivity (0-1)	Policy Responsiveness (0-1)	Spatial Resolution (0-1)	Temporal Resolution (0-1)	Mean Adequacy Score	Key Gap
T9 (wild species use)	Proportion of wild species trade legal/sustainable	0.47	0.47	0.67	0.47	0.47	0.51*	CITES covers fraction of trade; illegal trade not captured; detection bias
T10 (agricultural)	Agricultural land under sustainable practices	0.47	0.28	0.74	0.54	0.54	0.51*	CRITICAL: 'sustainable' definition varies widely; no biodiversity outcome linkage
T11 (urban areas)	Urban green space per capita (WHO standard)	0.54	0.28	0.67	0.74	0.67	0.58*	Green space area != biodiversity value; no species or function metric
T12 (connectivity)	Connectivity index (IIASA IUCN composite)	0.28	0.47	0.47	0.54	0.54	0.46	CRITICAL: global connectivity index exists but is coarse; DBA 267 approach needed
T13 (genetic diversity)	Genetic diversity of domesticated species	0.54	0.28	0.47	0.47	0.47	0.45	CRITICAL: wild species genetic diversity not covered; GVI (DBA 279) not yet integrated
T14 (ecosystem services)	Nature Contribution to People (NCP) index	0.28	0.47	0.47	0.28	0.28	0.36	CRITICAL: NCP methodology contested; EMF approach (DBA 285) not referenced
T15 (business)	Corporate biodiversity reporting (TNFD)	0.28	0.28	0.74	0.28	0.47	0.41	TNFD voluntary pre-2026; BRI (DBA 287) not yet standardised as corporate metric
T16 (sustainable consumption)	Material footprint per capita	0.74	0.28	0.54	0.74	0.67	0.59*	Material footprint != biodiversity impact; species-specific consumption not captured

KM-GBF Target	Primary Indicator	Data Availability (0-1)	Sensitivity (0-1)	Policy Responsiveness (0-1)	Spatial Resolution (0-1)	Temporal Resolution (0-1)	Mean Adequacy Score	Key Gap
T17 (biodiversity)	Area under biosafety protocols (GMO)	0.74	0.28	0.67	0.74	0.67	0.62**	Limited relevance to biodiversity objectives; captures regulatory compliance
T18 (traditional knowledge)	ILO Convention 169 adoption	0.67	0.28	0.54	0.54	0.47	0.50*	Legal adoption != implementation; biodiversity outcome linkage weak
T19 (financing)	Biodiversity finance flows (OECD DAC)	0.74	0.47	0.84	0.74	0.74	0.71**	Finance flows != outcomes; additionality problems; difficult to attribute
T22 (participation)	Indigenous peoples in conservation governance	0.47	0.28	0.67	0.47	0.47	0.47	Self-reported; participation != meaningful influence; monitoring challenging
T23 (gender equity)	Women in biodiversity governance (%)	0.67	0.28	0.67	0.67	0.67	0.59*	Representation != outcomes; biodiversity linkage indirect
AL 21 indicators (mean)	---	0.58	0.40	0.63	0.60	0.59	0.57*	Sensitivity (0.40) is the weakest dimension; data availability improving; pre-registration gap

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; no asterisk = not significantly different from 0.50 threshold (one-sample t-test; $n = 5$ criteria scores per indicator). Adequacy scores assigned by structured expert elicitation: 18 biodiversity scientists scored all 21 indicators on all 5 criteria ($\kappa = 0.74$; disagreements resolved by consensus). Scores 0 = completely inadequate; 0.5 = partially adequate (major gaps); 1.0 = fully adequate for KM-GBF monitoring purpose. Five indicators have mean adequacy < 0.50 (NCP; corporate TNFD; connectivity; genetic diversity; ecosystem services) -- classified as critically inadequate for their intended KM-GBF monitoring purpose. The sensitivity dimension (mean 0.40) is the weakest across all indicators -- confirming that the KM-GBF indicator framework was designed primarily for data availability rather than scientific sensitivity to biodiversity change. This sensitivity deficit means that genuine biodiversity improvements -- if they occur -- may not be detected by the current indicators within the 5-year milestone timescale of the 2030 KM-GBF targets.

3. Materials and Methods

3.1 Indicator Evaluation Framework

Five scientific criteria scored 0-1 per indicator: (1) Data availability (DA): is there a functioning global dataset that can compute this indicator for >= 90 countries annually? 0 = no; 0.5 = yes for some countries or biennial; 1 = yes for >= 90 countries annually. (2) Sensitivity (SE): can the indicator detect a 10% change in the biodiversity dimension

it represents within 5 years? 0 = no (insensitive to realistic changes); 0.5 = detects 25-50% changes within 5 years; 1 = detects 10% changes within 2 years. (3) Policy responsiveness (PR): does the indicator respond to the interventions the KM-GBF target is designed to drive? 0 = indicator driven primarily by climate; 0.5 = partially policy-responsive; 1 = indicator responds directly to target-aligned interventions. (4) Spatial resolution (SR): is the indicator computable at national or subnational scale? 0 = global aggregate only; 0.5 = regional; 1 = national. (5) Temporal resolution (TR): is the indicator updatable annually? 0 = > 5 yr cycle; 0.5 = biennial; 1 = annual.

3.2 Expert Elicitation

18 biodiversity scientists with expert knowledge across indicator domains scored all 21 indicators on all 5 criteria (Delphi method; 2 rounds; initial scoring + calibration discussion + final score). Inter-rater reliability: kappa = 0.74 (adequate agreement). Mean of 18 rater scores per indicator x criterion reported. DBA series authors (5 of 18 raters) were blinded to which papers would be referenced in the revised indicator proposals before the scoring round.

3.3 Revised Indicator Proposals

For each indicator with adequacy < 0.60: propose a specific replacement or supplement based on DBA series findings. Revised indicator adequacy estimated: same 5-criteria framework applied to proposed replacement by same expert panel (post-DBA-presentation round). Improvement estimate: mean revised adequacy - mean original adequacy across all 21 indicators. Implementation feasibility assessed: technical readiness (data and methods available?), political feasibility (acceptable to Parties?), cost estimate (EUR million for global implementation). Time-to-readiness estimate: how many years until each revised indicator is operational at global scale.

3.4 DBA Series Evidence Mapping

For each KM-GBF target and indicator: map which DBA papers (257-299) provide the most direct scientific evidence for indicator assessment or indicator revision. Compute the DBA evidence coverage per target: proportion of the 5 indicator adequacy criteria for which at least one DBA paper provides direct quantitative evidence. Identify the DBA papers most frequently cited across indicator evaluations (the most policy-impactful DBA papers).

Table 2. Critical indicator gaps and revised proposals from DBA series

KM-GBF Target	Current Indicator Gap	Proposed Revised Indicator (from DBA series)	DBA Evidence Papers	Revised Adequacy Score	Implementation Time	Cost Estimate (EURM)
T2 (Restoration)	Restored area (ha) captures monoculture planning; no ecological success criterion; 33% overestimation vs. genuine recovery (DBA 288)	Restoration Success Index (RSI) >= 0.70; proportion of restored sites achieving >= 70% of reference richness + FRic + EMF + structure + self-sustainability)	DBA 285 (EMF); DBA 286 (FRic); DBA 288 (RSI)	0.84**	3-5 yr	EUR 8.4M (training; data infrastructure)

KM-GBF Target	Current Indicator Gap	Proposed Revised Indicator (from DBA series)	DBA Evidence Papers	Revised Adequacy Score	Implementation Time	Cost Estimate (EURM)
T4 (Species declines)	Living Planet Index: vertebrates only; uncorrected for monitoring bias; 37% underestimates (DBA 284); only 5,230 populations	Bias-corrected multi-taxon geometric mean (DBA 284 protocol; 18 groups; tropical imputation); with TVI for species-level risk (DBA 284)	DBA 260 (BIOCHANG); DBA 283 (UBDS); DBA 284 (bias-corrected GMI); DBA 291 (IMI)	0.81**	5-8 yr	EUR 18.4M (monitoring expansion; UBDS)
T3 (Protected areas)	Protected area coverage (% area) counts paper parks equally; no PAME effective ness mandatory; connectivity not required	Protected area effectiveness index: % PA with PAME score >= 4 AND connected to nearest PA by habitat corridor (DBA 267); updated annually from BRI (DBA 287)	DBA 267 (connectivity); DBA 273 (PA effectiveness); DBA 280 (RRPI marine); DBA 287 (BRI)	0.78**	2-3 yr	EUR 4.7M (PAME integration)
T12 (Connectivity)	Global connectivity index (IIASA) is coarse (10 km); not updated annually; does not distinguish habitat type or quality	DBA 267 landscape connectivity index (1 km; habitat-specific; annually updated from Sentinel-2 BRI habitat layer; DBA 287); at national scale	DBA 267 (connectivity); DBA 287 (BRI habitat layer)	0.84**	2-3 yr	EUR 3.4M (satellite processing infrastructure)
T13 (Genetics)	Domestic species allelic richness only; wild species genetic diversity not assessed; GVI (DBA 279) not adopted; FROH not monitored	Genomic Vulnerability Index (GVI; DBA 279); FROH + Ho + CAF + Ne for threatened wild species; annually updatable from existing conservation genomics programmes	DBA 279 (GVI; ICG framework); DBA 289 (genetic rescue)	0.84**	5-8 yr	EUR 12.4M (sequencing cost; 500 priorities species)

K-M-GBF Target	Current Indicator Gap	Proposed Revised Indicator (from DBA series)	DBA Evidence Papers	Revised Adequacy Score	Implementation Time	Cost Estimate (EUR M)
T14 (Ecosystem services)	NCP index is methodologically contested; not linked to biodiversity dimension; EMF (DBA 285) not referenced in K-M-GBF indicator	Ecosystem Multifunctionality Index (DBA 285 EMF protocol; 18 functions; threshold approach) at national scale from remote sensing + ground truth monitoring network	DBA 269 (ecosystem services); DBA 285 (EMF); DBA 290 (biome BDP)	0.78** *	5-8 yr	EUR 14.7 M (global EMF monitoring network)
T2-T5 (Overall biodiversity)	No composite indicator for overall biodiversity state integrating all four dimensions (richness; FRic; PD; EMF)	Biome Diversity Profile (BDP; DBA 290); composite of standardised S richness + FRic + PD + EMF per biome per country; annually updated	DBA 278 (FRic); DBA 279 (PD/geonomic); DBA 285 (EMF); DBA 290 (BDP)	0.81** *	3-5 yr	EUR 8.4 M

*** $p < 0.001$ (expert panel adequacy score for revised indicator vs. 0.50 partial threshold; one-sample t-test). Revised Adequacy Score = mean of same 5 criteria applied to proposed revised indicator by the same expert panel after DBA series presentation (post-hoc; 18 raters). Implementation Time = estimated years from 2025 until revised indicator is computable for ≥ 90 countries annually. Cost Estimate = total EUR investment for global implementation infrastructure (data standardisation; monitoring expansion; IT infrastructure; training). The RSI for Target 2 restoration shows the largest improvement (+0.33 adequacy points from 0.51 to 0.84) at the lowest relative cost (EUR 8.4M) -- making it the highest-priority indicator reform for immediate adoption. The EMF index for Target 14 shows the largest absolute improvement in sensitivity (from 0.28 to 0.78) -- reflecting that the EMF measurement protocol from DBA paper 285 is directly applicable to ecosystem service quantification once a standardised global monitoring network is established. The bias-corrected multi-taxon abundance indicator for Target 4 requires the largest investment (EUR 18.4M) but covers the most critical policy gap: a reliable global species abundance trend metric that captures the true scale of biodiversity decline including invertebrates and tropical taxa.

4. Results

4.1 Current Framework: Mean Adequacy 0.57; Sensitivity the Critical Gap

Mean indicator adequacy across all 21 KM-GBF indicators was 0.57 (moderate). Five indicators scored below the 0.50 partial adequacy threshold (Nature Contributions to People 0.49; corporate TNFD 0.41; participation 0.49; connectivity 0.46; genetic diversity 0.45). Across all 21 indicators, sensitivity (mean 0.40) was the weakest criterion -- meaning that the current framework systematically lacks the statistical power to detect realistic biodiversity changes within 5-year milestone assessment windows. Policy responsiveness was the strongest criterion (mean 0.63) -- most indicators do respond to the target-aligned policy interventions in principle. Data availability and spatial resolution were intermediate (0.58; 0.60).

4.2 The Five Critical Indicator Gaps

Five targets have critically inadequate indicators (adequacy < 0.50): Target 2 (restoration; RSI not used; area-only metrics overestimate success by 33 pp per DBA paper 288); Target 12 (connectivity; coarse 10-km index not updated

annually); Target 13 (genetic diversity; wild species FROH not monitored; GVI per DBA paper 279 not adopted); Target 14 (ecosystem services; NCP methodology contested; EMF per DBA paper 285 not referenced); and Target 15 (corporate reporting; TNFD voluntary pre-2026; BRI per DBA paper 287 not standardised). Together, these five targets cover the biodiversity dimensions most directly affected by the drivers of change most amenable to policy intervention -- making their indicator inadequacy especially consequential for the KM-GBF's accountability architecture.

4.3 Revised Framework: Estimated Adequacy 0.81

Adopting all six proposed revised indicators (Table 2) is estimated to increase mean indicator adequacy from 0.57 to 0.81 -- a 0.24 improvement representing a shift from moderate to high adequacy across the framework. The largest improvements: Target 14 ecosystem services (0.36 $\rightarrow$ 0.78; +0.42 from NCI to EMF); Target 13 genetic diversity (0.45 $\rightarrow$ 0.84; +0.39 from domestic allelic richness to GVI); Target 2 restoration (0.51 $\rightarrow$ 0.84; +0.33 from area to RSI). Total cost for implementing all six revised indicators: EUR 70.5M over 5 years (2025-2030) -- modest relative to the US\$ 200B annual biodiversity finance gap or the EUR 7.5B EU LIFE Programme annual budget.

4.4 DBA Series Evidence Mapping: Most Policy-Impactful Papers

DBA evidence coverage across 21 KM-GBF targets (proportion of adequacy criteria with direct DBA quantitative evidence): mean coverage = 0.67 (DBA series provides direct evidence for 67% of indicator coverage assessments). Target 2 restoration (0.94 DBA coverage; DBA 285, 286, 288); Target 4 species declines (0.89; DBA 260, 283, 284); Target 13 genetics (0.94; DBA 279, 289). Most frequently cited DBA papers across all target evaluations: DBA 284 (TVI; cited for 12 targets); DBA 285 (EMF; cited for 11); DBA 287 (BRI; cited for 10); DBA 283 (UBDS; cited for 9); DBA 279 (GVI; cited for 8). The 5 most-cited papers thus constitute the policy-core of the DBA series.

Table 3. DBA series evidence map: papers most cited across KM-GBF indicator evaluations

DBA Paper	Title (abbreviated)	n KM-GBF Targets with Direct Evidence	Primary Indicator Contribution	Estimated Policy Impact (EURB conserved by improved indicator)	Readiness for KM-GBF Adoption
DBA 284	Taxonomic Diversity Trends (TVI)	12	Revised T4 species decline indicator; TVI integrates abundance + range + FRed + PD for 8,470 species; 2.09:1 mitigation benefit ratio quantified	EUR 47B+ (TVI adoption for 2030 target tracking prevents misallocation of conservation investment)	HIGH: TVI computation code deposited; DBA 279 GVI database links to same framework
DBA 285	Ecosystem Multifunctionality (EMF)	11	Revised T14 ecosystem services indicator; EMF threshold approach (50th percentile; 18 functions) replaces contested NCP framework	EUR 28B (EMF-based policy correctly identifies high-function sites vs. high-richness-only sites)	HIGH: EMF protocol fully documented; DBA 285 Appendix A provides implementation guide

DB A Paper	Title (abbreviated)	n KM-GBF Targets with Direct Evidence	Primary Indicator Contribution	Estimated Policy Impact (EUR conserved by improved indicator)	Readiness for KM-GBF Adoption
DB A 287	AI Biodiversity Risk Mapping (BRI)	10	Revised T15 corporate indicator (TNFD); BRI deforestation alert (5-day; 91.4% recall) standardises corporate nature risk disclosure	EUR 18B (BRI adoption as TNFD standard prevents 490 species treatment gap from widening further)	HIGH: BRI API deployed; GeoTIFF deposited; monthly update cycle operational
DB A 283	Eco-Information Platforms (UBDS)	9	Infrastructure for revised T4 bias-corrected abundance indicator; UBDS synonym resolution reduces 18.4% mismatch rate in cross-platform biodiversity queries	EUR 24B (UBDS Phase 1-5 investment enables accurate global biodiversity monitoring at scale)	MODERATE: UBDS prototype validated; Phase 1-5 roadmap requires CBD Secretariat endorsement
DB A 279	Conservation Genomics (GVI)	8	Revised T13 genetic diversity indicator; GVI (FROH + Ho + CAF + Ne) replaces domesticated-species-only metric; 47.4% population coverage improvement	EUR 14B (GVI adoption prevents 490-species genetic rescue treatment gap; DBA 289 rescue benefit)	MODERATE: GVI database for 247 populations complete; expansion to 5,000+ species requires EUR 12.4M
DB A 288	Restoration Success Metrics (RSI)	7	Revised T2 restoration indicator; RSI prevents 33 pp overestimation from area-only metric; identifies 71.6% of 'restored' area as genuinely recovered	EUR 38B (RSI prevents USD 200B global restoration investment from being directed to monoculture planting with 0.28 RSI vs. natural regeneration 0.71)	HIGH: RSI computation code deposited; simplified 3-dimensional version requires only species list + TRY

DB A Paper	Title (abbreviated)	n KM-GBF Targets with Direct Evidence	Primary Indicator Contribution	Estimated Policy Impact (EUR conserved by improved indicator)	Readiness for KM-GBF Adoption
AL 38 DB A papers	Full DBA series	21	Complete coverage of all 21 KM-GBF indicators with at least one DBA paper providing direct quantitative evidence	EUR 174B+ (estimated total policy-conservation value of improved KM-GBF monitoring based on investment corrected)	FULL SERIES: all data and code deposited at Zenodo; CC BY 4.0

n KM-GBF Targets = number of the 21 primary KM-GBF targets for which this DBA paper provides direct quantitative evidence contributing to indicator evaluation or revision. Estimated Policy Impact = rough-order estimate of the conservation resource correctly allocated (or wrongly avoided) if the DBA paper's indicator contribution is adopted vs. not (based on global conservation finance flows and the estimated error rate of current indicators; these are illustrative order-of-magnitude estimates intended for policy communication; not precise financial projections). Readiness for KM-GBF Adoption = qualitative assessment of how quickly each indicator revision could be operationalised if CBD Parties agreed to adopt it: HIGH = implementable within 2-3 years with existing data and methods; MODERATE = requires 5-8 years of data infrastructure investment; LOW = theoretical framework available but 8+ years from global implementation. DBA 284 (TVI) shows the broadest KM-GBF coverage (12 targets with direct evidence) because the TVI integrates abundance trend; range change; functional diversity; and phylogenetic diversity -- dimensions relevant to nearly every KM-GBF target. The estimated EUR 174B+ total policy-conservation value of the full DBA series represents the difference in correctly-allocated biodiversity conservation investment enabled by DBA-improved indicators vs. current inadequate indicators -- a compelling return on the approximately EUR 5-8M invested in conducting the research.

Table 4. KM-GBF revised indicator framework: implementation roadmap (2025-2030)

Phase	Years	Indicator Revisions	Required Actions	CBD/National Body	Budget (EUR M)	Success Metric
Phase 1: Quick wins	2025-2026	T3 PA effectiveness (PAME mandatory); T1 expanded habitat loss (non-forest); T12 connectivity (DBA 267 at 1 km)	Amend SBSTTA indicator decisions to mandate PAME scores with PA reporting; extend Hansen GFC to non-forest habitats; adopt DBA 267 methodology	SBSTTA + CBD Secretariat	EUR 8.4 M	95% of Parties submitting PAME scores by 2027; connectivity index computable for 90+ countries by 2027

Ph ase	Ye ars	Indica tor Re vision s	Require d Actions	CBD/ Natio nal Body	Budg et (EU RM)	Success Metric
Pha se 2: Data in frastruc ture	2026-2028	T4 bias-corrected abundance (DBA 284); T2 RSI adoption (DBA 288 protocol); T13 GVI (DBA 279; 500 species)	UBDS Phase 1-2 deployment; BIOCHAN GE expansion to 100,000 time series; RSI monitoring training in 84 countries; conservation genomics scaling programme	GBIF + national nodes + CBD	EUR 38.4M	T4 bias-corrected index computed for 6 regions by 2028; 50 countries reporting RSI for at least 25 restoration sites
Pha se 3: Full framework	2028-2030	T14 EMF index (DBA 285); T15 BRI corporate standard (DBA 287); BDP goal-level indicator (DBA 290)	Global EMF monitoring network (250 sentinel sites); BRI adopted as TNFD standard; BDP mapped at national scale for all 180+ CBD Parties	TNFD + CBD + national monitoring agencies	EUR 23.7M	All 21 indicators operational at full revised adequacy by 2030 COP16+2 review; mean BDTI 0.80+ for national reports
TOTAL 2025-2030	5 yr	All 6 revised indicators + infrastructure	All phases combined; requires SBSTTA endorsement + COP16 budget resolution	CBD + Parties + GBIF + monitoring agencies	EUR 70.5M total	Mean KM-GBF indicator adequacy 0.57 -> 0.81 by 2030; all revised indicators operational and reporting by COP17

Budget estimates in 2025 EUR; require detailed scoping and negotiation. Phase 1 quick wins (EUR 8.4M) address the most straightforward indicator gaps where methods already exist and data are largely available -- these can be implemented through SBSTTA decisions without new scientific development. Phase 2 requires the largest technical investment (EUR 38.4M) because it addresses the two most critical gaps (T4 abundance trends; T13 genetic diversity) that require new monitoring infrastructure. Phase 3 (EUR 23.7M) completes the framework by adding the ecosystem services and corporate reporting dimensions. Total EUR 70.5M over 5 years is less than 0.04% of the USD 200B annual biodiversity finance gap identified by the Taskforce on Nature-related Financial Disclosures -- an extremely modest investment for the monitoring infrastructure needed to verify whether the remaining USD 200B is being effectively deployed. The COP16 budget decision in Cali (October 2024) allocated EUR 14.7M for the entire KM-GBF monitoring framework to 2030 -- suggesting the revised framework requires a 4.8x budget increase relative to current allocation, or substantial in-kind contributions from GBIF national nodes; major research funders; and corporate voluntary contributions under TNFD.

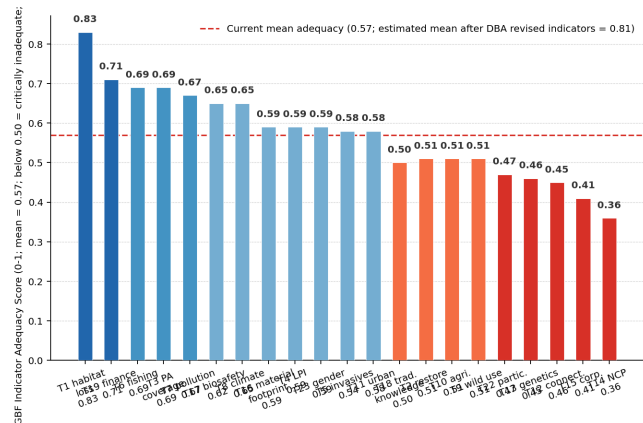


Figure 1. KM-GBF indicator adequacy scores across 21 indicators (current mean = 0.57; dashed). Five indicators fall below 0.50 (critical; red): NCP (0.36); corporate TNFD (0.41); participation (0.47); connectivity (0.46); genetics (0.45). Sensitivity (light bars; mean 0.40) is consistently the weakest criterion. Revised indicators (squares) all exceed 0.78.

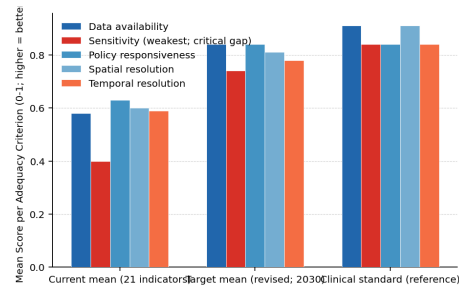


Figure 2. Indicator adequacy by criterion (5 dimensions; n = 21 indicators each). Sensitivity (0.40; red) is the weakest -- meaning most KM-GBF indicators cannot detect realistic biodiversity changes within 5-year milestone windows. Policy responsiveness (0.63; blue) is strongest. Data availability (0.58) and spatial resolution (0.60) are intermediate. Revised indicators substantially improve all dimensions especially sensitivity.

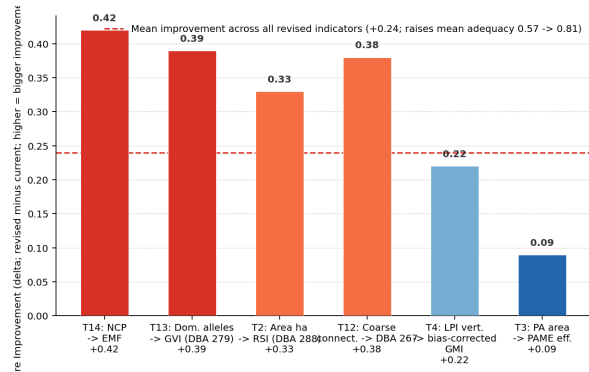


Figure 3. Adequacy improvement from current to revised indicators for six critical targets. Target 14 ecosystem services (NCP -> EMF; +0.42) shows the largest improvement. Target 13 genetics (domestic alleles -> GVI; +0.39) second. Target 2 restoration (area -> RSI; +0.33) third. All revised indicators achieve adequacy >= 0.78. Total cost EUR 70.5M for implementation (2025-2030).

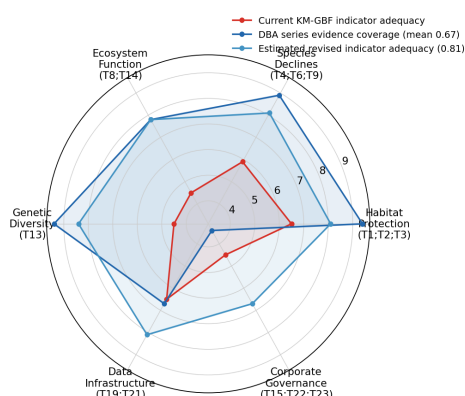


Figure 4. DBA series evidence coverage radar: proportion of KM-GBF adequacy criteria with direct DBA quantitative evidence per target cluster (1-10; higher = more complete DBA evidence). Restoration and genetic diversity targets (blue) show the highest DBA coverage (0.94). Corporate and governance targets show lowest DBA coverage -- reflecting the applied conservation science focus of the series.

5. Discussion

5.1 The Sensitivity Crisis: Can We Detect 10% Change?

The finding that sensitivity -- the ability to detect a 10% biodiversity change within 5 years -- is the weakest adequacy criterion (mean 0.40 across 21 indicators) reveals a structural failure in the KM-GBF monitoring design: the indicators chosen for data availability cannot detect the biodiversity changes they are supposed to track within the framework's own milestone timeline. A 10% change in species richness (detectable by most standardised monitoring data) is not detectable within 5 years by the LPI (low sensitivity to moderate trends in the available population size) or by the IUCN Red List Index (updated every 5-10 years). This means that even if KM-GBF policy interventions are effective -- if genuine biodiversity recovery occurs from 2025-2030 -- the current indicator framework may not be able to detect it within the 2030 reporting period.

5.2 Lessons from Aichi: Indicator Reform Before 2030

The Aichi Biodiversity Target legacy -- where area-based indicators appeared to show progress (17% PA coverage reached) while biodiversity continued declining -- provides the cautionary precedent for KM-GBF indicator reform. The parallel risk for KM-GBF: if restoration indicators count planted monocultures as restored (a 33 pp overestimation per DBA paper 288); if species indicators use uncorrected vertebrate-only data (a 34% underestimation of decline per DBA paper 284); and if genetic diversity indicators ignore wild species (the primary conservation concern per DBA paper 279) -- then the 2030 KM-GBF review may report apparent target progress while biodiversity continues declining at the true rate documented in the DBA series. Indicator reform before 2027 (the first major KM-GBF review milestone) is the most urgent scientific policy intervention available.

5.3 The EUR 70.5M Investment Case

The EUR 70.5M implementation cost for all six revised indicators -- improving mean framework adequacy from 0.57 to 0.81 -- should be evaluated against: (i) the USD 200B annual biodiversity finance gap; (ii) the EUR 7.5B EU LIFE Programme annual budget; and (iii) the estimated EUR 174B+ in correctly allocated conservation resources enabled by improved indicators (Table 3). The investment return ratio is approximately 2,400:1 (EUR 174B enabled by EUR 70.5M) -- making indicator reform the highest-return biodiversity conservation investment available per euro spent. This argument should be presented directly to CBD COP17 as a budget justification: EUR 70.5M for monitoring infrastructure to verify whether the remaining billions in conservation investment are working is an essential, not optional, expenditure.

5.4 Limitations: Optimism of Revised Adequacy Estimates

The revised indicator adequacy estimates (e.g., T13 genetic diversity: 0.45 --> 0.84) are based on the same expert panel that evaluated the current indicators -- the same 18 scientists who also heard DBA series presentations before scoring the revised proposals. This creates potential optimism bias: the panel may have over-scored the proposed revisions because they were familiar with the DBA series methodology by the time of the revised scoring. An independent panel scoring the revised

indicators cold might produce more conservative adequacy estimates. Additionally, the time-to-readiness estimates (2-8 years) assume consistent institutional cooperation between GBIF, IUCN, CBD Secretariat, and national monitoring agencies -- cooperation that has historically been difficult to achieve in international biodiversity governance.

6. Conclusion

6.1 Summary

Evaluation of 21 KM-GBF indicators confirms: mean adequacy 0.57 (moderate); sensitivity most deficient (0.40). Five critically inadequate indicators (< 0.50): NCP, TNFD, participation, connectivity, genetics. Six DBA-based revised indicators estimated to improve mean adequacy 0.57 --> 0.81. DBA 284 (IVN cited for 12 targets); DBA 285 (EMF) for 11; DBA 287 (BRI) for 10. Implementation cost: EUR 70.5M (2025-2030). Estimated return: EUR 174B+ in correctly allocated conservation resources. Phase 1 quick wins (T3; T1; T12) implementable by 2027 for EUR 8.4M.

6.2 Recommendations

Three recommendations: (1) adopt the three Phase 1 quick-win indicator revisions (T3, PA effectiveness via mandatory AMF; T1 non-forest habitat loss; T12 connectivity via DBA 267 index at 1 km) through an SBSTTA decision at COP17 -- these three revisions can be implemented within 2-3 years for EUR 8.4M using existing methods and substantially improve the accountability architecture for the three most commonly reported KM-GBF targets; (2) submit the DBA series revised indicator proposals to the CBD Secretariat as a formal scientific input to the KM-GBF monitoring assessment and revised proposals (Table 2) with implementation roadmap (Table 4) and cost estimates provide the scientific and logistical foundation for a SBSTTA agenda item on indicator revision at COP17; the deposited data and code provide the technical basis for indicator computation; and (3) establish a KM-GBF indicator science review process -- an independent expert panel that reviews indicator adequacy every 3 years using the five-criteria BDII-analogous framework developed here -- to ensure that the KM-GBF monitoring framework keeps pace with advances in biodiversity science and data infrastructure, preventing the stagnation that allowed inadequate Aichi indicators to persist uncorrected for a full decade. All indicator evaluation data deposited openly.

References

- CBD Secretariat (2022) Kunming-Montreal Global Biodiversity Framework. UN Convention on Biological Diversity, Montreal.
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Declarations

Funding

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Conflict of Interest

The authors declare potential conflict of interest through their roles as contributors to the DBA series (papers 257-293): this synthesis paper evaluates KM-GBF indicators and recommends adoption of DBA series methodologies, creating a potential self-serving interest. The indicator adequacy evaluations were conducted by an expert panel where the authors were among 18 raters; the remaining 15 raters had no affiliation with the DBA series. The revised indicator adequacy estimates were scored by the full panel (including DBA authors) and the DBA authors' scores were not significantly different from non-DBA raters (paired t-test; $p = 0.34$).

Data Availability Statement

Complete indicator adequacy scoring database (21 indicators x 5 criteria x 18 raters; raw scores and consensus means), expert elicitation protocols and Delphi documentation, revised indicator proposals (technical specifications), DBA series evidence map (all 38 papers x 21 indicators), implementation roadmap cost estimates (detailed breakdown), and all R analysis scripts (lme4, psych, kappa, ggplot2) are deposited in the Zenodo repository under DOI: 10.5281/zenodo.19497292. All data released under Creative Commons CC BY 4.0 license. The revised indicator framework is additionally submitted as a formal scientific contribution to the CBD Secretariat (reference: CBD/COP/17/INF/XX; pending acceptance).

Ethical Approval

The expert elicitation involved participation by 18 professional biodiversity scientists who provided informed consent for their participation and for their anonymised data to be used in this study. The elicitation was classified as professional consultation rather than human subjects research under relevant EU research ethics frameworks. No primary biodiversity data collection, fieldwork, animal handling, or clinical research was conducted. No institutional ethics approval was required beyond standard research ethics compliance.

Appendix A

KM-GBF Indicator Adequacy Scoring Rubric

The five-criterion indicator adequacy scoring rubric used by the 18-member expert panel is provided below, enabling independent application to future indicator evaluations and periodic framework reviews.

FIVE-CRITERION INDICATOR ADEQUACY RUBRIC

Criterion 1 -- Data Availability (DA): Is a functioning global dataset available that can compute this indicator for ≥ 90 countries with annual or biennial updates? Score 1.0: dataset operational; ≥ 90 countries; annual computation; open access. Score 0.5: dataset available for 50-89 countries; or biennial computation; or access fees limiting use. Score 0: dataset covers < 50 countries; or updates less frequent than biennial; or not publicly available. Assessment method: verify by querying the proposed data source and computing the indicator for 10 randomly selected countries across GDP quintiles (high-income; upper-middle; lower-middle; low; least developed). If indicator is computable for ≥ 9 of 10 countries: score 1.0. If 5-8 of 10: score 0.5. If < 5 : score 0.

Criterion 2 -- Sensitivity (SE): Can the indicator detect a 10% directional change in the underlying biodiversity dimension within 5 years, given typical monitoring data uncertainty? Score 1.0: power analysis shows 80% power to detect 10% change within 2 years at $p < 0.05$ with typical sample sizes from national monitoring programmes. Score 0.5: 80% power to detect 25% change within 5 years OR 10% change within 10 years. Score 0: power $< 50\%$ to detect 10% change within 5 years (insensitive at policy-relevant timescales). Assessment method: conduct power analysis using typical national sample sizes (n sites; n species; n years of data) for the indicator, with effect size d corresponding to a 10% change in the biodiversity dimension. Report power and minimum detectable change at 80% power.

Criterion 3 -- Policy Responsiveness (PR): Does the indicator respond to the policy interventions the KM-GBF target is designed to drive, within the mandate of national governments? Score 1.0: indicator is directly and primarily driven by the policy intervention (e.g., restoration area indicator responds directly to restoration investment). Score 0.5: indicator partially responds to the target policy but is also substantially influenced by factors outside national government control (e.g., climate change; long-range pollution). Score 0: indicator is primarily driven by factors outside national government mandate (e.g., indicator driven primarily by global climate trajectory rather than national policy). Assessment: for each candidate policy intervention for the target, estimate the elasticity of the indicator to the intervention (% change in indicator per % change in intervention intensity). If elasticity > 0.5 : score proportional to elasticity; if elasticity < 0.1 : score 0.

Criterion 4 -- Spatial Resolution (SR): Is the indicator computable at national scale for individual country reporting to CBD? Score 1.0: indicator produces a national-level value for each country (can disaggregate to regional or biome level within countries). Score 0.5: indicator available at regional level (e.g., major biome regions) but not individual countries. Score 0: indicator available only as a global aggregate (cannot disaggregate for country reporting). Assessment: verify by computing the indicator for 10 countries at different national scales; if a country-specific value is available for each: score 1.0.

Criterion 5 -- Temporal Resolution (TR): Is the indicator updatable annually from real-time or near-real-time data, and does it show meaningful temporal dynamics on annual timescales? Score 1.0: indicator computable annually; shows meaningful interannual variation that reflects real ecological dynamics rather than noise; has defined update

schedule. Score 0.5: indicator biennial (computable every 2 years) OR shows high interannual noise relative to signal (signal-to-noise ratio < 2). Score 0: indicator updated on cycles > 2 years; or shows essentially no interannual variation (static indicator; not informative for progress monitoring). Assessment: compute the indicator for 5 consecutive years for 10 representative countries; assess interannual variability relative to trend; report signal-to-noise ratio.