ENVIRONMENTAL GENOMICS RESEARCH PROGRAMME

An IOGP programme

International Association of Oil & Gas Producers

DECEMBER 2025

RFP05. Development of a framework on how to use eDNA for nature reporting

Deliverable 2: Evaluation of the suitability of eDNA to meet nature-related reporting requirements and how to use it

This Guidance is publicly available for readers to review and use. Any comments that improve the content or workability of the guidance are welcomed by the JIP. We will endeavor to address comments in future updates to the guidance, which are planned every 1 to 2 years to capture the rapid advances in this field. Please send comments to info@iogp-edna.org.

Prepared by:

Nature Metrics for the International Oil and Gas Producers' Association Joint Industry Program on Environmental Genomics.

NATURE METRICS
DNA-BASED MONITORING

Contents

Document details	
Document title	RFP05. Development of a framework on how to use eDNA for nature reporting Deliverable 2: Evaluation of the suitability of eDNA to meet nature-related reporting requirements
Document subtitle	N/A
Project code	PROJ06783
Report ID	NS-BDF926

Issue	Date issued	Description	Prepared by	Reviewed by
1.0	13/11/2025	Issued for comment	Isadora F Ferreira Molly Clavey	Pippa Howard Paola Bernazzani Ashlyn Anderson
1.0	10/12/2025	Issued for comment	Isadora F Ferreira	Pippa Howard

Disclaimer

1 Executive summary

1.1 Report objectives

This report provides industry guidance on applying eDNA to nature-related reporting requirements in the oil and gas sector (O&G). Previously, Phase One of this project assessed the use of eDNA evidence to fulfil 280 reporting requirements across 8 nature-related frameworks (please refer to Table 16 in the Appendix). The analysis found that eDNA is particularly suited to measure the state component of the widely used "state-pressure-response" (SPR) model that determines progress toward nature-positive outcomes (Figure 2, chapter 1). "State of nature" (SoN) indicators and metrics[1] generally describe the condition of natural systems through measurements of air quality, water quality and quantity, soil, health, biodiversity, habitat conditions, and climate.

This report builds on the initial analysis by further evaluating the SoN reporting requirements that eDNA is best suited to address. **Because SoN indicators establish the baseline against which pressure and response variables are measured, they represent the most practical and informative entry point for integrating eDNA**. This report, therefore, focuses on SoN requirements rather than pressure or response metrics. The only pressure-type requirement directly addressable through eDNA within these frameworks is the detection of invasive or non-native species.[2]

Three reporting use cases have been reviewed here in detail, focusing on the applicability of eDNA to contribute to the following SoN reporting topics: 1) species, 2) ecosystem condition, and 3) biodiversity sensitive areas. These are the use cases where eDNA adds the most value, although eDNA can provide supplementary evidence to support claims related to ecosystem extent, ecosystem services and connectivity, as shown in the '*RFP05: Development of a Framework on How to Use Environmental DNA (eDNA) for Nature Reporting — Deliverable 1: Mapping Applicable Nature Reporting Standards and Frameworks' – Phase One.* This report also considers the benefits and drawbacks of eDNA relative to other conventional monitoring methods (see glossary for definition of what is included)/ remote sensing, based on efficacy, efficiency, and scalability in meeting certain reporting requirements.

Box 1. Report Structure

1. Introduction and Objectives
    - Explains why eDNA is relevant for corporate nature reporting.
    - Builds on Phase 1 mapping of 280 metrics across eight frameworks and sets out Phase 2 objectives (i.e. when and how eDNA should be used, what metrics it can generate, and what other tools are required).
    - Explains the screening → measurement → reporting workflow. This is because most nature-related frameworks prescribe a similar process for assessing impacts and dependencies on nature. The process from desktop analysis to verifiable evidence defines where eDNA fits.
2. Analysis by Topic Area (Three Use Cases)
    - Core analytical section. Each subsection details how eDNA performs across distinct SoN topics: Species, Ecosystem Condition, and Biodiversity-Sensitive Areas.

[1] The frameworks analysed in this report do not directly differentiate between metrics or indicators. For clarity, this analysis distinguishes between two related but distinct concepts: Metric: a direct, quantitative measurement that can be calculated in a consistent manner each time. For example: Total spatial footprint (km2) by type of ecosystem and business activity. Indicator: a quantitative or qualitative factor or variable that provides a simple and reliable means to measure performance. An indicator can be measured through one or multiple metrics. For example, The Extent of the spatial footprint assessed to be in "Good" condition. This typology underpins the classification in the database of Phase One.

[2] While eDNA can inform certain pressure- or response-related topics, the frameworks assessed predominantly require direct measurements of impacts (e.g., quantified habitat loss, pollution loads) and evidence/explanation of response actions (e.g., not necessarily measure the success of restoration actions) that fall outside the scope of the eDNA signal alone.

- Explain how eDNA performs against remote sensing/LiDAR, bioacoustics/visual, and conventional surveys across efficacy, efficiency, scalability, cost-effectiveness and sampling efficiency.

3. eDNA Benefits for Oil & Gas

- Outlines how eDNA can directly address O&G sector compliance and biodiversity-risk challenges across the full asset lifecycle.
- Shows how eDNA enables auditable, site-specific biodiversity data supporting the the mitigation hierarchy and early detection of critical habitats.
- Highlights regulatory and operational benefits.

4. eDNA Limitations and Complementary Technology

- Acknowledges that eDNA is not a stand-alone solution; outlines biological, analytical, and operational constraints.
- Provides recommendations on complementary tools to use alongside eDNA
- Promotes a multi-method monitoring approach to close data gaps and meet TNFD / CSRD-E4 / SBTN requirements.

4. Conclusion

- Summarises findings across all three SoN topics and recommendations.

4. Appendix

- Contains methodology, bibliography and glossary.
- Longer discussion on efficiency, scalability and effort comparison of eDNA and other biodiversity monitoring tools.

1.2 Key findings

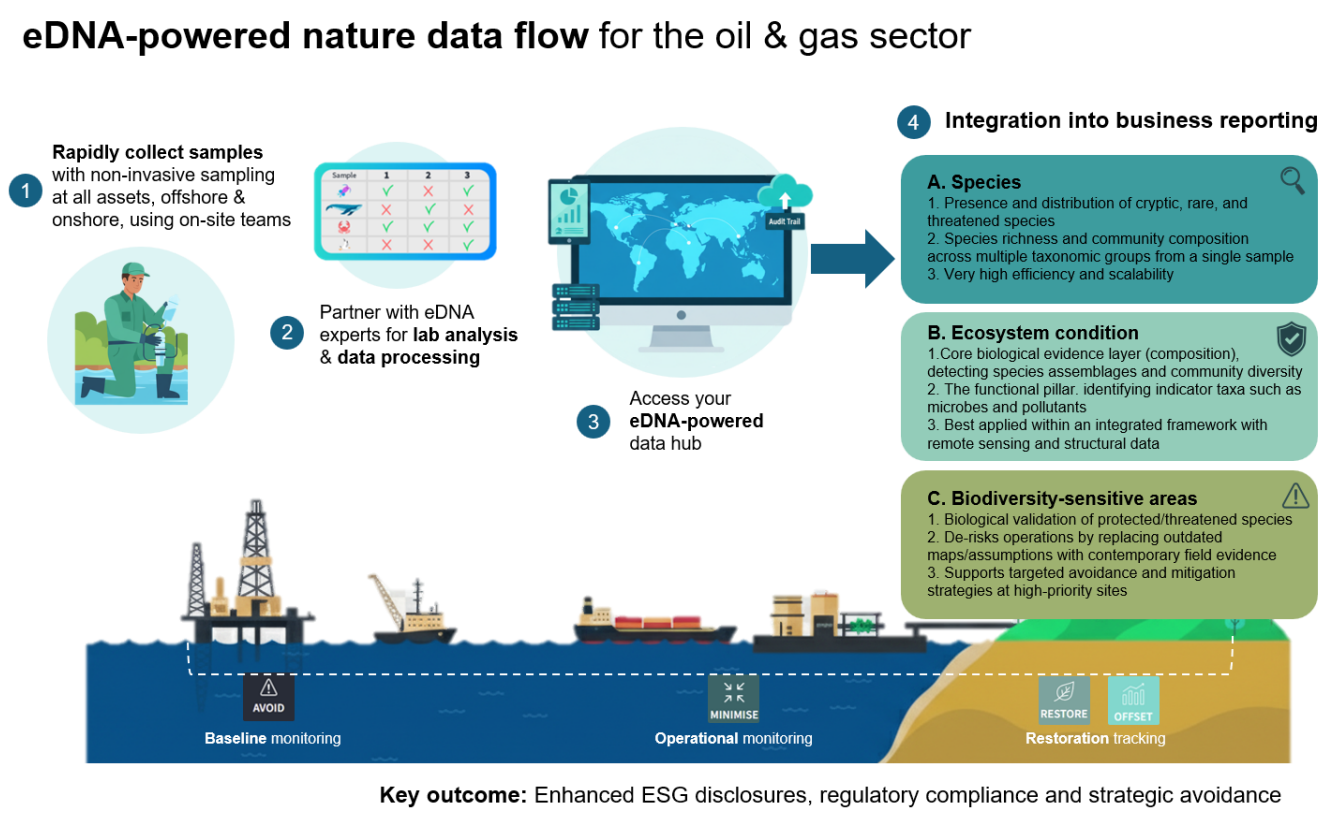


Figure 1 | Visual summary of key findings

1.2.1 eDNA to meet species reporting requirements

Species-level reporting under frameworks analysed, such as Corporate Sustainability Reporting Directive (CSRD-E4), Taskforce for Nature-Related Disclosures (TNFD) and Science Based Targets for Nature (SBTN) recommends data on presence, abundance, distribution, and extinction risk. Generating these datasets consistently at site level and across large portfolios typically requires substantial investment. eDNA provides a rapid, scalable and cost-efficient means of identifying species presence and distribution, including the detection of threatened taxa. However, assessing abundance and extinction risk requires multiple evidence sources; therefore, eDNA should be complemented with additional tools to meet the full breadth of disclosure expectations.

eDNA surveys can often provide a more sensitive and efficient picture of species presence and richness across habitats than conventional survey methods, particularly for hard-to-detect or cryptic species. This enables industries to detect elusive and nocturnal taxa, sample multiple taxonomic groups simultaneously from a single survey, and support early detection of invasive species. . This breadth of detections from diverse environments is not usually feasible with conventional methods. Moreover, remote sensing can identify habitat features and vegetation patterns linked to species presence, but it cannot detect the species themselves, making it less precise than eDNA. As a result, eDNA-based assessments are a valuable tool for establishing more comprehensive baselines, with the statistical power of big data to track community shifts of threatened species and verify the success of mitigation or restoration actions.

eDNA is highly efficient because a single set of methodologies and analyses can be applied to all taxonomic groups in all environments. The in-field process is also rapid, non-invasive, and requires far less extensive fieldwork. Scalability and cost-effectiveness are very high when compared to conventional methods analysed in this report, since standardised protocols enable consistent monitoring across large and remote portfolios at a fraction of the cost of conventional methods. eDNA sampling requires relatively limited field effort compared with many conventional methods (such as traps, nets, electrofishing, visual surveys, or acoustic point counts). When processed through batch laboratory analysis using standardised workflows, it enables consistent monitoring across diverse sites. Conventional methods, by contrast, are time-intensive and geographically constrained.

Measuring species abundance from eDNA is not currently available at scale for commercial use, and it is recommended that complementary tools be used in combination with eDNA to disclose abundance. Few ecological methods can quantify abundance precisely. Techniques, such as acoustic and visual monitoring, camera traps, and mark–recapture, remain stronger for quantifying the absolute abundance and range information needed for nature reporting.

On a case-by-case basis, eDNA could be used to answer abundance requirements, but it is a complex and rapidly evolving field with methodological challenges (box 2 – section 3.1). The relationship between eDNA quantity and organism abundance is not straightforward (i.e. it does not translate to "more eDNA equals more animals"). eDNA read counts[3] can indicate relative trends, but they cannot yet produce accurate population sizes or density estimates without site- and species-specific calibration. Research has successfully shown strong correlations between eDNA concentration and population size under specific conditions (i.e. species- and context-dependent; accounting for body size and environment improves predictions)[4]. For quantitative population trends, extinction modelling, or behavioural data, eDNA should be complemented with acoustic, visual, and conventional ecological surveys. For extinction risk, a combination of methods is needed to forecast risk.

[3] Read counts represent the number of DNA sequences attributed to each species detected in an environmental DNA (eDNA) sample after laboratory sequencing and bioinformatic processing. They provide an indication of the relative amount of DNA from different species present in the sample. While higher read counts may suggest greater abundance, they are influenced by factors such as sampling design, DNA degradation, and amplification efficiency. For this reason, read counts are best used as a semi-quantitative indicator of species presence rather than a precise measure of population size.

[4] https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0035868; https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/j.1365-294X.2012.05600.x; https://onlinelibrary.wiley.com/doi/10.1002/ece3.9785; https://pmc.ncbi.nlm.nih.gov/articles/PMC6243290/ ; https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0122763&

In summary, eDNA is very well suited to serve as the primary detection tool for species presence and richness due to its accuracy, efficiency, and scalability in establishing those metrics. eDNA may also complement conventional methods by addressing abundance and demographic gaps. When combined, these methods deliver a comprehensive, verifiable approach that will satisfy species-related disclosure expectations across frameworks

1.2.2 eDNA to meet ecosystem condition reporting requirements

Reporting frameworks, such as CSRD-E4, TNFD, and Global Reporting Initiative (GRI 304), recommend that companies assess and disclose the condition of ecosystems they operate within or influence. These disclosures aim to determine whether corporate activities are occurring in degraded, stable, or recovering ecosystems, guiding priorities for mitigation and restoration. The indicator recommended is Ecosystem condition (EC), which represents the link between species, habitat, and ecological processes. No single method is able to measure all its dimensions: composition, structure, and function.

Remote-sensing tools can map habitat extent, vegetation cover, and structural change, while conventional ecological monitoring provides insights into species presence and certain functional indicators. However, these approaches often miss the underlying biological signals that reveal shifts in ecosystem health. eDNA helps close this gap by generating fine-scale data on species richness, community composition, and trophic relationships — key indicators of ecological composition and parts of ecological function (Table 1). eDNA achieves high efficacy for the compositional pillar, detecting species assemblages and community diversity[5] with much greater taxonomic breadth than conventional methods. It also contributes to the functional pillar by identifying drivers of key ecological processes, such as microbes for nutrient cycling and pollutant breakdown, up to the identification of functional traits of herbivores and predators. Structural attributes of ecosystems, such as canopy height, fragmentation, or connectivity, are better measured through LiDAR, remote sensing, or field vegetation surveys. The efficiency, scalability, and cost-effectiveness of eDNA are all very high for meeting ecosystem condition requirements for similar reasons as in the species-related section above.

By combining eDNA (composition and aspects of function) and remote sensing (structure), it is possible to report in a robust, scalable and transparent manner towards ecosystem condition requirements. [6] This integrated evidence allows companies to report on ecosystem condition with greater accuracy and confidence, supporting compliance, impact measurement, and long-term nature-positive planning. Therefore, eDNA is very well-positioned as a primary source of biological data within an ecosystem condition measurement framework, complemented by remote sensing for structure, bioacoustics for functional activity, and periodic conventional surveys for local validation. Together, these approaches create a scientifically robust and auditable dataset aligned with the nature-related frameworks analysed.

Table 1 | How eDNA contributes to Ecosystem Condition (non-exhaustive)
The table links different eDNA-derived metrics to the aspects of ecosystem condition they reveal. It shows how analysing DNA in environmental samples can provide early, data-driven insights into ecological health.

eDNA metric	Ecosystem condition indicator where eDNA metrics contribute to	What it shows	Example Interpretation

[5] Species assemblages refer to the group of species found together in a specific habitat or sampling site. It describes which species co-occur, for example, the set of fish, invertebrates, and algae living in a stream. A community refers to the collection of species living together in a given area, and its diversity can include measures of species richness (the number of species present) and evenness (how evenly individuals are distributed among them).
[6] We acknowledge that species data, as discussed above, is also a key input for assessing ecosystem condition.

Species Richness	Biodiversity / Biotic Integrity	Reveals the variety and balance of species in an ecosystem. High native richness signals stability; low richness or dominance of tolerant or invasive species indicates degradation.	An ecosystem with a high diversity of native, specialist species is considered "healthy," while one dominated by a few, pollution-tolerant, or invasive species is "unhealthy."
Presence of Invasives	Threat Level / Ecosystem Risk	Provides early warning of harmful species or diseases that can disrupt ecological balance.	Detecting the DNA of a pathogen, like the chytrid fungus (*Batrachochytrium dendrobatidis*) that devastates amphibians, is a direct indicator of disease pressure and ecosystem ill-health.
Presence of Indicators of species sensitive to change	Water/Habitat Quality	Shows environmental quality through species that are sensitive to pollution or habitat change.	Finding trout or mayfly DNA suggests clean, well-oxygenated water; their absence signals deterioration.
eDNA Concentration	Population Trend / Biomass	Tracks population size or biomass trends over time using DNA quantity as a proxy.	A 90% decline in eDNA concentration for a native fish over three years indicates population collapse.
Trophic Composition	Food Web Integrity / Stability	Detects DNA across producers, prey, and predators to assess ecosystem structure and resilience.	DNA from plankton, insects, fish, and predators indicates a complete, balanced food web

1.2.3 eDNA to meet biodiversity sensitive area reporting requirements

Reporting frameworks analysed recommend that companies identify and disclose operations located in or near areas of high biodiversity importance or sensitivity. These are commonly characterised by the presence of threatened, endemic, or protected species and ecosystems, or by conditions where an organisation's activities may create material impacts or face significant nature-related dependencies or risks. In this report, "priority areas" refer to these biodiversity-sensitive and risk-relevant locations. The intent is to identify material sites and to support a company's rationale for focusing on them. While spatial datasets and Geographic Information System (GIS - see glossary) tools efficiently flag the proximity/overlap of sites to biodiversity-sensitive areas, they are unable to confirm ecological conditions on the ground. eDNA strengthens the evidence base for biodiversity-sensitive area assessments by verifying, through species detection, whether protected or threatened taxa are currently present within or adjacent to mapped high-value zones. Surveys using eDNA can also reveal the presence of critically endangered species and create evidence for a company to identify that site as a biodiversity sensitive area or for the new designation of critical habitats. This capability strengthens corporate disclosures and risk assessments, reducing the likelihood of regulatory or reputational issues caused by outdated or incomplete biodiversity information that may be present in some spatial datasets.

As mentioned previously, the efficiency and scalability of eDNA are high relative to conventional methods, which helps deliver faster and more comprehensive results at a lower overall cost. For example, conventional methods, such as field surveys, camera traps, and bioacoustics, often miss cryptic or low-abundance species, whereas eDNA detects trace genetic material from multiple taxa simultaneously, offering greater detection certainty. Its sensitivity makes it particularly useful for confirming the ecological value of sites flagged through GIS or remote-sensing analysis. By using eDNA in sites identified as high priority (through spatial datasets and GIS tools), companies can target avoidance and impact mitigation strategies and test effectiveness over time. A robust method is to use eDNA to confirm which species are present on the ground, and combine this with mapping data that shows how close the site is to important habitats and the size of those t. When used together, these methods provide a defensible framework that combines spatial, ecological, and biological evidence for disclosure and management purposes.

Table 2 | Summary of where and how eDNA adds value across the SoN topics

Topic Area	When eDNA Should Be Used	What It Measures / Delivers	How It Should Be Applied	How It Reports	Complementary Tools
Species	After screening identifies high-risk sites (protected, endemic, cryptic, invasive taxa). Use during baseline and periodic monitoring.	1. Presence of threatened species and invasive species 2. Species richness 3. Relative abundance trends (when calibrated) 4. Indirect population[7]	• Metabarcoding (see glossary) for multi-taxa surveys • Targeted qPCR/ddPCR (see glossary) for key species • Repeat sampling for turnover tracking[8]	• Satisfies species presence/richness indicators • Supports extinction-risk analysis	• Acoustic/camera for abundance and population, • Modelling for extinction risk
Ecosystem Condition	When reporting ecosystem health, restoration progress, or management outcomes at material sites.	1. Composition (species assemblages, trophic structure) 2. Partial function (microbial & nutrient-cycling taxa)	• Soil, water, or sediment eDNA for compositional & functional analysis • Use diversity indices and indicator taxa	• Provides a biological layer for condition metrics	• Remote sensing for structure; Bioacoustics for function
BiodiversitySensitive Areas	Where operations overlap or lie adjacent to protected areas, KBAs, high-integrity habitats, or ecological corridors.	1. Current presence of protected or threatened species 2. Early detection of compositional change 3. Biological validation of sensitivity	• Targeted metabarcoding in and around mapped sensitive areas, linked with GIS layers	• Strengthens sensitive-area disclosures	• GIS/spatial mapping for proximity analysis

Table 3 | Comparative Evaluation of Monitoring Methods and eDNA across topics

Overall, eDNA offers the highest efficiency and scalability for biological validation. Remote sensing adds structural context; conventional surveys and Bioacoustics/Visual Monitoring remain vital for abundance calibration. The qualitative ratings below assess each monitoring approach in relation to CSRD, TNFD and broader corporate biodiversity disclosure requirements. They evaluate how well each method supports portfolio-scale monitoring,

7 eDNA provides an indirect measure of population because it detects DNA traces left by organisms rather than the organisms themselves. This indicates which species are present, but it does not provide a direct count of individuals.
8 Repeat sampling refers to collecting eDNA samples at multiple points in time. This allows changes in species presence or composition to be tracked, helping to identify turnover such as new species appearing, existing species disappearing, or shifts in community structure. This is for future iterations of reporting.

standardised data generation, multi-taxa coverage, and reduced field effort, rather than comparing the absolute scientific performance of ecological survey techniques. The ratings therefore, reflect organisational suitability for scalable, repeatable and cost-effective reporting, not a universal hierarchy of methodological accuracy across all taxa or environments.

Method Type	Efficacy	Efficiency	Scalability	Cost-Effectiveness	Sampling Efficiency
Aquatic eDNA (marine & freshwater)	***Very High** – confirms species presence, multi-taxa detection, and site sensitivity*	***Very High** – minimal vessel time, rapid collection, automated lab processing*	***Very High** – standardised global protocols enable repeatable monitoring*	***Very High** – reduced field labour, batch lab analysis cuts per-sample cost*	***Very High**– small water samples, minimal field time*
Terrestrial eDNA	***Medium–High** – – strong for invertebrates, microbes, and plants; limited for large vertebrates*	***Very High** – faster than trapping or transects, requires careful planning*	***Very High** – consistent when soil types/conditions are similar. Standardised global protocols enable repeatable monitoring*	***Very High** – reduced field labour, batch lab analysis cuts per-sample*	***Very High** – small soil samples, short campaigns*
AirDNA	***Medium**–effective for broad biodiversity screening; spatial precision limited*	***Very High** – passive, continuous or large-area sampling*	***Very High** – scalable with automated devices.*	***High** – low setup and lab processing cost*	***Very Low** – automated or minimal field effort*
Remote Sensing / LiDAR	***High** – captures ecosystem structure; ideal for spatial analysis, indirect species detection*	***Very High** – automated data collection at broad scales*	***Very High** – repeatable global coverage*	***High–Very High** – free satellite data or low per-site cost after setup*	***Very High**– entirely remote*
Bioacoustics / Visual Monitoring *(camera traps, observers)*	***Medium** – good for conspicuous/vocal taxa, behaviour; misses cryptic species*	***Medium** – deployment, retrieval, and data review required*	***Medium** – scalable with automated AI identification*	***Medium** – moderate hardware and data-processing costs*	***Medium** – devices need installation and maintenance*
Conventional Ecological Surveys *(transects, trapping, netting)*	***High** – strong for abundance, behaviour, and ground-truthing*	***Low** – time-consuming, labour-intensive*	***Low** – constrained by logistics and expertise*	***Low** – high personnel and travel costs*	***Low** – extended field effort required*

1.3 Recommendations

To meet *SoN* biodiversity reporting requirements under frameworks analysed, companies should adopt an integrated monitoring approach that positions eDNA as a core biological evidence tool. eDNA provides a robust and

scalable method for corporate biodiversity assessment, combining scientific rigour with cost-efficiency and standardisation across large and complex portfolios, as regulations increasingly emphasise site-level data after the screening phase, such as GRI 304. When applied strategically, it enables organisations, including those in the O&G, to move from modelled assumptions to measurable, verifiable outcomes.

Beyond meeting disclosure demands, eDNA also delivers three major operational benefits. First, it transforms risk screening into evidence-based management by producing reliable biological data for site prioritisation and monitoring. Second, it accelerates permitting and compliance by delivering auditable baselines. Third, it provides continuous, comparable data for long-term tracking of biodiversity change. Its very high efficiency and scalability allow for rapid sampling across multiple sites, while laboratory standardisation ensures data consistency worldwide. For O&G operators seeking to implement tracking and compliance at high-priority sites, these benefits translate into faster environmental approvals, lower field deployment costs, and verifiable progress against biodiversity targets and other measures of positive change. Training site personnel to collect samples further reduces reliance on specialist ecologists, cutting costs and improving coverage for large or remote portfolios.

eDNA data should be systematically embedded across the 'avoid, minimise, restore, offset' stages of the mitigation hierarchy. It provides verifiable, site-specific data to establish baselines, detect threatened or invasive species, and measure the success of restoration and management actions. This eDNA data also aligns with supporting both *pressure* and *response* requirements identified in Phase One of this project and ensures that biodiversity assessments are grounded in measurable biological evidence rather than desk-based assumptions.

However, eDNA should not operate in isolation. A multi-method approach remains important in most scenarios pertaining to species, ecosystem condition and biodiversity sensitive areas to achieve full coverage of biodiversity metrics. Each complementary tool addresses specific requirements:

- Remote sensing and LiDAR provide the information on structure missing from eDNA by mapping habitat extent, canopy height, fragmentation, and connectivity.
- Bioacoustics and camera traps can provide indicators of abundance.
- Conventional ecological surveys remain valuable for certain small-scale projects and for calibration of eDNA indices.

For asset-intensive energy projects, this integrated model supports the full project life cycle by supplying rapid, verifiable biodiversity data that can be monitored and compared over time. For O&G companies, for example, where assets progress from exploration and construction through operation to decommissioning, this model enables early identification of critical habitats, more accurate measurement of impacts and mitigation, and credible evidence of restoration outcomes at closure. To maximise the reliability of eDNA data, companies should adopt harmonised sampling protocols, accredited laboratories, and curated taxonomic databases to ensure comparability across sites and time periods.[9] Centralised data governance and georeferenced metadata are crucial for integrating eDNA outputs with other monitoring tools and corporate reporting frameworks. Partnering with eDNA providers that maintain ISO-accredited laboratory quality systems (e.g. 14001; 56002; 17025) and verified reference libraries further ensures taxonomic accuracy and global consistency[10]. Finally, eDNA outputs should be embedded directly into corporate reporting systems. They can substantiate disclosures under TNFD's LEAP framework, CSRD-E4 metrics on ecosystem condition, and SBTN Step 1 screening and target-setting. Combining eDNA with spatial and

[9] Survey design, sample size, and frequency depend on each site's habitat type, climate, hydrology, and operational footprint. Sampling design must be developed on a case-by-case basis by technical experts or accredited providers, following ISO standards and local regulatory requirements. Some general guidance will be provided in the last deliverable of this project (Framework), but we cannot prescribe these parameters without compromising scientific validity. Please refer to https://www.iogp-edna.org/publications/ for the full assessment.

[10] There is currently no ISO standard specifically for eDNA methodologies. In this context, "ISO-accredited workflows" refers to eDNA laboratories operating under ISO-accredited quality systems (e.g., ISO 17025 or ISO 9001), which ensure validated laboratory processes, quality control, and consistent taxonomic assignment.

functional datasets allows companies to move from qualitative biodiversity statements to quantified, auditable evidence of performance at their high-risk sites.

2 Introduction

Corporate nature reporting requirements are driving organisations to assess which methods can support reporting obligations efficiently. eDNA now offer alternative, cost-effective ways to measure nature and biodiversity compared with conventional field surveys and visual/acoustic monitoring and newer techniques such as eDNA, remote sensing, and modelling.

This report builds on '*RFP05: Development of a Framework on How to Use Environmental DNA (eDNA) for Nature Reporting — Deliverable 1: Mapping Applicable Nature Reporting Standards and Frameworks' – Phase One*. It examines the key use cases for eDNA identified in that work and outlines when and how eDNA can be integrated with other methods to deliver accurate, efficient reporting. The report also evaluates the efficacy, efficiency, and scalability of eDNA relative to other measurement approaches.

2.1 A review of eDNA applicability to nature-related reporting requirements

In Phase One of this project, a database of 280 biodiversity-related requirements across eight leading frameworks was developed to determine which requirements could be fully or partially met using eDNA evidence. Every requirement was mapped to one of the three components of the SPR model (Figure 2).

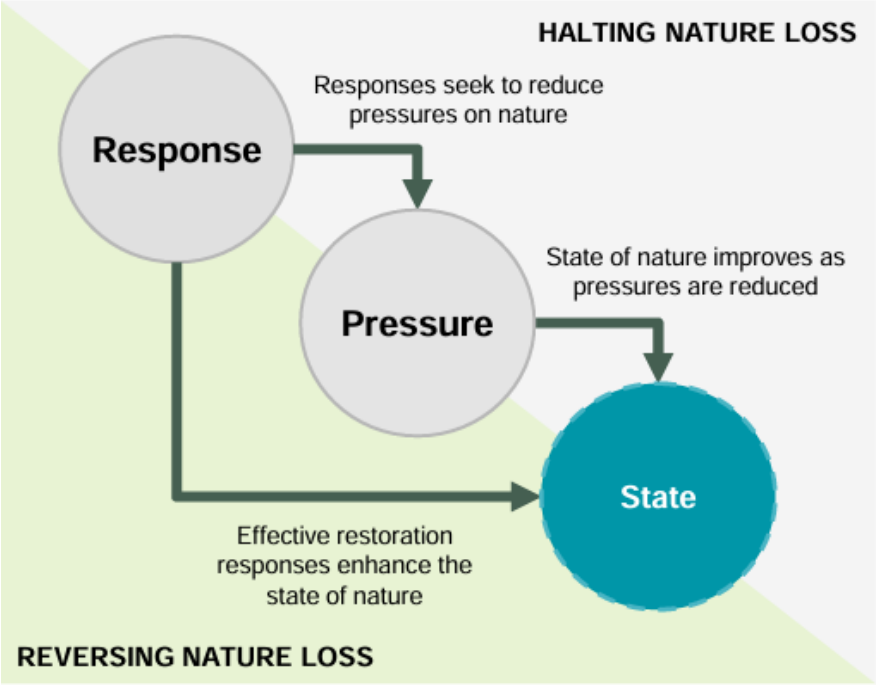


Figure 2 | State-Pressure-Response Conceptual Model, Nature Positive Initiative

Of the requirements analysed, 69 were identified as potentially measurable, either fully or partially, through the application of eDNA. Among these, SoN requirements are the most applicable, with more than half being capable of being fully or partially assessed using eDNA. SoN metrics and indicators measure the condition of the natural environment in which companies operate, including baseline conditions, ecosystem health, and species composition. They can also inform the tracking of pressures, impacts, and responses (as identified in Phase One and shown in Table 2), supporting the assessment of progress toward nature recovery and other intended outcomes.[11] Because SoN requirements establish the baseline against which pressure and response variables are measured, they represent the most practical and informative entry point for integrating eDNA. This report, therefore, focuses on SoN requirements rather than pressure or response metrics. As a result, the only pressure-type requirement directly addressable through eDNA within these frameworks is the detection of invasive or non-native species.

This report focuses on the topics of Species (including invasive species), Ecosystem Condition, and Biodiversity Sensitive Areas found to be most relevant for eDNA application among the SoN reporting requirements assessed in Phase One. These are the use cases where eDNA adds the most value, although eDNA can provide supplementary evidence to support claims related to ecosystem extent, ecosystem services, indigenous peoples, and connectivity, as shown in Phase One (Table 2). The methodology of our assessment can be found in Appendix 1.

Table 2 | Overview of requirements across frameworks

Category	Number of req.	Mandatory	Quantitative	Qualitative	Mixed (Q/Ql)	Specific metric provided	Can eDNA be used to answer this requirement?		
							Yes	Partial	No
State	70	50%	57%	7%	36%	50%	13%	41%	46%
Pressure	53	66%	72%	19%	9%	74%	2%	13%	85%

[11] For example, in the first report we discussed how eDNA could be used in some response requirements to track the progress of mitigation actions. This would be done by using a SoN metric or indicator, such as ecosystem condition pre- and post-project.

Response	61	67%	23%	74%	3%	20%	0%	21%	79%
Pressure and response	3	67%	67%	33%	0%	33%	0%	67%	33%
N/A (strategy, methods…)	93	68%	5%	92%	2%	5%	0%	3%	97%

2.2 From desk to data: the role of eDNA in evidence-based nature reporting

Most nature-related frameworks analysed in this report, especially CSRD-E4, TNFD and SBTN, prescribe a similar workflow to meet corporate nature reporting requirements. The process begins with a portfolio-level screening of sites and activities across a company's direct operations to identify priority areas[12] and potential nature-related risks. Once this stage is complete, value chain screening is recommended to extend the analysis beyond direct operations, as many impacts occur in the supply chain. The identified high-risk sites and activities are then prioritised for direct measurement and ongoing monitoring using primary evidence.

This section analyses that progression, from broad, compliance-focused screening to detailed, evidence-based site assessment, and clarifies where eDNA methods can be applied and can add value compared with remote sensing and GIS-based approaches. This framing clarifies the entry point for eDNA and distinguishes it from desktop analysis, which cannot verify ecological conditions on the ground or reliably establish baselines for target-setting and measuring progress over time. Once priority sites are identified in the screening process, eDNA provides verifiable biological data to establish baselines, confirm species presence, and track ecological change, turning assumptions from desktop assessments into measurable outcomes.

2.2.1 Screening and compliance

All frameworks analysed in this report recommend (and in the case of CSRD-E4 require) that companies evaluate their nature-related impacts and dependencies across direct operations while assessing the SoN in the areas where they operate. This process forms the first step toward meeting reporting requirements and developing holistic nature strategies. It aligns with the Locate phase of the TNFD LEAP approach, Step 1 of the SBTN framework, and the materiality and site identification steps required under CSRD-E4, GRI, CDP, and Ipieca (see Figure 3).

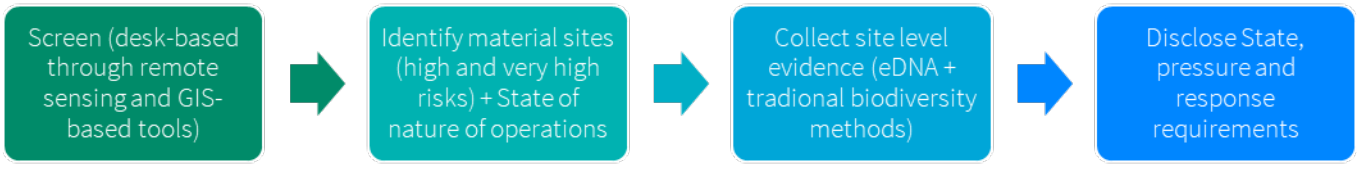


Figure 3 | General workflow across nature-related frameworks

Enterprise-level nature assessments are typically led by corporate sustainability teams responsible for preparing disclosures and often begin with cross-company data gathering to identify material impacts, dependencies, high-

[12] In this report, "priority areas" refer to locations of high biodiversity importance or sensitivity, including areas with threatened or protected species or habitats and areas where operations may create or face material nature-related risks.

risk biodiversity sites, and existing management actions. This work is primarily carried out through a desk-based screening process using global biodiversity datasets and other geospatial tools (see glossary). It constitutes an initial screening stage, designed to be efficient, flexible, and iterative, particularly for companies with large, complex portfolios such as those of IOGP members. Companies typically draw on a mix of open-access and licensed data sources for SoN requirements, including the following:

- Integrated Biodiversity Assessment Tool (IBAT): a subscription-based platform combining the World Database on Protected Areas (WDPA), the World Database of Key Biodiversity Areas (KBA), and the IUCN Red List of Threatened Species, widely used for biodiversity risk screening.[13]
- Global Biodiversity Information Facility (GBIF): open-access repository of global species occurrence records from research institutions, monitoring networks, and citizen science.
- National biodiversity datasets: country-specific sources offer locally verified species and habitat data (access levels vary).

These datasets are often supplemented by satellite imagery-based products providing environmental context, such as the following:

- Land cover and land-use change (e.g. ESA Climate Change Initiative, Copernicus Global Land Cover, MODIS Land Cover Type).
- Forest extent and loss (e.g. Hansen Global Forest Change, Global Forest Watch).
- Soil and vegetation productivity (e.g. FAO SoilGrids, MODIS NDVI).
- Biodiversity intactness and ecosystem condition (e.g. Biodiversity Intactness Index, UNEP-WCMC Global Ecosystem Typology).

Together, these datasets enable companies to prioritise sites based on potential ecological sensitivity and biodiversity value before proceeding to direct site-level measurement using field methods such as eDNA. This does not mean that eDNA or other site-level data cannot be used during screening. Where available, such data can strengthen assessments by grounding them in field evidence. However, for compliance and reporting purposes, frameworks generally do not require field-based data at this stage.

To assess impacts and dependencies associated with specific business activities or commodities sourced by the company, organisations also use sector-level tools such as the following:

- ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure), developed by the Natural Capital Finance Alliance and UNEP-WCMC, helps users understand how business sectors depend on and impact natural capital. It links economic activities to ecosystem services, supporting the identification of material nature-related risks and dependencies across portfolios.
- The SBTN materiality framework guides companies through a structured process to identify and prioritise their most material impacts and dependencies on nature across five key domains: freshwater, land, ocean, biodiversity, and climate. It builds on ENCORE outputs and aligns with the SBTN methodology, helping organisations determine where to set targets and focus data collection efforts.
- These can be complemented with company data if available.

Together and often in combination with company data, these tools support companies in identifying high-impact business activities and their associated sites for deeper analysis and target-setting, bridging the gap between high-level screening and site-specific measurement. High-risk sites and activities identified through this screening process are then prioritised for detailed analysis to understand dependencies, impacts, and management effectiveness. This information forms the foundation of a corporate nature strategy and subsequent reporting. Sites

[13] The World Database on Protected Areas (WDPA) is an spatial data on legally designated protected and conserved areas. The World Database of Key Biodiversity Areas (KBA) provided data on sites of global biodiversity importance. The IUCN Red List of Threatened Species is an open-access global species distribution and conservation status data.

with the greatest impacts and dependencies become the focal points for site-level data collection/analysis, disclosures, and transition plans.

2.2.2 Beyond screening: the entry point for eDNA and other conventional biodiversity tools

As shown above, the screening stage efficiently narrows down where further investigation, often at the site level, is needed. Desk-based assessments provide contextual risk information, such as proximity to protected areas or ecosystem type, but they do not yield primary scientific evidence on the SoN at each site. For O&G companies with large portfolios, desktop screening remains efficient for initial risk sorting and meeting basic compliance requirements.

Once priority sites are identified, reporting requirements shift toward the collection of primary evidence to establish an accurate understanding of local impacts and dependencies. All frameworks assessed, especially TNFD, SBTN, CSRD-E4, and GRI, emphasise the need for site-level evidence because biodiversity impacts and dependencies are inherently local. Understanding the ecological context of high-risk sites is therefore critical for assessing real effects and tracking recovery. This is where eDNA and other field-based methods become essential. eDNA provides direct biological evidence to establish baselines, confirm species presence, and detect ecological change, enabling companies to turn screening assumptions into verifiable evidence. This shift is crucial because relying solely on desk-based data for high-risk sites may introduce compliance and financial risks. For example, some spatially represented species range data layers are static, spatially coarse, or temporally outdated (i.e., a global biodiversity database may show where a species *used to occur* across its historical range, but it cannot confirm whether the species is currently present within an asset boundary or reflect recent operational impacts or restoration activities).

The shift from spatial screening to site-level measurement is driven by the requirement to demonstrate credible, evidence-based data of biodiversity at high-priority sites. Therefore, spatial datasets remain valuable for screening and prioritisation, while eDNA complements these tools by validating biological conditions, detecting changes over time, and supporting disclosures that rely on measurable evidence rather than inference. This strengthens regulatory compliance and helps manage reputational risk, particularly in the O&G sector, where site-level monitoring is expected.

The remainder of this report compares eDNA with conventional biodiversity monitoring methods in providing site-specific SoN data at priority locations. It highlights eDNA's efficiency and sensitivity in detecting elusive or cryptic species, tracking community-level diversity, and establishing robust baselines for ongoing assessment.

3 Assessing eDNA's suitability for nature-related reporting

This section examines specific use cases for eDNA in corporate nature reporting that were identified in Phase One. The analysis is designed to:

1. Assess the advantages and limitations of eDNA for measuring requirements related to 1) biodiversity sensitive areas, 2) ecosystem condition, and 3) species, providing a balanced evaluation of where eDNA offers measurable improvements and where complementary conventional methods remain necessary.
2. Compare eDNA to conventional monitoring techniques in terms of:
    - **Efficacy:** It means how well something works at achieving its intended result. High efficacy means the method consistently produces valid, dependable results, for example, confirming that a particular species is present when it actually is.

- **Efficiency - Labour and time efficiency:** Whether eDNA could be implemented with reduced field effort compared with direct observation, camera traps, or physical specimen collection.
- **Scalability:** Whether the method can generate large, standardised datasets across multiple taxa and ecosystems using harmonised protocols.
- **Cost-Effectiveness:** Whether fewer field visits and reduced reliance on taxonomic specialists would lower total survey and reporting costs.
- **Sampling Efficiency:** Whether data is collected remotely or over site-based samples. This was compared with the relative effort required for conventional biodiversity monitoring.

3. Please note that the comparisons in this report assess each monitoring approach in relation to CSRD, TNFD and broader corporate biodiversity disclosure requirements. The focus is on how well different methods meet organisational needs for scalable, standardised and cost-effective biodiversity disclosures. The ratings evaluate each approach's suitability for portfolio-scale monitoring, consistent data generation, multi-taxa coverage and reduced field effort, rather than comparing the absolute scientific performance of ecological survey techniques. They therefore reflect organisational suitability for scalable, repeatable and cost-effective reporting, not a universal hierarchy of methodological accuracy across all taxa or environments.Identify opportunities for integrating eDNA with complementary nature-tech tools to enhance data coverage and reporting accuracy across frameworks.

See the Appendix for an overview of the methodology of this report and a comparison of eDNA with other monitoring techniques. For discussion on the limitations of eDNA, please refer to Chapter 5.

3.1 Species

3.1.1 Overview

Frameworks require companies to assess and disclose a broad set of requirements that extend from single species to community-level metrics and indicators. Species-level requirements under frameworks such as the CSRD-E4, TNFD, SBTN and GRI place significant emphasis on understanding presence, abundance, threat status, and extinction risk.

Across the 15 species-state requirements reviewed in Phase One of the project, we found that eDNA can fully address 7 of them and partially address 8, where demographic or physical data are still required (Table 3). In other words, eDNA can fully support requirements concerning the presence and distribution of threatened species and multi-species community composition, while only partially meeting those related to population size, abundance, and extinction risk quantification.

Three pressure requirements are related to invasive species, and here, eDNA can provide evidence to support disclosure. This section assesses the applicability, advantages, and limitations of eDNA for species-related monitoring requirements.

Table 3 | Species reporting requirements where eDNA can partially/fully support the requirement

Sub-topic	CSRD-E4	TNFD	TNFD O&G	SBTN	GRI	GRI O&G	ipieca	CDP
Species – State requirements	E4-5 -40(b) E4-5 -40(c) E4-5 -40(d)(i) E4-5 -40(d)(ii) E4-5 -41(b)(ii) SBM 3 - 16(c)	C5.1 A5.3 A5.4		Step 1 &2, Task 9: SoN indicators (2 requirements) Step 1. Appendix 1. SoN Biodiversity indicators - Water use and water pollution (2 requirements) and soil pollution (1 requirement)		304-4		

Invasive Species – Pressure requirement	E 4-5. AR 32	A4.0	OG.A4.0

3.1.2 Applicability of eDNA

Across the 8 frameworks analysed, mandatory SoN species requirements centre on 4 main topics: presence of threatened species, species richness, community-level indices, species abundance, population size and range and extinction risks. There are also species-related pressure requirements related to invasive species (for discussion on limitations see chapter 5).

3.1.2.1 Threatened species

eDNA can robustly support requirements for determining whether operational activities affect the presence of threatened species across a company's footprint. eDNA is widely recognised as a valid and reliable method for detecting species occurrence. When a species' DNA is detected, and the result meets all quality-control criteria, it is treated as a confirmed presence; no visual or physical observation is required. In many contexts, eDNA identifies species that are otherwise difficult or impossible to detect through traditional survey methods.. By capturing genetic traces from water, soil, or sediment, eDNA detects rare, nocturnal, migratory, or cryptic taxa that are often missed by visual or trapping surveys in/near material sites. Routine metabarcoding[14] or targeted qPCR[15] can confirm overlaps between operational footprints and conservation-sensitive biodiversity, such as IUCN Red List species screened to be potentially located near a site. This makes eDNA particularly valuable for early-warning compliance and risk management. One example is a NatureMetrics project with Thungela, in a mine in South Africa. With just 7 samples, 108 species were detected, including two Red List species (the African clawless otter and the large-mouthed frog), which provided auditable data to inform long-term planning.[16] There are many more examples where simple yet effective site-level eDNA measurement has detected species that inform management and reporting (see bibliography).

In aquatic systems, eDNA has demonstrated strong alignment with morphology-based methods while providing greater taxonomic resolution. A NatureMetrics validation study for EDF Renewables at an offshore wind farm detected 70% more fish species than conventional trawling methods, illustrating its superior detection capacity.[17] Another study found, on a per-site basis, eDNA achieved a detection rate 5.5 times higher than conventional trapping and was nearly 19% cheaper when accounting for labour, travel, and equipment.[18] Similarly, terrestrial eDNA applications can identify more soil fauna species, with some studies showing detection of a higher number of species than conventional methods like hand-sorting, and providing a more comprehensive picture of biodiversity, improving understanding of soil biodiversity and the ecological processes driven by microbiota (see bibliography). Industrial applications further demonstrate its relevance. Studies from offshore O&G sites confirm eDNA's ability to detect shifts in bacterial and benthic eukaryotic communities consistent with morphology-based results, often with greater taxonomic resolution. Its capacity to identify pressure-indicator species (e.g., hydrocarbon degraders) makes it suitable for ongoing ecological monitoring and early detection of environmental change.[19]

3.1.2.2 Extinction risk

[14] Metabarcoding is a DNA-based method used to identify many species simultaneously from a single environmental sample (like soil, water, or sediment).
[15] Targeted qPCR (quantitative Polymerase Chain Reaction) is a DNA testing method used to detect and measure one specific species in an environmental sample. It's called targeted because the assay is designed around DNA sequences unique to that particular organism, for example, a single fish species, an invasive mussel, or a protected amphibian.
[16] https://www.naturemetrics.com/resources/nature-intelligence-for-extractives
[17] https://www.naturemetrics.com/case-study/edf
[18] https://onlinelibrary.wiley.com/doi/full/10.1002/edn3.525
19 https://www.sciencedirect.com/science/article/abs/pii/S0025326X17309992; http://www.iogp-edna.org/wp-content/uploads/2025/01/Chapter-1-Efficacy-of-eDNA-vs-Conventional-Monitoring-Methods.pdf ; https://pubmed.ncbi.nlm.nih.gov/33070453/

No single method, including eDNA, can measure extinction risk on its own. Risk assessments require integrating population trends, threat data, and habitat condition. eDNA strengthens these analyses by confirming species' presence in historical or impact areas, helping validate modelled persistence scores and screening-indicators like Species Threat Abatement and Restoration (STAR) or species persistence scores.20 While it cannot measure habitat extent or degradation, eDNA adds biological evidence to habitat-suitability and fragmentation models, linking real species occupancy with environmental change data to refine extinction-risk evaluations.

3.1.2.3 Species richness

eDNA provides a reliable and scalable way to measure species richness across ecosystems, for the same reasons discussed above. Moreover, eDNA metabarcoding analyses multiple taxonomic groups simultaneously from a single sample, unlike conventional surveys that require separate methods for different taxa. This approach enables a comprehensive assessment of species richness and community composition without the logistical complexity of conducting distinct fish, macroinvertebrate, and microbial surveys.

Studies show eDNA captures comparable or higher richness estimates in freshwater, marine, and terrestrial systems, particularly for fish, amphibians, and invertebrates. Metabarcoding captures vertebrates, invertebrates, fungi, and microbes in one assay, supporting indicators like native vs. non-native ratios and threat-weighted biodiversity indices aligned with the Kunming–Montreal GBF. By linking detections to IUCN or national threat lists, eDNA enables aggregated conservation-status tracking. The main limitations are taxonomic resolution and long-term comparability, which depend on consistent lab methods and reference libraries. eDNA's high sensitivity also supports rarity-weighted richness metrics, especially for freshwater and amphibians. DNA data combined with IUCN rarity scores help identify conservation hotspots quickly and at scale. Soil eDNA extends this to microbial and invertebrate diversity, revealing pollution or land-use impacts and providing direct input for hotspot mapping.

3.1.2.4 Population

eDNA can inform population size and range, but only indirectly. Quantitative assays such as qPCR or dPCR[21] estimate relative abundance indices rather than true population counts, providing useful trend indicators over time. Mapping detections across multiple sites reveals a species' current distribution and persistence, supplying key data for range assessments and spatial modelling. True population size, however, typically requires complementary methods such as mark–recapture studies, distance sampling, camera-trap modelling, acoustic density estimation, and structured visual surveys (e.g., transects or point counts). These approaches measure individuals or groups directly, enabling absolute abundance estimates that meet the more quantitative requirements of nature reporting.

3.1.2.5 Species abundance

eDNA can only partially meet disclosure requirements concerning species abundance. The number of sequence reads (via eDNA metabarcoding) sometimes correlates with biomass or population density. However, these relationships are confounded by hydrology, temperature, species-specific shedding rates, primer bias, and variable DNA degradation.[22] As a result, eDNA alone cannot yet produce reliable absolute abundance estimates in open environments. When calibrated against conventional methods, such as mark–recapture, distance sampling, or acoustic surveys, quantitative eDNA (qPCR or dPCR) can track relative population trends with lower cost and

[20] The STAR metric estimates the potential contribution of actions (threat reduction and habitat restoration) at a given location to reducing species extinction risk. Species persistence scores are modelled estimates of the probability that a species will continue to survive in a given area or landscape, based on habitat quality, extent, and pressures.

[21] Quantitative assays such as qPCR (quantitative Polymerase Chain Reaction) and dPCR (digital Polymerase Chain Reaction) are laboratory techniques used to measure the amount of DNA from a target species in an environmental sample. Both qPCR and dPCR are used to estimate how much DNA from a particular species exists in a sample. This can help infer presence, and sometimes relative abundance, of that species.

[22] The amount of DNA found in a sample *can* reflect how many animals are in an area, but the relationship is not consistent. DNA behaves differently depending on the environment. Water flow, temperature, how much DNA a species naturally sheds, and how quickly DNA breaks down can all change the amount detected. Because of this, "more DNA" does not always mean "more animals," and results need to be interpreted carefully.

sampling effort (correlation strength is context-dependent and most reliable in closed or controlled systems) (box 2). In controlled or closed systems such as ponds, tanks, or mesocosms, strong correlations between eDNA concentration and biomass have been demonstrated, but large-scale applications remain experimental[23]. .Soil sampling offers a more stable, albeit spatially patchy, signal. While soil eDNA undergoes rapid initial degradation, a fraction stabilises by binding to minerals and organic matter, persisting longer than aquatic eDNA. This provides a temporally integrated picture of site usage rather than a real-time snapshot. Consequently, differences in DNA sequence reads may reflect broad patterns of relative abundance, though comparisons between species must be made cautiously due to amplification biases. Furthermore, because "legacy DNA" can persist in soil, sequence reads should not always be interpreted as current population size.[24]

Repeated, standardized eDNA sampling is therefore best utilized to monitor directional change (trends) rather than absolute abundance. Absolute population counts currently rely on methods that model individuals directly, such as mark–recapture studies, distance sampling, camera-trap modelling, acoustic monitoring, or structured visual surveys.**Box 2 | How eDNA can be used to estimate abundance**

Purpose

eDNA abundance analysis seeks to correlate the concentration of DNA in an environmental sample (for example, the number of target gene copies per litre of water) with the actual number or biomass of organisms present. It offers a practical, though indirect, indicator of population density. This can be done at two levels:

1.Species-level quantification (absolute abundance)

This approach estimates the population size or biomass of a target species.

- Methods: Quantitative PCR (qPCR) and Droplet Digital PCR (ddPCR). Both measure how much DNA of a species is present, but ddPCR provides a more precise and inhibition-resistant count by partitioning the sample into thousands of droplets to count positive signals directly, reducing inhibition and improving accuracy.
- Application: Works best when supported by species-specific calibration studies that relate DNA copy numbers to known population densities (accounting for DNA shedding, degradation, and transport). Without calibration, results show DNA concentration rather than true abundance
- Typical Use Case: Monitoring target or indicator species such as fish in controlled or semi-contained systems (ponds, small rivers, aquaculture tanks).

2. Community-level quantification (relative abundance)

This is a more common use, especially for biodiversity surveys. It aims to determine if a species is rare or common relative to other species in the same sample. (ie. compares the relative presence of species within a community.)

- Method: eDNA metabarcoding, which uses universal primers to amplify a shared gene (e.g., 12S for fish) from all species in the sample. The resulting sequence reads indicate which species are present.
- Interpretation: Read counts provide a semi-quantitative signal of relative presence, useful for ranking common versus rare taxa. But it is not a direct measure of abundance because of primer bias, amplification efficiency, and sequencing depth. Because amplification efficiency differs between taxa, these proportions must be interpreted cautiously or adjusted using internal standards or quantitative metabarcoding approaches.
- Typical Use Case: Biodiversity surveys, community composition monitoring, or before-and-after comparisons in impact assessments.

[23] https://onlinelibrary.wiley.com/doi/10.1002/edn3.298; https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0035868; https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0086175; https://pub.epsilon.slu.se/30497/1/karlsson-e-et-al-20230327.pdf; https://www.nature.com/articles/s42003-019-0696-8; https://academic.oup.com/icesjms/article/80/4/1066/7077003

[24] https://pubmed.ncbi.nlm.nih.gov/30507072/; https://pmc.ncbi.nlm.nih.gov/articles/PMC6892050/; https://www.nature.com/articles/s41598-020-67452-1; https://onlinelibrary.wiley.com/doi/full/10.1002/edn3.581

Key challenges

The relationship between eDNA quantity and true species abundance is variable.

- Biological factors: Shedding rates differ by species, size, life stage, and condition. DNA also originates from multiple sources (mucus, faeces, gametes, carcasses), and single individuals can release disproportionate amounts.
- Environmental factors: eDNA degrades rapidly in warm, acidic, or sun-exposed conditions and can be transported by water currents, so DNA detected in one location may have originated elsewhere.
- Analytical factors: PCR inhibition from humic acids or tannins can reduce detection. In metabarcoding, universal primers amplify some species more efficiently than others.

Because of these factors, eDNA measures "DNA abundance," not direct organism counts. With proper calibration, replication, and quality controls, however, it provides a reliable, scalable indicator of relative species presence and biomass trends for biodiversity monitoring and impact assessments.

3.1.2.6 Invasive species

eDNA is highly effective for detecting and tracking invasive alien species (IAS) across terrestrial, freshwater, and marine environments. It can identify multiple invasive taxa simultaneously, including rare or early-stage introductions, making it ideal for early warning and post-removal verification. eDNA metabarcoding can produce reliable species lists and quantify the number of invasives detected at each site, provided reference sequences exist. It also helps confirm the success of removal actions by showing the disappearance of IAS DNA from samples. These capabilities make eDNA a strong tool for disclosures on the *presence* and *number* of invasive species within owned or operated areas.

Requirements also ask for the number and the extent of invasions, introduction pathways, and the volume of organisms introduced/removed. For these, eDNA must be complemented by spatial data (e.g. remote sensing for habitat coverage) and management records (e.g. removal programmes and outcomes). Used together, these methods provide a complete and verifiable basis for corporate biodiversity reporting and compliance with TNFD or ESRS E4 disclosure requirements.

3.1.2.7 Current eDNA Limitations

eDNA still faces some technical limitations, but these are steadily diminishing through methodological standardisation, database expansion, and integration with complementary monitoring tools. Reliable identification depends on comprehensive reference libraries and strict laboratory quality control. Gaps remain for some taxonomic groups, particularly in tropical or data-poor regions, yet collaboration with providers maintaining curated databases and ISO-accredited workflows is improving accuracy and comparability across regions. Uncertainties about DNA persistence and timing are also decreasing as studies refine sampling frequency and environmental calibration. Repeated or seasonally aligned surveys, combined with contextual data such as temperature and hydrology, now allow more confident interpretation of species presence. Detection bias across taxa and habitats, caused by differences in shedding rates or sampling media, is being reduced through standardised protocols, spatial replication, and multi-marker metabarcoding. While eDNA cannot directly establish ecological causality, linking it with remote-sensing, chemical, and acoustic datasets enables more integrated cause-and-effect analysis. As these advances converge, eDNA's limitations are narrowing, reinforcing its role as a dependable component of long-term biodiversity monitoring.

3.1.2.8 Comparison with other conventional biodiversity methods

eDNA provides a rapid, sensitive, and scalable method for measuring threatened species, species richness, and community-level indices (Table 4). On average, it outperforms conventional surveys in detection breadth and efficiency while lowering costs and field effort. Its limitation lies in quantifying abundance, extinction risk and population size, so it works best when paired with complementary tools for a full ecological picture in these cases.

Table 4 | Evaluation of eDNA and other tools for species reporting requirements

Efficacy	High-eDNA has very high efficacy for confirming species presence and determining metrics of community diversity and richness, such as alpha and beta diversity. It is consistently more sensitive than conventional methods for aquatic taxa. Its efficacy is medium for true quantitative abundance estimation and population size, which still requires supplementary data or highly calibrated study designs.
Efficiency	Very High - eDNA requires far less field effort than direct observation, camera traps, or specimen collection. Sampling is quick, non-invasive, and typically completed in a single site visit, with most processing handled in laboratories. This greatly reduces time in the field and the need for specialist personnel while maintaining consistent, repeatable results across sites.
Scalability	Very High - Standardised, non-invasive sampling makes it easy to train non-specialist site personnel or local community members for data collection, facilitating vast spatial coverage and long-term time series monitoring programs globally. Anglo American's use of NatureMetrics eDNA services across its global portfolio demonstrates this by generating species data across 3 marine and 12 terrestrial ecoregions in 11 countries.
Cost-Effectiveness	High - Costs are lower overall because local staff or technicians can collect samples, reducing travel and field labour. Centralised lab processing and batch analysis deliver substantial savings compared with conventional biodiversity surveys. eDNA delivers more species detections per unit cost than conventional biodiversity surveys, particularly in complex or remote environments.
Sampling Efficiency	Low Overall - Physical samples still need to be collected in the field, but the effort is limited to small volumes of water, soil, or sediment. Field sampling is minimal, and campaigns can be scheduled flexibly. Most subsequent processing, sequencing, and interpretation occur remotely. This low-effort model supports large-scale biodiversity baselining and ongoing monitoring with limited disruption to operations or field logistics.

Table 5 | Evaluation of eDNA and other tools for species reporting requirements

Method Type	Efficacy	Efficiency	Scalability	Cost-Effectiveness	Sampling Efficiency
Aquatic eDNA (marine + freshwater)	Accurately confirms species presence and site sensitivity. Strong congruence with conventional data; less effective for abundance, extinction risk and population size	Rapid sampling with minimal vessel time and automated processing No need for taxonomic expertise Reduced the time when many samples are processed simultaneously	Scalable across sites and seasons; suitable for large portfolio screening. Reduced costs when many samples are processed simultaneously	Substantially cheaper than ecological or imagery surveys.	Minimal sample collection, lower hazard and time. Sampling is more effective, independent of species activity and habitat The same samples can be used for surveying multiple taxonomic groups **Can be implemented via manual campaigns or automatic samplers[25]. Automated systems enable unattended, high-frequency sampling at fixed locations, further increasing temporal resolution and consistency**
Terrestrial eDNA	Reliable for presence confirmation. Stronger for soil invertebrates and microbes than for large vertebrates. limited by abundance and population size. results vary by substrate and DNA persistence	Faster than trapping or camera surveys, but requires careful site planning. Reduced the time when many samples are processed simultaneously No need for taxonomic expertise	Scalable when soil types and conditions are consistent; Reduced costs when many samples are processed simultaneously	Lower cost when multiplexed across sites	Minimal sample collection, lower hazard and time. Sampling is more effective, independent of species activity and habitat The same samples can be used for surveying multiple taxonomic groups

[25] There are no commercially available automatic soil eDNA samplers, and automated air samplers are still in experimental research settings, not in operational biodiversity workflows. Automatic eDNA samplers are currently available for aquatic environments and can significantly enhance temporal resolution and reduce field effort for long-term monitoring programmes

AirDNA	Captures airborne traces of multiple taxa, strong for insects and plants; spatial resolution is still developing.	Rapid, passive collection. No need for taxonomic expertise	Suitable for continuous or large-area sampling; Reduced costs when many samples are processed simultaneously	Low deployment cost; moderate lab analysis.	Minimal field effort; can be automated. The same samples can be used for surveying multiple taxonomic groups.
Visual and Acoustic Monitoring (camera traps, bioacoustics, observers)	Directly records visible or vocal species; effective for vertebrates and behaviour, but may miss cryptic or microscopic taxa.	Equipment setup, calibration, and data processing required. The turnaround time of sample processing and storage can be short Species Identification is possible if taxonomic expertise is available	Scalable with automated sensors and AI identification.	Moderate equipment and data-management costs. Camera traps and other trapping devices have comparably low unit costs	Devices need placement, retrieval, and maintenance.
Conventional Ecological Surveys (traps, transects, netting, visual ID)	Accurate species identification, abundance, and behavioural data; strong ground-truthing for all other methods.	Time and labour-intensive; requires taxonomic expertise. The turnaround time of sample processing and storage can be short Species Identification is possible if taxonomic expertise is available	Constrained by geography and specialist availability.	Expensive fieldwork, travel, and personnel.	Extended on-site work and high manpower needs.

Remote Sensing	Indirect species detection through habitat association and phenology proxies.	Automated, repeatable data capture.	Broad spatial coverage; repeatable through time.	Moderate per-site cost after setup; free satellite data available.	No field labour required.

Rating	Meaning across all columns (efficacy, efficiency, scalability, cost-effectiveness, sampling effort)
Very High	Performs exceptionally well or provides substantial advantages compared with conventional biodiversity methods. For Cost-Effectiveness, indicates very low relative cost per unit of data or coverage.
High	Performs strongly and consistently, with clear benefits in most contexts. For Cost-Effectiveness, it indicates lower cost and a strong return on data value.
Medium	Provides moderate improvement or equivalent performance relative to conventional approaches. For Cost-Effectiveness, indicates a moderate cost proportional to output quality.
Low	Provides limited or situational benefit. For Cost-Effectiveness, it indicates a relatively high cost compared with the data yield.
Very Low	Performs poorly or is unsuitable for the requirement. For Cost-Effectiveness, it indicates high cost and low data efficiency.

3.1.3 Recommendations

eDNA methods have been demonstrated to be capable of providing efficient, scalable and cost-effective species-level information that can contribute to robust biodiversity disclosures. In particular, they enable multi-taxa detection from a single sampling campaign and can reduce dependence on intensive field surveys and specialist taxonomic effort. Although conventional methods lack the combined advantages identified in this chapter, they remain essential for verifying abundance, population size and other metrics that eDNA cannot yet quantify with sufficient accuracy.. Companies should also consider integrating eDNA into the phases of the mitigation hierarchy to establish robust baselines, track changes in threatened or invasive species and prove the efficacy of species-focused mitigation and restoration responses over time, which can inform response and pressure requirements of nature reporting

Summary of application

- Primary tools for species detection: eDNA (terrestrial and marine): broad, sensitive, and cost-efficient, ideal for confirming species presence across large portfolios. AirDNA enhances scalability for detecting airborne taxa but remains less precise spatially.
- Recommended integrated approach:
    - Step 1: Apply eDNA to confirm presence of threatened species, species richness, community-level indices and local biodiversity condition
    - Step 2: Use acoustic/visual monitoring and conventional surveys to determine population size, range and abundance.
    - Step 3: For extinction risk, use extinction-risk models such as STAR or species persistence scores. These indicators may be collected at an earlier screening-level stage to identify priority areas for collecting direct evidence.
    - Step 4: Use remote sensing if contextual habitat and phenology data are required.

Table 6 | Complementary tools and methods for addressing species-related requirements

Requirement Type	Complementary Tool / Method	Tool Function	How It Complements eDNA	Benefits	Limits
Population Size and Abundance Trends	Mark–recapture studies	Quantitative population estimation	Validates whether eDNA detections reflect abundance trends	Statistically robust, widely accepted	Labour-intensive, invasive for some taxa
	Distance sampling (transects, point counts)	Density and abundance estimation	Provides absolute abundance benchmarks for calibration of eDNA indices	Standardised, transferable between sites	Observer bias, weather/season effects
	Acoustic call-rate analysis	Relative abundance from vocal activity	Adds temporal and behavioural context for vocal taxa	Continuous and low-cost	Limited to taxa with distinct calls

	Camera-trap occupancy models	Population-level inference	Converts eDNA presence data into occupancy-based abundance trends	Time-series detection data	Requires calibration and maintenance
Species Range and Extinction Risk	Red List assessment methods / expert elicitation	Conservation status classification	Adds official extinction-risk categories to eDNA detections	Globally standardised (IUCN)	May be outdated for lesser-known taxa
	Pressure–response models	Causal linkage analysis	Connects species presence and decline with operational pressures	Predictive, management-relevant	Requires integrated datasets
	STAR / BIC / Persistence Score models	Quantitative extinction-risk estimation	Incorporate eDNA presence to validate local occurrence and support model inputs	Connect local detections with global risk accounting	Require high-quality Red List and geospatial data
Habitat Change as Proxy for Extinction Risk	Remote sensing and GIS land-use change mapping	Detects habitat extent, fragmentation, and degradation	Links eDNA species detections to habitat trends	Scalable, frequent updates	Does not identify specific species
	Field vegetation or structural habitat surveys	Fine-scale habitat condition assessment	Validates habitat associations identified by eDNA	Detailed ecological data	Costly, localised coverage

Together, these methods form an integrated biodiversity monitoring system for combining biological, spatial, and risk-based evidence.

3.2 Ecosystem Condition

3.2.1 Overview

Ecosystem Condition is increasingly positioned as the cornerstone of nature reporting, acting as the critical nexus that connects species, climate, and water pressures to real-world outcomes. It's a multidimensional concept that spans 3 pillars: composition (which species are present and in what balance), structure (physical attributes and connectivity), and function/processes (flows and ecological interactions). [26]

In Phase One of the project, it was identified that CSRD-E4, TNFD, SBTN and GRI have mandatory ecosystem condition requirements (8 requirements total that can be partially answered by eDNA). However, specific indicators

[26] There are many methodologies to measure Ecosystem Condition, and these are beyond the scope of this report. Please see here for an overview of methodologies from the EU Align Project: https://capitalscoalition.org/wp-content/uploads/2025/06/Align_eco_condition_primer.pdf

or metrics are rarely prescribed.[27] For example, CSRD-E4 4-5 41(b)(i) (ecosystem condition relative to a reference), and 4-5 41(b)(iii) (structural components such as connectivity), SBTN - Ecosystem intactness/integrity (ecosystem structure, function, and composition) (table 6 or Phase 1 Excel Database). Thus, all 4 frameworks recommend assessing ecosystem structure, composition, function, and the pressures that influence them. TNFD and GRI reference example indicators, such as the Forest Structural Condition Index, Mean Species Abundance (MSA), and Accounting for Nature (Econd), to capture these dimensions. SBTN takes a broader approach, requiring measures of ecosystem integrity or intactness that integrate structure, function, and composition. GRI also expects companies to disclose site-level data on ecosystem type, area (in hectares), and condition for both the baseline year and the current reporting period.

Table 7 | Ecosystem condition reporting requirements where eDNA can partially/fully support the requirement

Sub-topic	CSRD-E4	TNFD	TNFD O&G	SBTN	GRI	GRI O&G	ipieca	CDP
Ecosystem Condition	E4-5 -41(b)(i) SBM 3 - 16(a)(ii) Appendix ESRS 2 IRO -AR 7(c)	A5.0 C5.0		Step 1& 2, Task 9: Biodiversity SoN indicators Step 1, Task 9: Pressure-sensitive SoN indicators	101-7a			

3.2.2 Applicability of eDNA

A complete assessment of ecosystem condition aligned with nature-related frameworks requires evaluating structure (physical organisation), composition (biological components), and function (ecological processes). No single technology can capture all three dimensions. A robust and defensible monitoring programme should therefore integrate multiple data sources, combining remote sensing, conventional surveys, eDNA, and bioacoustics, for example, to provide a holistic and verifiable picture of ecosystem health.

Within this context, eDNA can partially support ecosystem condition-related requirements across frameworks. It is most effective for assessing composition, offering early, scalable biological evidence of change. It also contributes to the functional pillar by identifying drivers of key ecological processes, such as microbes for nutrient cycling and pollutant breakdown, up to the identification of functional traits of herbivores and predators. However, eDNA alone cannot capture structural metrics (e.g., canopy height, connectivity, fragmentation), abiotic parameters (e.g., water chemistry, soil nutrients), or process rates (e.g., productivity, carbon and nutrient cycling). As such, eDNA should serve as the biological evidence layer within an integrated condition assessment that also incorporates spatial, chemical, and structural data.

3.2.2.1 Composition

For the compositional dimension of ecosystem condition, eDNA provides direct biological evidence of which species are present and how biodiversity is changing. By analysing DNA traces in soil, water, or sediment, eDNA can identify hundreds of species simultaneously, including rare, cryptic, or nocturnal taxa that conventional surveys often miss. In terrestrial systems, eDNA from soil or sediment reveals plant, fungal, and invertebrate communities that underpin habitat integrity and below-ground biodiversity. In marine and freshwater environments, eDNA captures multi-trophic biodiversity, from microbes to fish, without the need for netting or diving. Comparing eDNA

[27] The Nature Positive Initiative's State of Nature Metric framework, expected to be finalised in 2026, aims to provide more detailed guidance on measuring ecosystem condition.

results with baseline or reference datasets shows whether the biological condition is stable, recovering, or declining, for example, through the loss of sensitive species or the rise of tolerant or invasive ones.

When integrated with spatial and abiotic datasets, eDNA strengthens assessments across structure, composition, process, and pressure dimensions. However, the same limitations and practices to address them discussed above apply.

Visual and acoustic monitoring complement eDNA assessment of composition by adding temporal and behavioural insight: while eDNA confirms if a species is or was recently present, bioacoustics captures activity and calling frequency over time. Conventional surveys (e.g., transects, trapping) validate eDNA detections and provide demographic and behavioural context, such as abundance, health, or breeding status, that molecular methods cannot yet deliver. Remote sensing supports this pillar by mapping habitats that sustain species diversity, explaining spatial patterns in community composition.

3.2.2.2 Structure

For structural aspects of ecosystem condition, such as habitat connectivity, vertical complexity, and fragmentation, remote sensing is the primary measurement tool. Satellite and aerial data quantify metrics like canopy height, vegetation density, and landscape fragmentation across large scales. Conventional field surveys remain essential for calibration and ground-truthing, ensuring that mapped “green” areas correspond to healthy native vegetation rather than monoculture plantations.

eDNA plays a supporting role here. While it cannot directly measure physical attributes such as canopy height, vegetation structure, or landscape configuration, it can provide complementary biological context by revealing how community composition varies across structural gradients (e.g., edge vs. interior habitats). This integration helps link structural conditions to biological responses.

3.2.2.3 Function

Function represents the most complex pillar of ecosystem condition, encompassing the ecological processes and services that sustain ecosystem health, from microbial activity to landscape-scale productivity. Assessing these processes requires an integrated approach that combines biological, chemical, and spatial data.

Remote sensing provides a macroscopic view of ecosystem function by quantifying key biophysical processes over large areas. For example. it can be used to measure Gross Primary Production (GPP) to track rates of photosynthesis and carbon uptake, offering insight into the ecosystem’s overall metabolic performance. It can be used to track phenology, detecting the timing of seasonal events such as leaf-out and senescence to assess ecosystem responses to climatic or anthropogenic pressures. Together, these indicators provide a high-level understanding of how ecosystems function and change over time.

eDNA complements these observations by identifying functions performed by the microbial and benthic taxa, which are responsible for nutrient cycling, decomposition, and pollutant breakdown. This is particularly relevant for the O&G sector, where environmental monitoring extends to benthic and aquatic environments. Studies from offshore oil and gas sites confirm eDNA’s ability to detect shifts in bacterial and benthic eukaryotic communities that align with morphology-based results, often with greater taxonomic resolution. Moreover, in offshore operations, eDNA provides unique data on microbial and invertebrate communities, revealing pollution indicators, such as hydrocarbon-degrading taxa, thus directly linking industrial pressures to potential shifts in ecosystem function. Its capacity to identify pressure-indicator species (e.g. hydrocarbon degraders) makes it valuable for continuous ecological assessment. Based on NatureMetrics' experience and studies in the bibliography of this

report,for terrestrial assets, eDNA-based soil assessments provide essential insight into soil health and below-ground functional integrity, detecting biological complexity that conventional methods overlook[28] .

Bioacoustics adds a temporal and behavioural layer to functional assessment. By capturing animal activity patterns, such as the timing and intensity of dawn choruses or seasonal calling events, bioacoustics provides a real-time measure of ecological vitality and faunal participation in ecosystem processes. Visual monitoring can provide indirect indicators of ecosystem function through observations of activity patterns, feeding behaviour, or trophic interactions (e.g. predator–prey dynamics), though this remains qualitative rather than quantitative. Conventional surveys remain essential for direct measurement of key functional parameters, including biomass, soil carbon, infiltration rates, and water quality. These data sets calibrate and validate interpretations from eDNA and remote sensing, ensuring that observed functional changes correspond to measurable ecological outcomes.

The main limitation of eDNA in assessing function is its inability to quantify the rate or magnitude of ecological processes. While it identifies taxa and genes linked to specific functions, it cannot measure productivity, fluxes, or energy transfer directly. eDNA should therefore be viewed as an indicator of functional capacity rather than functional performance. When combined with other technologies, it provides a robust, multi-dimensional understanding of how ecosystems operate and respond to change.

3.2.2.4 Other topics within EC requirements

Within the Ecosystem Condition topic, certain requirements have been included even though they do not explicitly use the term 'ecosystem condition.' These requirements are briefly discussed below.

For site breakdown by impacts/dependencies and ecological status against a baseline (CSRD-E4 - SBM 3 - 16(a)(ii)), eDNA can help classify sites by their ecological status and sensitivity, revealing which locations support rare or habitat-specialist species and therefore have higher environmental dependency or risk. It strengthens site classification by identifying biological values that may not be captured through habitat mapping alone. Negative impacts on biodiversity can also be characterised with eDNA - Both in the soil and land itself by using soil eDNA tests, and in any connected waterbodies using aquatic eDNA tests. When combined with spatial and operational data (e.g., land cover, water use, emissions), it can explain why certain sites diverge from reference conditions, helping companies link ecological status with specific pressures or dependencies. This integration highlights sensitive species or communities and strengthens impact and dependency assessments by linking biological evidence to ecosystem condition and service use.

For ecosystem integrity and importance (SBTN - Step 1, Task 9: Pressure-sensitive SoN indicators), eDNA reveals how biologically intact an area is and identifies locations with high conservation value. It can detect threatened or range-restricted species that signal high ecological integrity, or early signs of degradation through changes in native and alien species balance. However, eDNA cannot fully measure structural or functional integrity without other datasets. SBTN informs that this requirement can be assessed directly using datasets describing ecological integrity or using datasets describing the degradation of ecosystems through human activities.

The limitations of eDNA are the same as those explored in the species section.

3.2.2.5 Comparison with other conventional biodiversity methods

eDNA provides a rapid, scalable, and cost-efficient approach for measuring the compositional component of ecosystem condition and partially the structural component. For a full understanding of ecosystem condition, eDNA

[28] Some studies here for reference are: https://www.biorxiv.org/content/10.1101/2025.08.28.672370v2.full.pdf; https://www.sciencedirect.com/science/article/abs/pii/S001393512401836X; https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2021.630560/full; https://royalsocietypublishing.org/rspb/article/287/1918/20192353/85416/A-comparison-of-eDNA-to-camera-trapping-for; https://pmc.ncbi.nlm.nih.gov/articles/PMC3568620/; https://pmc.ncbi.nlm.nih.gov/articles/PMC3568620/

results should be integrated with complementary tools such as remote sensing, LiDAR, and chemical or soil analyses to address structural and functional components of ecosystem condition. In summary, eDNA offers a high-efficiency, high-scalability solution for ecological condition monitoring and corporate biodiversity disclosure, best applied as part of a hybrid framework that combines molecular, structural, and functional indicators.

Table 8 | Evaluation of eDNA and other tools for ecosystem condition reporting requirements

Efficacy	High - eDNA effectively measures the compositional aspect of ecosystem condition by detecting community structure, species balance, and indicator taxa. It analyses multiple taxonomic groups from a single sample, providing higher detection consistency and taxonomic resolution than conventional surveys. In aquatic and terrestrial systems, it reveals microbial, benthic, and soil biodiversity often missed by conventional methods. Combining eDNA for compositional and functional data with spatial and structural metrics provides a best-practice, integrated approach to ecosystem condition assessment.
Efficiency	Very High - eDNA is far faster and less labour-intensive than conventional methods such as observation, trapping, or netting for assessing ecosystem condition. Sampling requires only short site visits and minimal expertise, with most analysis carried out in laboratories, cutting field time and manpower. Conventional surveys demand repeated visits and specialist identification across seasons, increasing cost and complexity. Standardised and repeatable eDNA protocols make monitoring baseline conditions and seasonal trends more efficient and affordable, a clear advantage for oil and gas operators managing large asset portfolios and long-term restoration programmes.
Scalability	Very High - Standardised eDNA protocols and high-throughput sequencing workflows make ecosystem condition monitoring scalable across portfolios and geographies. Data from multiple sites and sampling periods can be processed in a single analytical pipeline for consistent comparison. Conventional field surveys are far less scalable due to site-specific logistics, seasonal timing, and dependence on expert ecologists.
Cost-Effectiveness	Very High - Overall costs are lower because local staff or technicians can collect samples, reducing travel and field labour. Centralised laboratory processing and batch sequencing deliver substantial savings compared with conventional ecological surveys. Conventional methods require greater field effort, specialist taxonomists, and prolonged campaigns, resulting in significantly higher overall expenditure.
Sampling Efficiency	Very High - Field sampling for eDNA remains necessary but minimal. Only small volumes of soil, water, or sediment are collected, and campaigns can be scheduled seasonally or annually. Most processing, scoring, and reporting occur remotely. This uniform data collection method supports consistent, comparable ecosystem condition metrics across biomes, which is critical for global corporate reporting. Conventional surveys require prolonged on-site presence for species counting, habitat measurements, and repeat sampling, creating higher physical and time demands.

Table 9 | Evaluation of eDNA and other tools for ecosystem condition reporting requirements

Method Type	Efficacy (in relation to what it can measure)	Efficiency	Scalability	Cost-Effectiveness	Sampling Efficiency
eDNA (Aquatic, Marine & Terrestrial)	Captures the *compositional* pillar (community structure, native–alien balance, indicator taxa). Detects changes in microbial and benthic assemblages consistent with morphology-based surveys; limited for structure and function.	Requires short field visits and centralised lab processing; far faster than transect or plot surveys.	Standardised protocols and sequencing pipelines allow repeatable cross-site monitoring.	Field sampling is inexpensive; batch lab analysis reduces per-site costs.	Small water/soil samples needed; minimal field expertise required.
AirDNA	Effective for rapid compositional screening and detecting airborne biodiversity signals; low spatial precision for site-level conditions.	Passive collection via filters or pumps; fast deployment.	Supports continuous or wide-area monitoring.	Low-cost setup, moderate lab processing.	Minimal on-site labour; can be automated.
Conventional Visual and Acoustic Monitoring (camera traps, observers, bioacoustics)	Adds real-time functional data (activity, behaviour, presence of vocal taxa) supporting the *function* pillar.	Deployment and data analysis are time-intensive. Requires expertise	Scalable with automated sensors and AI classifiers.	Moderate hardware and data-processing costs.	Devices require placement and periodic maintenance.
Conventional Ecological Surveys	Strongest for *function* and *structure* validation (biomass, soil chemistry, hydrology, habitat quality).	Time-consuming and labour-intensive. Requires expertise	Limited by logistics, access, and specialist availability.	Expensive equipment, travel, and taxonomists.	Requires extended fieldwork and high manpower.
Remote Sensing	Dominant tool for the *structure* pillar (vegetation height, canopy cover, habitat extent, fragmentation).	Automated data collection over large areas.	Global coverage, repeatable at multiple temporal scales.	Moderate cost per site after initial setup; data freely available from satellites.	No field presence required; entirely remote.

3.2.3 Recommendations

To build a credible and actionable ecosystem condition framework, clients should integrate multiple monitoring technologies. Each method contributes unique strengths, together forming a scientifically robust and defensible system suitable for corporate reporting and site management.

- Use eDNA as the compositional core:
  Employ eDNA for comprehensive, multi-taxa detection across habitats and trophic levels. This provides the biological evidence base for condition assessments and early warning of ecological change.
- Leverage remote sensing for structural data:
  Use LiDAR, satellite, and hyperspectral imagery to quantify canopy height, vegetation density, habitat fragmentation, and land-cover change at scale. Ensure all models are calibrated with field data.
- Integrate bioacoustics and conventional surveys for functional insight:
  Apply acoustic sensors to track faunal activity and behavioural patterns, revealing trophic interactions and habitat use that other tools may miss.
  Apply conventional surveys for direct measurement of key functional parameters, including biomass, soil carbon, infiltration rates, and water quality.
- Retain conventional field surveys for validation:
  Continue targeted ground surveys to collect demographic, behavioural, and process-level data (e.g., biomass, pollination, soil activity). These are essential for verifying eDNA detections and remote sensing outputs.
- Develop a harmonised data framework:
  Establish protocols for sampling frequency, spatial alignment, and metadata management so results from each method can be integrated into a unified reporting system.

Table 10 | Complementary tools and methods for assessing ecosystem condition and integrity

Ecosystem condition component	Tool / Method	Purpose and Application	How It Complements eDNA	Key Benefits	Main Limitations
Composition	Visual and Acoustic Monitoring	Records vocal species (birds, amphibians, insects) and diel activity patterns. Camera traps and visual surveys are useful for detecting medium- to large-bodied vertebrates	Adds behavioural and temporal dimensions to eDNA species detections.	Continuous, real-time data; sensitive to disturbance.	Limited to vocal taxa; species identification requires AI/experts.
	Conventional Ecological Surveys	Provide demographic and abundance data.	Validate eDNA presence and support abundance estimates.	High accuracy; essential for validation.	Resource-intensive, small-scale.
	Remote Sensing (Habitat Typing)	Identifies broad habitat types supporting species assemblages.	Locates suitable areas for eDNA sampling and biodiversity hotspots.	Large-scale, high-resolution habitat maps.	Indirect; no species-level detail.
Structure	Remote Sensing (Multispectral, LiDAR, Radar/SAR)	Measures three-dimensional vegetation and habitat structure at scale.	Links eDNA species changes to habitat form and complexity.	Scalable, quantitative, time-series analysis.	May overlook fine-scale heterogeneity.
	Conventional Structural Surveys	Ground-based habitat and vegetation assessments. Providing detail that satellites cannot see.	Calibrates and validates remote-sensing measurements.	Provides local detail and accuracy.	Labour-intensive and costly.

Function	**Remote Sensing**	Monitors large-scale ecosystem processes such as productivity or evapotranspiration.	Contextualises eDNA results by showing functional changes in vegetation or hydrology.	Continuous global datasets; scalable for trend analysis.	Indirect proxies; limited mechanistic insight.
	Visual and Acoustic Monitoring	Tracks ecosystem activity and soundscape diversity linked to ecological functioning.	Provides a behavioural signal of ecosystem vitality complementary to eDNA.	Continuous, non-invasive; sensitive to degradation.	Requires expert processing; taxa limited.
	Conventional Ecological Surveys	Directly measure key functions (water quality, soil respiration, pollination rates).	Supply reference data for calibrating eDNA microbial and macrofaunal signals.	Ground-truths, remote-sensing and molecular data.	Resource-intensive; localised results.

3.3 Biodiversity sensitive areas

3.3.1 Overview

Biodiversity sensitive areas are typically identified because they contain protected species, habitats, or ecosystems recognised as valuable under legal or scientific criteria (e.g., Key Biodiversity Areas, IUCN categories, Natura 2000 sites, national reserves). The sensitivity comes from the biological or ecological value, such as the presence of threatened species, high endemism, or intact ecosystem functions. Habitat condition data (like vegetation cover or water quality) help assess how intact or degraded those sensitive areas are, not whether they are sensitive in the first place.

In Phase 1 of the project, it was identified that every major framework requires companies to identify sites located in or near areas of high biodiversity importance (Table 4). In addition to identification, some frameworks require companies to disclose quantitative information about the extent of a site's exposure to a sensitive area (e.g., hectares, % footprint, % reserves) as well as qualitative descriptions of the ecological importance of those locations.

Across frameworks, the 15 proximity requirements previously identified have a broader definition of "sensitive location" and do not depend solely on spatial overlap with mapped areas (Table 11). Therefore, while it is not typically relevant for the initial mapping of exposure, eDNA can provide critical biological evidence once sensitive sites are identified across these requirements. Consequently, eDNA is most powerful when used to validate the biological importance of mapped places and to detect change in biodiversity attributable to nearby activities, while spatial calculations (e.g., "distance to," "% footprint in/near," "% reserves overlapping") must be derived from GIS and other datasets (see section above for examples).

Table 11 | Biodiversity Sensitive Area reporting requirements where eDNA can partially/fully support the requirement

Sub-topic	CSRD-E4	TNFD	TNFD O&G	SBTN	GRI	GRI O&G	IPIECA	CDP
Biodiversity sensitive areas	SBM 3 - 16(a)(iii) ESRS 2 IRO-19(a) - Related AR 7d Appendix ESRS 2 IRO -AR 7(d)	Part of the LEAP approach, but not a metric in core or additional disclosures	OG.A1.2 OG.A1.3	Step 1 and 2, Task 9: Biodiversity SoN - State of Nature indicators (5 requirements)	101-5b (i) 101-5b (ii) 101-5b (iii)		ENV-4: C1	11.4

3.3.2 Applicability of eDNA

eDNA is aligned with the reporting requirements for biodiversity sensitive areas because, where appropriate markers and reference data exist, it provides direct biological evidence to verify whether sites designated or mapped as sensitive actually host the threatened, endemic, or indicator species that justify those designations.[29] While geospatial tools efficiently flag potential proximity risks, eDNA offers the biological validation step needed to confirm the current ecological reality. Mapped datasets such as protected-area layers, habitat integrity indices, or species-range models may not reflect current ecological conditions on the ground, potentially overstating species presence or underrepresenting cryptic/ migratory taxa, for example.[30] Recent evaluations indicate that modelled species-occurrence layers and habitat maps can diverge substantially from field-based detections, especially for cryptic taxa or in data-poor regions. [31]

By sampling water, soil, or sediment, eDNA can provide evidence on whether sites in or near protected areas, Key Biodiversity Areas (KBAs), endangered species habitats, high-integrity ecosystems, or ecological corridors still support the species and communities that underpin their classification. This adds a biological dimension to materiality assessments and proximity disclosures, complementing static maps with contemporary evidence of species presence. Repeated surveys can further reveal early signs of compositional change, such as the decline of sensitive taxa or the rise of tolerant species, supporting early detection of ecosystem disturbance near operations.

In marine and coastal systems, water and sediment eDNA cqn efficiently capture multi-taxa richness and detect cryptic or migratory species, improving the identification of species-rich zones. For example, eDNA metabarcoding and targeted assays are increasingly proposed and trialled for monitoring protected or priority sites (e.g. MPAs, freshwater reserves), where they can complement or partially substitute traditional methods to document communities and flag priority species.[32] On land, eDNA supports verification of KBAs, ecological corridors, and threatened-species habitats by confirming functional species use of these areas. For migratory and connectivity assessments, it can detect key species at critical nodes, verifying corridor functionality. Across all contexts, the method enables multi-taxa detection through metabarcoding, offering a community-level view of biodiversity composition rather than focusing on a few indicator species. This makes eDNA an effective, non-invasive, and scalable approach for terrestrial, freshwater, and marine environments, significantly reducing field time and improving coverage compared with conventional surveys (see comparison below).

Therefore, in terms of compliance and reporting, eDNA can increases confidence in disclosures by supporting the classification of biodiversity-sensitive sites with contemporary biological evidence. It can identify additional "priority areas" for conservation that are not yet captured in official registries, ensuring that proximity analyses reflect actual biodiversity importance rather than solely mapped designations. Operationally, eDNA strengthens risk assessment and management planning by confirming species presence near operational areas and helping define buffer zones, mitigation priorities, and monitoring needs. The examples in box 3 demonstrate eDNA strategic value.

---

[29] eDNA detection remains subject to primer performance, environmental conditions and the completeness of reference databases. It is not always possible to design highly sensitive and specific primers for all taxa in all ecosystems, particularly for hyper-diverse groups, poorly represented clades in reference databases, or communities with many closely related sympatric species. The best practice is to acknowledge this, use multiple markers/primer sets where feasible, replicate sampling, and interpret eDNA results within formal detection-probability or occupancy frameworks rather than as deterministic presence/absence. (https://www.nature.com/articles/s41598-019-40233-1, https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0059520, https://onlinelibrary.wiley.com/doi/10.1002/rra.3610, https://pmc.ncbi.nlm.nih.gov/articles/PMC7140814/, https://data.jncc.gov.uk/data/8345b6ce-6099-42f6-903c-32ce1e09e4db/JNCC-Report-699-FINAL-WEB.pdf)

[30] https://pubmed.ncbi.nlm.nih.gov/27250865/; https://nsojournals.onlinelibrary.wiley.com/doi/10.1111/ecog.04871; https://www.nature.scot/doc/habitat-networks-reviewing-evidence-base-final-report; https://conbio.onlinelibrary.wiley.com/doi/10.1111/csp2.12978 ; https://pmc.ncbi.nlm.nih.gov/articles/PMC9060555/

[31] https://pubmed.ncbi.nlm.nih.gov/27250865/; https://nsojournals.onlinelibrary.wiley.com/doi/10.1111/ecog.04871; https://www.nature.scot/doc/habitat-networks-reviewing-evidence-base-final-report; https://conbio.onlinelibrary.wiley.com/doi/10.1111/csp2.12978 ; https://pmc.ncbi.nlm.nih.gov/articles/PMC9060555/

[32] https://pmc.ncbi.nlm.nih.gov/articles/PMC7904164/, https://www.sciencedirect.com/science/article/abs/pii/S1617138122001984, https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/csp2.70000

Box 3 | Case Study 1

Portfolio-species detection NatureMetrics[33]

Anglo American implemented a **global eDNA** program with NatureMetrics across **15 sites in 11 countries** to achieve its Net Positive Impact target (see glossary). This approach helped the company identify previously unknown risks through improved species detection, enabling proactive mitigation and reducing potential regulatory and financial impact at sites that screened as high risk. Similarly, the **Compagnie des Bauxites de Guinée (CBG)** uses eDNA monitoring in Guinea to capture the presence of IFC Performance Standard 6 (PS6) target species with high certainty in areas critical to achieving its No Net Loss target.

Despite these advantages, eDNA has practical limits when applied to reporting requirements for biodiversity sensitive areas. It cannot independently quantify spatial overlap or measure the geometry of sites; spatial analyses must be performed using GIS or remote-sensing data. Nor does it directly measure habitat condition variables such as vegetation cover, soil integrity, or water quality, which are essential for assessing overall ecosystem health and resilience. Transported or residual DNA, particularly in aquatic environments, may misrepresent the exact source location, so detections must be interpreted within a hydrological or spatial context. Some listed or rare species may also lack suitable reference sequences in genetic databases,[34] limiting taxonomic resolution, though this limitation is reduced when working with providers which maintain curated reference libraries and accredited workflows. .Seasonal variation and changes in species detectability can affect accuracy across all biodiversity monitoring methods, including eDNA. For this reason, repeated sampling at different times of the year is advisable to ensure reliability and comparability.

Comparison with other conventional biodiversity methods

Compared with conventional biodiversity methods such as field surveys, camera traps, and bioacoustics, eDNA provides a rapid, sensitive, and cost-efficient approach for confirming species presence and assessing site sensitivity. It enables consistent, repeatable monitoring across projects and is particularly effective for site-level verification. While field sampling is still required, eDNA substantially reduces on-site effort, specialist input, and overall cost compared to conventional observation or trapping methods. When undertaking biodiversity sensitivity risk assessments for a portfolio of sites, these efficiencies can help to reduce overall costs. Remote sensing and GIS tools are essential for mapping overlap with biodiversity sensitive areas. Often, a prioritisation of biodiversity sensitivity across a portfolio will highlight locations where additional detail and evidence are needed, and in these cases, eDNA is a useful tool.

Table 12 | Evaluation of eDNA and other tools for biodiversity sensitive area reporting requirements

Efficacy	**High** - eDNA methods are generally more effective than conventional surveys for confirming species presence in biodiversity-sensitive areas, as they detect trace genetic material from organisms that may be missed by visual or trapping methods, providing higher detection certainty, especially for elusive or low-abundance species. eDNA cannot measure overlap with biodiversity-sensitive areas.

[33] How water can help fingerprint species at our mines–by Anglo American - NatureMetrics; Anglo American leveraging NatureMetrics 'eDNA' solution to improve biodiversity knowledge at Woodsmith - NatureMetrics; Microsoft Word - R1620009030_CBG_VSV_July 2020_Final_CLEAN_7_10_20.docx

[34] The main genetic databases referenced in eDNA analyses are the global nucleotide archives managed under the International Nucleotide Sequence Database Collaboration (INSDC), comprising GenBank, the European Nucleotide Archive (ENA) and the DNA Data Bank of Japan (DDBJ). These primary repositories are complemented by curated reference databases tailored to particular markers and taxonomic groups, including BOLD for animal COI barcodes, SILVA and PR2 for ribosomal markers in microbes and protists, and UNITE for fungal ITS sequences. For plants, algae and some regional biotas, project-specific reference libraries are often compiled from these sources to improve taxonomic resolution and local relevance.

Efficiency	**Very High -** eDNA is consistently faster and less labour-intensive than conventional methods such as direct observation, trapping, or netting for measuring priority sites. Sampling typically requires short site visits and minimal field expertise. Most analysis is done in central labs, significantly reducing field time and manpower. Conventional surveys, in contrast, demand repeated visits and expert-led species identification, often extending over multiple seasons.
Scalability	**Very High** - eDNA is more scalable than conventional methods such as direct observation, especially for large portfolios with a few high-risk sites. Standardised protocols and high-throughput sequencing enable simultaneous monitoring across many sites, habitats, and species. Repeated monitoring can be done efficiently using the same workflows.
Cost-Effectiveness	**Very High** - Costs are lower overall because a few local staff or technicians can collect samples, reducing travel and field labour. Centralised lab processing and batch analysis deliver substantial savings compared with conventional biodiversity surveys.
Sampling Efficiency	**High -** Physical samples still need to be collected in the field, but the effort is limited to small volumes of water, soil, or sediment. Most subsequent work, processing, sequencing, and reporting, occurs remotely. Citizen science or outsourced collection is feasible, further reducing resource demands.

Table 13 | Evaluation of eDNA and other tools for biodiversity sensitive area reporting requirements

Method Type	Efficacy	Efficiency	Scalability	Cost-Effectiveness	Sampling Efficiency
Aquatic eDNA (marine + freshwater)	Accurately confirms species presence and site sensitivity; cannot measure spatial overlap	Rapid sampling with minimal vessel time and automated processing No need for taxonomic expertise Reduced the time when many samples are processed simultaneously	Scalable across sites and seasons; suitable for large portfolio screening. Reduced costs when many samples are processed simultaneously	Substantially cheaper than ecological or imagery surveys.	Minimal sample collection, lower hazard and time. Sampling is more effective, independent of species activity and habitat The same samples can be used for surveying multiple taxonomic groups
Terrestrial eDNA	Reliable for presence confirmation. Stronger for soil invertebrates and microbes than for large vertebrates. cannot measure overlap; results vary by substrate and DNA persistence	Faster than trapping or camera surveys but requires careful site planning. Reduced the time when many samples are processed simultaneously No need for taxonomic expertise	Scalable when soil types and conditions are consistent; Reduced costs when many samples are processed simultaneously	Lower cost when multiplexed across sites	Minimal sample collection, lower hazard and time. Sampling is more effective, independent of species activity and habitat The same samples can be used for surveying multiple taxonomic groups
AirDNA	Effective for broad biodiversity screening; limited site specificity; cannot measure overlap	Rapid passive collection using filters or pumps	Suitable for wide-area or continuous monitoring	Low-cost deployment; moderate lab analysis	Minimal field effort; can be automated
Conventional Ecological Surveys *(trawls, quadrats, pitfall traps, electrofishing)*	Strong for quantitative ecological condition and abundance metrics; cannot measure spatial overlap	Slow and labour-intensive	Constrained by logistics and safety zones, it may not be feasible to measure a high number of prioritised sites	Expensive equipment, vessels, and taxonomists	High manpower and time demand

Visual and Acoustic Monitoring (camera traps, observers, bioacoustics)	Suitable for conspicuous or vocal species, but misses cryptic taxa; cannot measure spatial overlap	Time-intensive and dependent on visibility or species behaviour	Limited by detection range and environmental factors may not be feasible to measure a high number of prioritised sites	Moderate to high operational cost	High effort for setup and data review
Remote Sensing & GIS	Ideal for spatial analysis, mapping habitats, and accurately determining proximity BSAs. Species-level accuracy can differ and depends on underlying data quality and may not reflect current ecological conditions.	Rapid computational analysis once data is acquired and GIS models are built.	Inherently scalable from local to regional or global levels.	Low cost using free public data (e.g., Landsat, Sentinel) and open-source software, but usually for better high-resolution needs, commercial data.	No field effort; analysis is desktop-based, though it requires specialist expertise.

3.3.3 Recommendations

eDNA is a powerful biological validator and early-warning tool that strengthens biodiversity sensitivity mapping by confirming real species presence and ecological activity. Compared to conventional surveys, it offers higher scalability, faster sampling, and lower costs, making it particularly effective for verifying biodiversity-sensitive areas where conventional methods may miss species. However, eDNA does not replace spatial overlap analyses required by frameworks. The most robust approach combines eDNA with GIS-based footprint mapping and remote sensing to capture both biological significance and spatial proximity. While current practice often relies on desk-based screening, incorporating eDNA provides definitive field evidence, reducing the regulatory and financial risks of overlooking protected or endemic species.

Table 14 | Complementary tools and methods for assessing biodiversity sensitive areas

Tool Type	Tool / Method	Purpose (Confirm Biodiversity Sensitivity / Overlap)	How It Complements eDNA	Key Benefits	Main Limitations
GIS-Based Tools	Spatial Overlays, Proximity, and Risk Mapping	Identify biodiversity-sensitive zones and measure spatial overlap with operational footprints.	Links eDNA detections to mapped protected areas, KBAs, and legal designations.	Fast, scalable, and aligned with regulatory compliance; strong visual outputs.	Depends on data quality and update frequency; may miss local sensitivities.
Remote Sensing Tools	Habitat Condition & Integrity Mapping (satellite or drone)	Detect habitat loss, degradation, and fragmentation in and around operational sites.	Provides spatial context for eDNA detections showing biodiversity change or stress.	Consistent, repeatable, and suitable for landscape-scale monitoring.	Indirect; cannot confirm species-level changes.
	Marine Habitat Mapping (Sonar / Satellite)	Map seagrass, mangrove, coral, and other coastal ecosystems overlapping with operations.	Links marine eDNA detections to mapped habitat units and degradation patterns.	Broad coverage; effective for marine/coastal sensitivity mapping.	Lower accuracy in turbid or deep waters.
	Remote Sensing Time-Series (e.g. Global Forest Watch)	Track ecosystem integrity trends and detect new overlap or encroachment risks.	Interprets biodiversity loss detected via eDNA in terms of land-use change.	Regularly updated, globally standardised.	Limited to broad habitat types; indirect biodiversity proxy.
Conventional Ecological Surveys	Visual Surveys (Transects / Point Counts)	Confirm presence of indicator or protected species in identified sensitive areas.	Validates eDNA species detections and supports local sensitivity mapping.	Established and interpretable; direct observation.	Labour-intensive; observer bias; limited coverage.

	Vegetation Quadrats / Plot Sampling	Assess habitat quality, species richness, and structure within overlap zones.	Complements eDNA where plant or fungal taxa are underrepresented.	Quantitative and repeatable; supports habitat condition scoring.	Requires expertise; slow; site-limited.
	Electrofishing / Net Sampling	Verify aquatic species presence in at-risk water bodies.	Confirms eDNA aquatic detections and helps assess population status.	Provides abundance and biomass data.	Invasive; permits required; spatially limited.
	Pitfall / Malaise / Light Traps	Capture invertebrates to identify habitat sensitivity or degradation.	Supports eDNA by providing morphological species evidence.	Enables specimen archiving; standard method.	Taxon-specific; time-consuming.
Visual and Acoustic Monitoring	Camera Traps	Record fauna activity in areas identified as sensitive or overlapping with sites.	Provide behavioural and presence data validating eDNA detections.	Direct observation; supports compliance evidence.	Requires maintenance; limited detection range.
	Acoustic Monitoring (Terrestrial)	Detect calls of key species (birds, bats, amphibians) within sensitive areas.	Confirms species activity patterns supporting eDNA records.	Continuous, non-invasive; sensitive to elusive species.	Restricted to vocal taxa; data-heavy.
	Passive Acoustic Monitoring (Marine)	Monitor marine mammals and fish activity in sensitive or overlapping zones.	Confirms species use and temporal activity linked to eDNA detections.	Long-term, low-disturbance coverage.	Requires specialist processing; limited taxa range.

4 eDNA benefits for O&G

The oil and gas industry operates across highly sensitive and often remote terrestrial and marine environments, facing mounting regulatory scrutiny and pressure to demonstrate alignment with global nature-positive goals. eDNA technology offers strategic advantages that directly address the sector's unique operational and compliance challenges.

4.1 De-risking operations and enhancing regulatory compliance

eDNA delivers verifiable, site-specific biodiversity data that allows companies to move beyond generic risk assessments toward auditable compliance and proactive risk mitigation. By detecting species and ecological conditions early in exploration and planning, eDNA helps identify critical habitats and at-risk species before development begins. This supports the “Avoid” step of the mitigation hierarchy from the earliest stage. This proactively identifies biological risks that could otherwise lead to stop orders, fines, or loss of asset value during construction or operation.

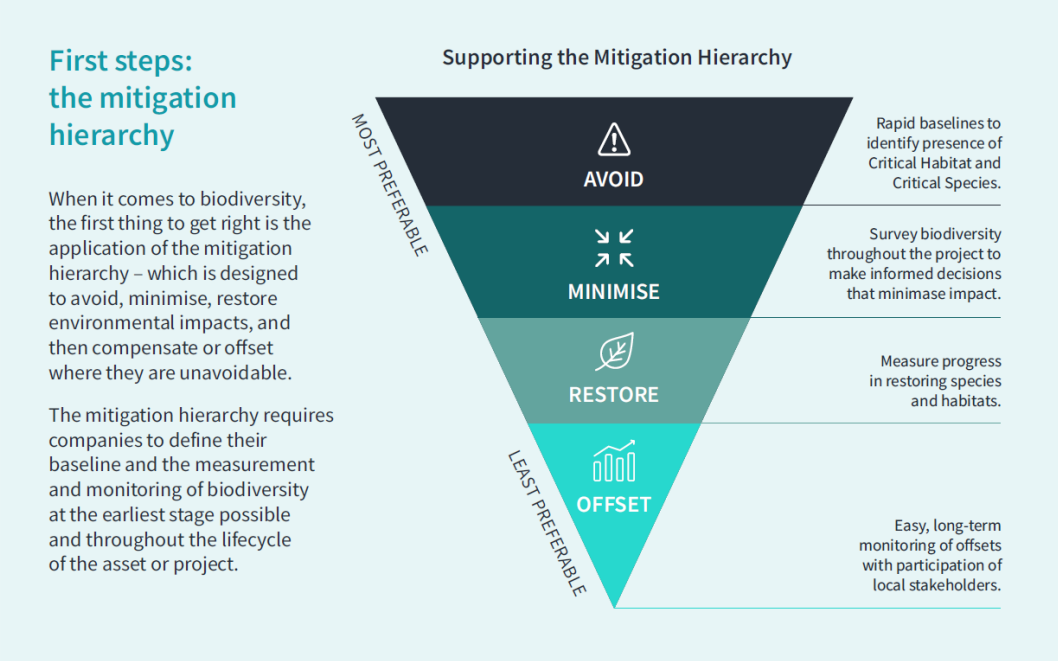


Figure 4 | eDNA & the mitigation hierarchy. Source: NatureMetrics guide to de-risking nature in the extractives sector

Applied consistently across exploration, permitting, construction, operations, logistics, and decommissioning, eDNA provides primary biological evidence from the first survey to post-closure restoration (fully supporting the mitigation hierarchy). This continuity enables earlier identification of risks and more targeted mitigation actions from the outset, strengthening decision-making across the entire value chain.

A key advantage of eDNA is its ability to detect a wide range of species groups, such as zooplankton, diatoms, aquatic macroinvertebrates, fish, mammals, amphibians, birds, bats, reptiles, and even the soil microbiome, far more comprehensively than conventional surveys, as discussed in this report (Figure 6).

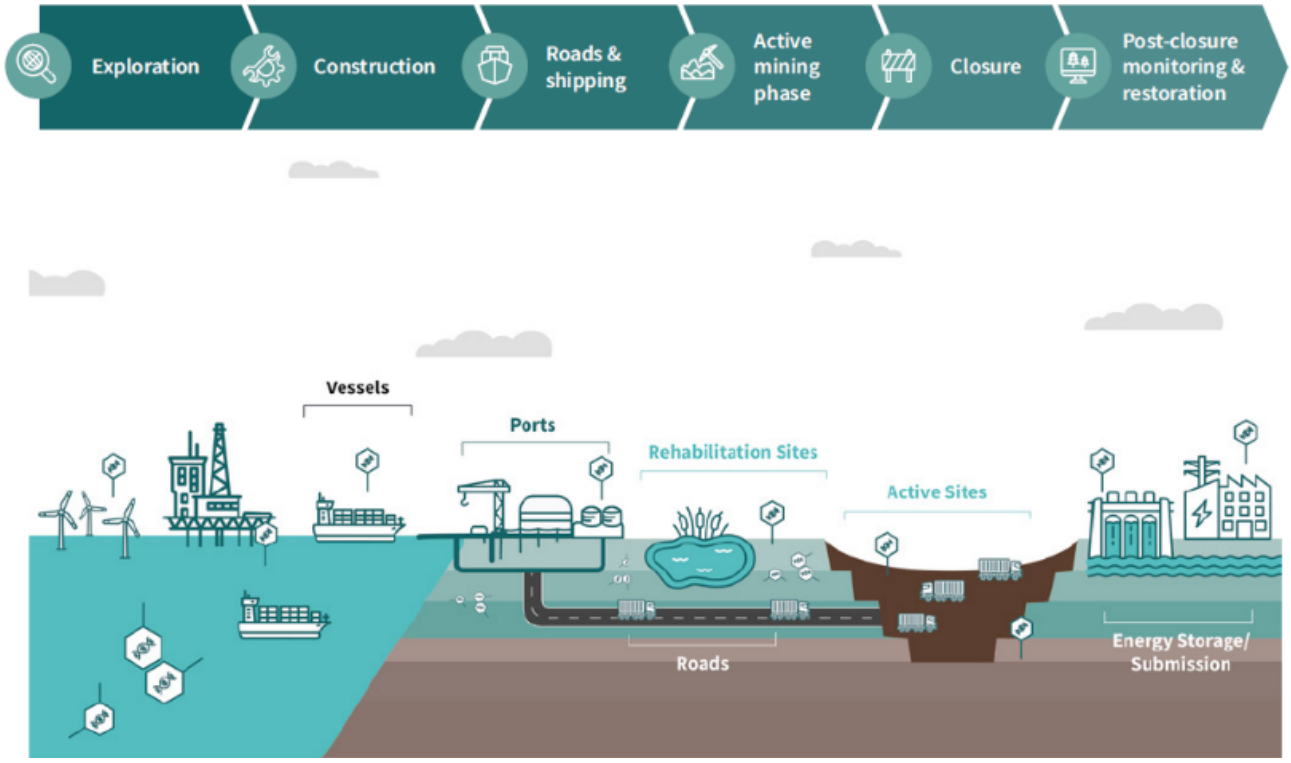


Figure 5 | eDNA can be applied across an asset life cycle. Source: NatureMetrics – Nature Intelligence for Extractives

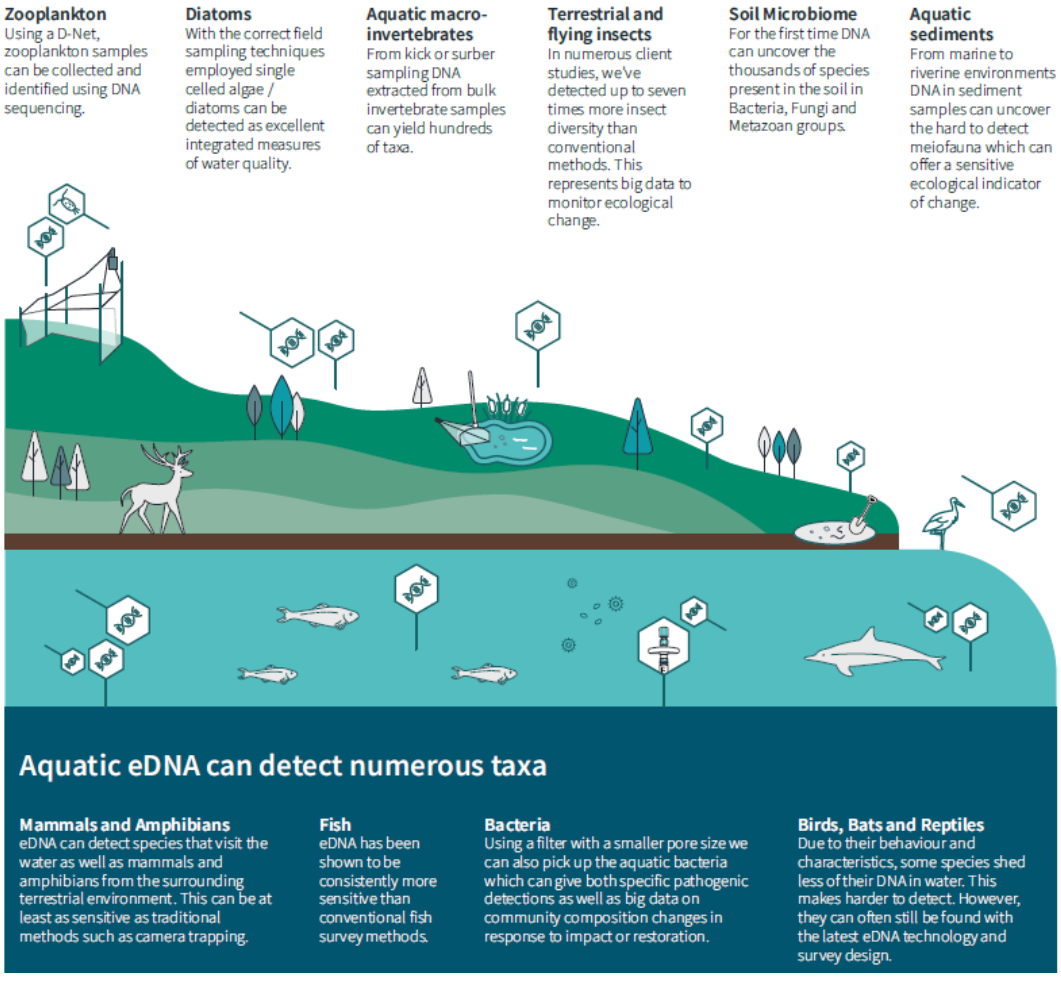


Figure 6 | DNA from complex biological samples can detect a range of species. Source: NatureMetrics – Nature Intelligence for Extractives. =

Case studies consistently show that eDNA programs detect significantly more species than conventional methods, providing a richer, more accurate baseline for Biodiversity Sensitive Area designations (Section 3.3) and Species reporting (Section 3.1). The EDF Renewables offshore wind farm pilot[35] showed eDNA detected 70% more species than trawling, providing deeper, faster, and cheaper data that reduces the risk of missed species and strengthens impact assessments and compliance.

The speed and efficacy of eDNA streamline the Environmental and Social Impact Assessment (ESIA) process. By rapidly generating comprehensive, auditable biodiversity baselines, eDNA helps fast-track regulatory approvals and avoids delays to operations. The cost and resource efficiency of eDNA sampling, requiring minimal training for non-specialist site personnel, allows for continuous, long-term monitoring across vast and remote asset portfolios, far cheaper than conventional expert-led surveys. This operational efficiency contributes to asset value preservation and allows for compliance monitoring across expansive global operations.

Finally, eDNA is a superior surveillance tool for detecting IAS early. For offshore and marine operations, where biofouling and vessel movement pose significant IAS risks, eDNA enables detection at incredibly low densities, long before visual inspection is possible, allowing for timely and cost-effective management and risk reduction.

4.2 Future-proofing metrics and reporting

The core reporting value of eDNA for the oil and gas sector lies in its ability to translate the complexity of nature into standardised, auditable metrics aligned with evolving global frameworks such as the TNFD and CSRD-E4. As these frameworks increasingly focus on ecosystem condition (Section 3.2), eDNA becomes the central technology for measuring biotic composition and ecosystem function. By capturing the interdependencies between nature, water, and climate, it provides a data nexus for demonstrating impact and progress in ways that conventional monitoring cannot achieve at scale or at comparable cost, labour, and time.

eDNA also addresses one of the long-standing barriers to biodiversity reporting: the lack of standardised, comparable data across global operations. By generating standardised data across all biomes, from marine sediments to terrestrial sites, eDNA addresses the historical problem of fragmented and incomparable biodiversity data across global operations. This standardisation simplifies aggregated corporate reporting for disclosures, enhancing transparency and strengthening corporate reputation and investor confidence through credible nature reporting.

eDNA is particularly valuable for monitoring and reporting on the end-of-life cycle for O&G assets. It can establish robust baselines before decommissioning and provide quantitative evidence of ecosystem recovery or Net Positive Impact following restoration efforts. This is essential for managing closure liabilities and demonstrating an environmental legacy that meets stakeholder expectations.

Operationally, eDNA also delivers measurable efficiency and cost savings compared to conventional survey methods, as evidenced in this report. Field sampling requires significantly fewer personnel and shorter site visits, resulting in major reductions in operational expenditure. A case study in the offshore marine environment from NatureMetrics showed a 40% reduction in vessel time and a 66% reduction in staffing while producing superior biodiversity data.[36] A NatureMetrics project with Anglo American estimated $12.4 million in savings credited to their eDNA program with NatureMetrics.Emerging technologies such as autonomous eDNA samplers are expected to amplify these gains by enabling continuous, unattended sample collection, reducing the need for repeat mobilisation, and providing higher-frequency biodiversity data at a fraction of the operational cost. As these systems mature, they are likely to deliver further reductions in vessel use and field personnel, strengthening the overall cost-effectiveness of eDNA-based monitoring programmes.

[35] Revolutionizing EIAs for Offshore Wind Farms with eDNA | NatureMetrics Success Story
[36] [36] https://www.naturemetrics.com/case-study/edf

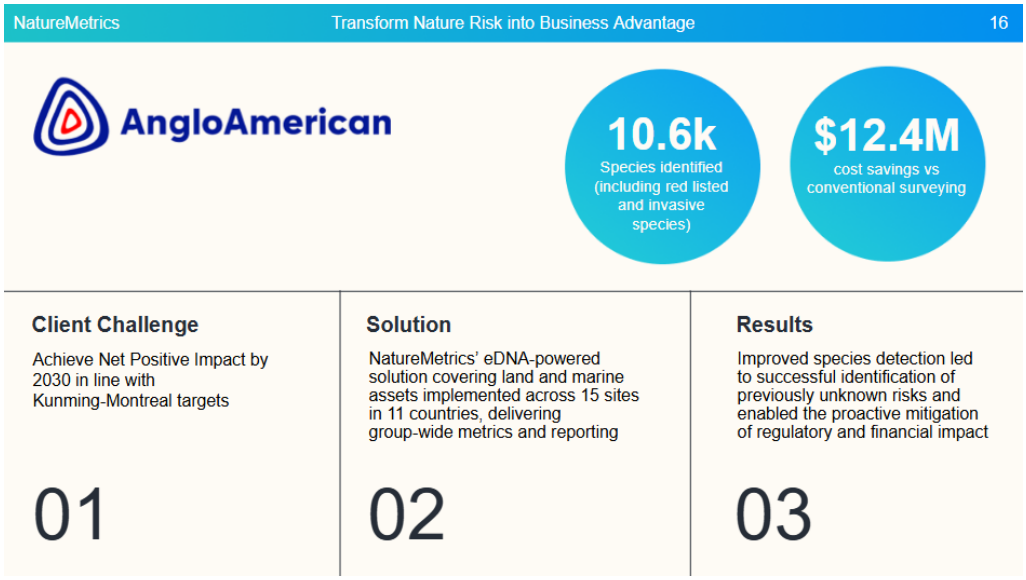


Figure 7 | Case study by NatureMetrics and Anglo American

Beyond efficiency, eDNA enables the oil and gas industry to move from broad environmental commitments to measurable, science-based performance metrics. These capabilities provide a foundation for data-driven decision-making, allowing companies to set and track meaningful long-term targets that support nature-positive and regenerative outcomes.

5 eDNA limitations & complementary technology

While eDNA offers unparalleled advantages in detection, standardisation, and speed for biotic reporting, it is not a panacea. Successful implementation, particularly for complex O&G operations and comprehensive nature disclosures, requires a clear understanding of its inherent limitations and the strategic use of complementary technologies to close the resulting data gaps.

5.1 Data gaps

The primary challenges with eDNA stem from the nature of the molecular information itself. These gaps directly impact a company's ability to meet reporting requirements for population metrics and physical ecosystem condition. Some key areas where eDNA does not measure towards requirements include:

1. Abundance data - eDNA measures the relative concentration of DNA fragments, which is not a direct measure of population size or biomass. This makes it difficult to meet absolute quantitative requirements, such as reporting on population size and range or changes in the number of individuals.

- Habitat structure - eDNA is a biological tool; it reveals what species are present but provides no information on the physical state of the habitat (e.g., canopy cover, water depth, physical degradation, or riparian zone health).
- eDNA persistence and transport - The longevity and movement of eDNA in the environment are influenced by local factors (temperature, flow, UV exposure). This can blur the boundary of the sampled area, creating false positives (DNA from a distant source) or false negatives (rapid decay), and these factors should be considered during the survey design for your sites.

  With the advent of metrics and indicator development, species identification is not always necessary in biodiversity monitoring. As outlined, the composite and aggregated metric and indicators not available using eDNA can focus on composition, structure and functional characteristics of an ecosystem, often providing more valuable insights and indicators of the health and resilience of the ecosystem. Presence/absence of species is useful for many appliations, however ecosystem condition is increasingly more relevant. We highlight some of the data gaps below, however these gaps are being closed as data is published and shared e.g. on GBIF:

  Incomplete taxonomic databases - Results may be limited by the available reference DNA libraries. If a species' DNA sequence is not in the database, the organism will be detected but not identified to species level. This leads to uncertainty in reported species richness and the verification of sensitive species. The largest taxonomic and geographic gaps in eDNA reference databases occur in hyper diverse tropical regions and among understudied invertebrate and microbial groups. In these cases, eDNA results remain valuable but should be interpreted with caution and, where possible, combined with traditional survey methods to improve species-level certainty.

  Major taxonomic gaps[37]

  Reference databases are most complete for vertebrates (especially birds and mammals) and well-studied fish, but show gaps in:

  - Invertebrates, especially insects, nematodes, and many marine invertebrates (e.g., crustaceans, molluscs, cnidarians).

[37] https://mbmg.pensoft.net/article/55162/; https://onlinelibrary.wiley.com/doi/10.1111/ddi.13142; https://academic.oup.com/bioscience/advance-article/doi/10.1093/biosci/biaf140/8251452?login=false; https://onlinelibrary.wiley.com/doi/full/10.1002/edn3.382

- Microbial eukaryotes (protists, fungi, microalgae) and bacteria/archaea, where many species lack any barcode sequence.
- Soil and detrital organisms (e.g., springtails, mites, enchytraeids, microarthropods), which are often poorly represented in public databases.
- Cryptic and morphologically similar species complexes, where even if sequences exist, they may not resolve to species level.

Major geographic gaps[38]

Reference libraries for eDNA are most complete in temperate, well-studied regions such as Europe, North America, parts of Australia, and coastal Japan. Coverage is similarly stronger in temperate marine and coastal habitats (North Atlantic, North Sea, Mediterranean, North American coasts),Well-studied lakes, rivers, and wetlands in northern latitudes also demonstrate high reference completeness for aquatic plants and many macroinvertebrates.

- Tropical freshwater systems, such as the Congo, Mekong, Amazon, and Mississippi basins, where fish diversity is high but many species (especially threatened ones) lack reference sequences.
- Tropical marine regions, including the Caribbean, East Africa, and parts of Southeast Asia, where many marine fish and invertebrates are missing from databases.
- Africa and parts of South and Southeast Asia, where both vertebrate and invertebrate coverage is lower than in Europe and North America, despite high biodiversity.
- Remote and under-sampled regions, such as high-mountain, deep-sea, and polar ecosystems, where sampling effort and sequencing are limited.

5.2 Common operational challenges

For O&G field teams, technical limitations mainly revolve around field execution and sample integrity, leading to costly data quality issues. Firstly, there is a contamination risk when working with eDNA, because eDNA analysis is highly sensitive. This could be contamination from the field team's own DNA, lab remnants, or nearby samples, and could be a common pitfall if not working with experts. A practical solution to this is to adhere strictly to validated, single-use, sterile sampling kits and protocols, which is non-negotiable for O&G staff, especially for compliance and baseline projects. Human DNA from field staff and other can also be excluded during bioinformatic processing, provided the study is designed with appropriate controls and filters.

In large operational areas, particularly in complex marine or delta environments, a single sample likely does not represent the entire ecosystem. It is important to design the eDNA sampling campaign based on expertise with the technology and local knowledge of the sites.

Finally, the eDNA output is, in its most basic form, a list of species and genetic read abundances. Without an in-house or consultancy-driven ecological context, this raw data is difficult to translate into actionable insights or reporting metrics (e.g., determining if a community shift is 'bad' or natural). It is recommended that O&G industry professionals work with experienced commercial providers who also integrate this level of results interpretation into the outputs, to make sense of the data.

[38] https://academic.oup.com/bioscience/advance-article/doi/10.1093/biosci/biaf140/8251452?login=false; https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2019.00337/full; https://www.naturemetrics.com/report-interpretation-guide; https://onlinelibrary.wiley.com/doi/10.1111/ddi.13142; https://www.nature.com/articles/s41597-020-0567-7; https://pmc.ncbi.nlm.nih.gov/articles/PMC10151745/; https://www.sciencedirect.com/science/article/pii/S2772735122000038; https://pmc.ncbi.nlm.nih.gov/articles/PMC10078450/; https://academic.oup.com/icesjms/article/80/10/2545/7394702?login=false; https://www.sciencedirect.com/science/article/pii/S004896972204654X; https://www.biorxiv.org/content/10.1101/2025.09.16.676481v1

5.3 Bridging data gaps with a multi-method approach for O&G disclosures

The most robust and auditable nature disclosures utilise eDNA's strengths while systematically compensating for its weaknesses using complementary tools. By strategically integrating these technologies, O&G companies can move from single-method data points to a holistic, verifiable dataset that meets the complex demands of frameworks like TNFD, CSRD-E4, and SBTN.

Table 15| A multi-method approach to O&G disclosure where there are data gaps

eDNA limitation (data gap)	Complementary technology	Benefit to eDNA outcome	Reporting requirements satisfied
No habitat structure/extent	Remote sensing (satellite, drone)	Provides the essential physical *context* (extent, land cover, habitat degradation, fragmentation) to interpret eDNA results.	Ecosystem Condition (structure, extent). BSA (footprint vs. protected area boundary).
No direct abundance (quantity)	Acoustics & camera traps	Provides direct, visual counts and behavioural data for specific high-profile taxa (e.g., mammals, birds, fish). Used for calibration and confirmation of eDNA signals.	Species (population size and range, abundance metrics). Ecosystem Condition (biomass proxy).
Taxonomic incompleteness	Conventional field surveys	Used selectively to confirm the presence of unassigned (or cryptic) species found by eDNA, allowing DNA to be sequenced and added to the reference database.	Species (verification of CITES/Red List species). BSA (ground-truthing key indicator species).
Dispersal & persistence uncertainty	Physicochemical sensors	Provides real-time data on temperature, flow, pH, and turbidity. This data is critical for modelling eDNA transport and half-life, improving the precision of interpretation.	Operational impact monitoring (linking timing of effluent release to biotic change).

6 Conclusions

This report demonstrates that environmental DNA (eDNA) represents an advanced and practical tool evolving and scaling rapidly to meet corporate biodiversity measurement and reporting requirements under frameworks such as TNFD, CSRD-E4, and SBTN. Across all categories assessed—Species, Biodiversity-Sensitive Areas, and Ecosystem Condition—eDNA shows consistently high efficacy, efficiency, scalability, and cost-effectiveness compared with conventional biodiversity monitoring methods.

eDNA provides reliable biological evidence where conventional field surveys are often constrained by time, cost, or taxonomic scope. It transforms biodiversity monitoring from a fragmented, expert-dependent activity into a standardised, data-driven process that can be scaled across global operations. For sectors such as oil and gas, where environmental risk and regulatory scrutiny are high, eDNA enables earlier detection of critical habitats, faster baseline establishment, and stronger proof of restoration outcomes.

However, eDNA is not a stand-alone solution. It should be implemented as part of a multi-method monitoring system that integrates remote sensing, bioacoustics, and targeted field surveys. This combination ensures full coverage of the compositional, structural, and functional dimensions of ecosystem health.

By embedding eDNA within corporate environmental management and disclosure processes, companies can shift from reactive compliance to proactive, evidence-based nature performance. This approach provides the clarity and accountability investors, regulators, and communities increasingly expect, and positions eDNA as a cornerstone technology for achieving credible, measurable, and nature-positive outcomes.

7 Appendix

7.1 Methodology

This assessment evaluated the applicability of eDNA for each of the 69 biodiversity-related requirements identified in Step 1 of the project. The methodology combined scientific literature review, expert judgment within NatureMetrics, and framework mapping to determine the degree to which eDNA can generate, support, or complement the data required under leading nature-related frameworks (Table 1).

Table 16 | Frameworks Analysed

Framework	Referenced in the document
Corporate Sustainability Reporting Directive (CSRD-E4) – European Sustainability Reporting Standards (ESRS) E4 Biodiversity and Ecosystems standard;	CSRD-E4
Taskforce on Nature-related Financial Disclosures (TNFD)	TNFD
Taskforce on Nature-related Financial Disclosures - Oil & Gas sector guidance;	TNFD O&G
Science-based Targets for Nature – Step 1: Assess and Step 2: Prioritise [39]	SBTN
Global Reporting Initiative - Biodiversity Standard 2024	GRI
Global Reporting Initiative - Oil and Gas Standard 2021	GRI O&G
"Sustainability Reporting Guidance for the Oil and Gas Industry" (Module 4 Environment -2025 ipieca/ API / IOGP	ipieca
CDP - Module 11: Environmental Performance – Biodiversity	CDP

Each requirement was assessed through a structured analytical matrix designed to ensure scientific consistency and transparency. The evaluation framework addressed the following guiding questions and criteria:

1. Can eDNA measure this requirement? (Y/N)
   A binary assessment determined whether eDNA could fully, partially, or not at all measure the biodiversity indicator in question. "Yes" indicates that eDNA can directly generate the required data (e.g., species presence, community composition), while "Partial" denotes indirect or supporting measurement capacity.
2. How eDNA can measure or partially measure this requirement
   A concise description of how eDNA can be applied to measure or partially measure each requirement, outlining both its scientific function and practical implementation. This includes a short explanation of how eDNA can be used to address the requirement, such as detecting species presence, community

[39] We focus on Steps 1 and 2 because they form the diagnostic stage of the SBTN process. These steps involve measuring a company's impacts and dependencies on nature, then prioritising the places and pressures where action is most needed. Without this evidence base, later stages risk being misdirected or ineffective. Steps 3 to 5 move into action—setting targets, implementing interventions, and monitoring progress—but they depend on the clarity and accuracy established in the diagnostic phase. By getting Steps 1 and 2 right, companies can ensure that their targets are credible, aligned with science, and focused where they will have the greatest impact.

composition, or ecological condition, and where relevant, identifying other tools (e.g., remote sensing, acoustic monitoring, or field surveys) that may be needed to complement eDNA and fully meet the data requirements.

3. Benefits and limitations of eDNA for the specific requirement
   Each requirement was evaluated in terms of its main benefits and limitations of using eDNA, with a maximum of five identified per requirement. This approach allows for a focused yet thorough assessment of how eDNA performs in relation to each specific metric, without extending into a comprehensive analysis of all possible advantages and constraints of the method. The benefits and limitations described are therefore directly linked to the context and data needs of each specific requirement, reflecting how eDNA contributes to, or is constrained in, meeting the intended measurement or reporting objective
4. Integration with other nature-tech tools
   Each requirement was evaluated for its potential integration with complementary conventional biodiversity methods, such as remote sensing and acoustic monitoring. While this assessment is not exhaustive—given the wide range of available technologies beyond the scope of this project—it identifies the most relevant and established approaches that have been effectively applied to support or enhance the specific measurement of the requirement. The aim is to highlight best-practice combinations where eDNA can be synergistically used with other tools to improve data accuracy, spatial coverage, and temporal resolution in biodiversity monitoring and reporting.

5. Operational efficiency compared to conventional biodiversity methods/tools. To evaluate implementation feasibility, four practical attributes were reviewed for each requirement:
   - Efficacy: It means how well something works at achieving its intended result. High efficacy means the method consistently produces valid, dependable results — for example, confirming that a particular species is present when it actually is.
   - Efficiency - Labour and time efficiency: Whether eDNA could be implemented with reduced field effort compared with direct observation, camera traps, or physical specimen collection.
   - Scalability: Whether the method can generate large, standardised datasets across multiple taxa and ecosystems using harmonised protocols.
   - Cost-Effectiveness: Whether fewer field visits and reduced reliance on taxonomic specialists would lower total survey and reporting costs.
   - Sampling Efficiency: Whether data is collected remotely or over site-based samples. This was compared with the relative effort required for conventional biodiversity monitoring.

The outcome of this methodology is a detailed, evidence-based evaluation of where eDNA provides strong measurement potential, where it acts as a partial or complementary tool, and where conventional ecological methods remain essential. This structured approach supports transparent decision-making on the integration of eDNA within biodiversity monitoring strategies and nature-related disclosure frameworks.

The recommended methodologies, including sampling approaches and analytical design, will be presented in the final phase of this project. That stage will focus on developing a practical framework for reporting biodiversity metrics effectively, whether through the use of eDNA alone or in combination with conventional monitoring methods and other nature-tech tools, to ensure robust, scalable, and decision-relevant biodiversity data.

7.2 Efficiency, Scalability, and Effort of eDNA Compared to Conventional Biodiversity Monitoring across State Requirements

Environmental DNA represents a substantial efficiency improvement over conventional biodiversity monitoring techniques such as direct observation, trapping, and camera surveys (For full in-depth research on this topic, see the IOGP report - Efficacy of eDNA vs Conventional Monitoring Methods). Conventional methods typically require extensive field time, taxonomic expertise, and long-term deployment, whereas eDNA compresses much of the effort into rapid sample collection followed by laboratory-based analysis. While spatial datasets and GIS-based screening tools can automate the identification of sensitive zones remotely, they lack biological confirmation—eDNA fills this gap by providing empirical, species-level evidence with much less labour and time. Therefore, eDNA delivers its largest efficiency gains when the objective is to quickly and consistently map presence/occupancy, screen for threatened species, validate overlaps with sensitive areas, and track compositional change across many sites and seasons, especially in freshwater and marine systems and for portfolio-level governance and risk questions. Where the requirement shifts to quantitative abundance or population-level dynamics, eDNA remains valuable, but the efficiency advantage becomes conditional on upfront calibration and/or usage of conventional.

Overall, eDNA is markedly more efficient and scalable than conventional biodiversity monitoring methods. It reduces field time and labour, decentralises data collection, and centralises expert analysis, offering a practical, cost-effective, and scientifically credible solution for portfolio-scale biodiversity assessment.

Efficacy

eDNA offers much higher efficacy for species detection than conventional biodiversity survey methods such as visual observation, acoustic monitoring, or trapping. Conventional surveys rely on directly seeing, hearing, or capturing organisms, which often miss rare, cryptic, or low-density species. eDNA, by contrast, detects genetic traces that organisms leave behind in water, soil, or sediment. This makes it particularly effective for confirming presence in habitats where visibility, accessibility, or detectability is low. For instance, amphibians or benthic fish that are seldom observed visually can be reliably detected through small-volume water samples collected at site boundaries or downstream points.

Because a single eDNA survey can detect multiple taxonomic groups at once, it achieves broad biodiversity coverage with fewer samples. Each sample captures DNA from the surrounding environment, providing an integrated record of species presence over time and space. Conventional visual and acoustic surveys and ecological surveys, by contrast, typically require multiple methods to cover different taxa, which increases effort and variability across observers and locations.

Field efficiency also contributes to eDNA's overall efficacy. Sampling can be done within hours by small teams or trained non-specialists, while all taxonomic identification occurs through standardised DNA sequencing in accredited laboratories. This reduces dependence on specialist field expertise and ensures consistent detection quality across sites. Because laboratory workflows apply uniform quality controls and reference databases, the probability of missing a species due to human error or observer bias is much lower than in field-based identification.

Acoustic and visual monitoring remain valuable for measuring abundance, behaviour, and population structure, data that eDNA cannot yet provide without calibration. However, their detection efficacy is limited by environmental conditions (e.g., noise, light, vegetation cover) and species behaviour (e.g., silent or inactive phases). In contrast, eDNA detects species regardless of activity level, allowing for more reliable presence/absence data across seasons.

This difference makes eDNA especially useful for early detection of threatened or invasive species, where rapid and accurate confirmation is critical.

Despite these advantages, eDNA efficacy depends on sound sampling design. DNA degrades over time and can move through water or soil, potentially diluting spatial precision. Results are also constrained by the completeness of reference DNA databases used for taxonomic assignment. For these reasons, eDNA is most effective when integrated with targeted visual or acoustic verification, combining broad, sensitive detection with confirmatory field evidence when required for regulatory or management purposes.

Time and Labour Efficiency

Conventional biodiversity surveys, such as transect walks, point counts, or camera trapping, can take weeks or months of sustained fieldwork to cover a single site or species group. In contrast, eDNA sampling requires only short site visits: water, soil, or sediment samples can be collected within hours by a small team or even by trained non-specialists. depending on site accessibility and sampling design. Sampling water, soil, or sediment at site boundaries or downstream areas allows biodiversity data to be gathered rapidly without the need for extensive visual observation or species-specific capture methods. This efficiency extends to threatened species detection, where minutes of eDNA fieldwork can generate data that would otherwise require multiple days of intensive field surveys.

Because a single eDNA survey detects multiple taxonomic groups simultaneously, it requires fewer samples than conventional multi-method surveys to achieve the same coverage. Each sample represents a spatially integrated snapshot of the community within a given medium (e.g., a river reach, pond, sediment layer), meaning fewer samples are required than for conventional species-by-species surveys.

Field visits are generally brief, often completed within a few hours, and the bulk of analysis (DNA extraction, sequencing, and bioinformatics) occurs centrally in accredited laboratories. This approach eliminates the need for prolonged on-site identification and greatly reduces travel and personnel costs.

This shift in workload from field to lab offers a major efficiency gain. eDNA can detect entire communities, including rare or cryptic species that would otherwise require multiple specialist surveys. eDNA offers strong efficiency benefits in freshwater fish and amphibian monitoring. Short visits during appropriate seasons (e.g., amphibian breeding) and simple bottle or soil/sediment sampling reliably generate large, multi-species datasets without specialist field teams. In marine and coastal environments, rapid water/sediment sampling avoids labour-intensive netting, diving, or trapping, with HTS pipelines enabling multi-site, multi-season coverage at low incremental cost. These aquatic settings are among the most operationally efficient deployments because DNA disperses into the medium being sampled. Terrestrial applications (e.g., soil or dust eDNA) can similarly detect taxa that are cryptic, nocturnal, or seasonal, avoiding extensive trapping or visual surveys. As a result, eDNA achieves broader biodiversity coverage with a fraction of the field effort.

Conventional biodiversity surveys, such as visual observations, camera trapping, mist-netting, or acoustic censuses, remain the most direct approach to recording species presence, abundance, and behaviour. They provide fine-scale insights into species demography, habitat use, and behaviour, including nesting, feeding, or reproductive activities. Conventional methods are also critical for verifying the presence of legally protected or cryptic species where visual confirmation is required for regulatory or permitting purposes.

However, these techniques are labour- and time-intensive, typically requiring multiple field campaigns and taxonomic specialists. Survey effort often varies by taxa and season, demanding long-term or multi-method campaigns to achieve representative coverage. At large spatial scales or across multiple project sites, this approach becomes prohibitively resource-intensive and inconsistent, especially for taxa that are nocturnal, rare, or difficult to observe. While conventional surveys remain indispensable for abundance estimation, behavioural studies, and

formal ecological impact assessments, they are unsuited for portfolio-scale biodiversity screening or repeated, standardised monitoring.

Caveats: Despite these advantages, eDNA still requires physical sample collection at each site, unlike fully remote tools such as GIS or satellite imagery. Field access is therefore still necessary, though the required duration and manpower are much lower. In dynamic or hydrologically complex environments, sampling design must account for DNA transport and degradation, which can affect localisation of species presence. Finally, eDNA alone cannot determine abundance or population size without calibration against conventional data (e.g., camera traps or mark–recapture studies).

Scalability and Portfolio Coverage

A key advantage of eDNA is its scalability across sites, seasons, and ecosystems. Standardised sampling kits and operating procedures enable consistent collection across large portfolios, ranging from terrestrial and freshwater systems to coastal and marine environments. Standardised sampling kits and laboratory workflows enable consistent application across dozens or hundreds of locations, allowing portfolio-wide biodiversity screening.

From a scientific monitoring perspective, eDNA is most effective when repeated over time to track community shifts. Quarterly to annual sampling is typically recommended for compliance or long-term biodiversity assessments, depending on ecological turnover and operational impacts.

- High-dynamics systems (e.g., rivers or estuaries) benefit from quarterly sampling to capture seasonal variation and hydrological influence.
- Stable terrestrial or marine benthic environments can often be monitored annually, aligning with corporate or regulatory reporting cycles
- Baseline (pre-impact) sampling should ideally occur at least twice before operations begin, followed by post-impact monitoring at the same frequency for trend analysis and statistical comparison.

Because of its scalability, hundreds of samples can be processed simultaneously through high-throughput sequencing (HTS – see glossary), allowing broad taxonomic coverage and time-series monitoring without exponential cost increases. This scalability supports a move from isolated site surveys to strategic, landscape-level biodiversity assessments. eDNA datasets can feed directly into corporate natural capital accounting, compliance reporting, or TNFD-aligned risk screening. Because samples can be collected rapidly and processed centrally, eDNA reduces both time and cost per unit of biodiversity data collected compared with repeated observational or trapping campaigns.

This uniformity of methods means that a single field protocol and analysis pipeline can be applied at local, national, or global scale, ensuring comparability of results across projects and reporting periods. Seasonal or periodic sampling is typically sufficient for most biodiversity indicators, allowing companies to align monitoring cycles with annual or semi-annual reporting. eDNA also lends itself to portfolio-level screening, identifying priority sites for further investigation while reducing duplication of effort across operations. When combined with GIS or remote-sensing data, eDNA can provide a biological validation layer, confirming whether mapped sensitive areas are ecologically active.

Caveats: While eDNA scales efficiently in processing and analysis, ecological interpretation does not always scale linearly. For example, relative-abundance estimates and ecological-condition metrics may require ecosystem- or species-specific calibration. In addition, the quality of results depends on reference library completeness, in poorly studied regions or for understudied taxa, species identification may be limited to higher taxonomic ranks. Therefore, portfolio-scale eDNA programmes should be complemented with ground-truthing and local ecological validation to ensure reliable interpretation.

Expertise and Cost Requirements

Unlike conventional biodiversity surveys, which depend heavily on specialist taxonomists in the field, eDNA requires minimal expert presence on site. Sampling can be undertaken by trained technicians, local staff, or citizen scientists using standardised procedures. Specialist expertise is primarily concentrated in laboratory analysis, bioinformatics, and ecological interpretation. This division of labour significantly reduces costs, since the most resource-intensive components, taxonomic identification, data quality control, and ecological modelling, are centralised and performed by a small number of experts rather than distributed field teams.

The cost efficiency of eDNA increases with scale. Once established, the same analytical workflow can process hundreds of samples, achieving economies of scale that conventional surveys cannot match. Furthermore, because sampling is rapid and requires only basic training, local capacity can be built easily, allowing biodiversity monitoring to be integrated into existing environmental management routines or outsourced to partners without compromising data integrity. This model allows organisations to redirect specialist expertise toward higher-value interpretation and decision support rather than routine fieldwork.

Caveats: eDNA efficiency depends on robust laboratory quality assurance/quality control, contamination controls, and skilled bioinformatic support. Errors in sample handling or processing can lead to false positives or negatives. In early project stages, initial calibration or joint sampling with conventional methods may increase costs and time before routine workflows become fully optimised. Furthermore, some legal or compliance contexts may require confirmatory visual records of protected species, meaning eDNA cannot yet fully replace conventional field validation in all jurisdictions.

Remote and Centralised Data Handling

Unlike GIS or remote sensing, which provide continuous spatial coverage but rely on indirect proxies (e.g., vegetation indices, land-cover classification), eDNA requires physical sample collection to detect species presence directly. Although physical sampling still requires site access, the process is rapid and non-invasive. Samples can be collected remotely via local partners or citizen science networks and shipped under cold-chain conditions to central labs. Analysis and reporting can then be fully centralised, allowing global portfolios to maintain consistent, comparable biodiversity datasets from multiple regions.

In contrast to camera traps or field-based surveys that must remain deployed or staffed over long periods, eDNA sampling can be completed quickly by local teams or citizen scientists, while analysis and data integration (e.g., with GIS or biodiversity databases) are performed off-site. This hybrid model, local collection, remote analysis, minimises travel-related emissions and operational costs while maintaining high scientific reliability.

Some organisations, including those in extractives and infrastructure sectors, now employ outsourced eDNA sampling models, where laboratories provide field kits and remote training, enabling local or in-country teams to collect and return samples with minimal oversight. This reduces carbon emissions from travel and speeds up project deployment.

Caveats: eDNA is not a remote data source; physical site access is always required. Results can also be influenced by hydrology, soil transport, and degradation rates, which may complicate interpretation in highly dynamic systems. While centralisation streamlines quality control, it also creates logistical dependencies on laboratory infrastructure and shipping networks, which may pose constraints for rapid reporting or remote regions with limited cold-chain capacity. Finally, eDNA's strengths lie in detecting species presence and community composition; it should be used in combination with remote-sensing and ecological datasets to capture ecosystem structure, function, and causal drivers of change.

GIS and Remote Sensing tools (not included as conventional biodiversity monitoring methods)

It is important to distinguish eDNA from GIS and remote-sensing tools. GIS and remote sensing are largely remote and proxy-based: they provide continuous spatial coverage, prioritisation layers and habitat condition indicators (e.g., fragmentation, productivity, edge effects) without any site visit. eDNA requires physical sampling on site. The value of eDNA is complementary rather than substitutive: it supplies the species-level biological confirmation that spatial datasets cannot, thereby validating sensitive-area designations, sharpening habitat polygons used in overlap calculations and evidencing biotic responses near operational boundaries. In effect, GIS and remote sensing define *where* to look and frame likely pressures, while eDNA confirms *what lives there now* and how communities are changing. GIS and remote sensing accuracy is often limited by spatial resolution and dataset update frequency, particularly in fast-changing or poorly mapped regions. Consequently, while GIS and remote sensing provide excellent context and prioritisation, they must be complemented by biological evidence to validate ecological relevance and regulatory compliance.

8 Glossary

1. α-/β-diversity: Measures of biodiversity: α-diversity refers to species richness within a site, while β-diversity compares differences in species composition between sites.

2. AirDNA: Airborne environmental DNA collected from filters or air pumps to detect organisms such as plants and insects in terrestrial environments.

3. Bioacoustics: Monitoring method using sound to detect, identify, and track species presence or activity through vocalisations.

4. CDP (Carbon Disclosure Project): A non-profit platform for environmental disclosure where companies report on climate, water, and biodiversity performance to investors and stakeholders.

5. Conventional Ecological Surveys: Traditional biodiversity monitoring methods, such as visual observation, trapping, quadrats, transects, electrofishing, or netting, used to record species presence, abundance, and behaviour. These surveys provide essential ground-truthing and complement eDNA and remote-sensing data.

6. Conventional Methods: In this report, these refer to traditional biodiversity monitoring approaches that rely on direct observation or physical evidence. They include ecological surveys (e.g. transects, trapping, quadrats, netting), bioacoustics (audio monitoring of species vocalisations), and visual monitoring (camera traps, drone imagery, or field observation).

7. Corporate Sustainability Reporting Directive – ESRS E4: Biodiversity and Ecosystems (CSRD–E4): EU regulation requiring companies to disclose on a wide range of topics, including climate and environmental data in the EU. ESRS E4 is a sustainability reporting standard under CSRD that requires companies to report on their impacts, dependencies, risks, and opportunities related to biodiversity and ecosystems

8. Ecosystem Condition (EC): An indicator of ecosystem health based on structure (physical characteristics), composition (species and community diversity), and function (ecological processes).

9. eDNA (Environmental DNA): Genetic material obtained from environmental samples (e.g. soil, sediment, or water) that can be analysed to identify species present without direct observation or capture.

10. eDNA Metabarcoding: A method that amplifies and sequences multiple DNA fragments from an environmental sample to identify entire biological communities, allowing broad biodiversity assessments.

11. eDNA qPCR/ddPCR (Quantitative / Digital Droplet Polymerase Chain Reaction): Techniques used to detect and quantify specific target species in an environmental sample. qPCR measures DNA concentration in real time, while ddPCR partitions samples into thousands of droplets for higher sensitivity and precision.

12. ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure)
A tool linking economic activities with ecosystem services to identify business dependencies and impacts on nature.

13. GBIF (Global Biodiversity Information Facility): An open-data platform that provides access to global species occurrence records collected from museums, research institutions, and citizen science initiatives.

14. GIS (Geographic Information System): Technology used to capture, store, analyse, and visualise spatial and geographic data for environmental assessment and decision-making.

15. Global Reporting Initiative (GRI): An international standard for sustainability reporting that includes biodiversity indicators within its environmental disclosures.

16. Global biodiversity datasets and other geospatial tools: Large, openly accessible databases and spatial platforms that compile biological, environmental, and conservation information from around the world. They support biodiversity assessments, risk screening, and reporting by providing mapped species occurrences, protected areas, habitat types, environmental pressures, and ecosystem characteristics. These tools allow companies to identify biodiversity-sensitive areas, evaluate exposure to nature-related risks, and align with frameworks such as CSRD-E4, TNFD, and SBTN. They typically include species occurrence records, ecosystem maps, satellite imagery, conservation priority layers, and environmental indicators

17. HTS (High-Throughput Sequencing): Advanced DNA sequencing technology that processes millions of DNA fragments simultaneously. Used in eDNA metabarcoding to identify multiple species from a single environmental sample with high accuracy and efficiency.

18. IBAT (Integrated Biodiversity Assessment Tool): An online platform providing access to global biodiversity datasets, including the IUCN Red List, Key Biodiversity Areas (KBAs), and protected areas, to support risk screening and conservation planning.

19. ipieca (Oil & Gas Association): The global oil and gas industry association for advancing environmental and social performance, including biodiversity and ecosystem guidance.

20. IUCN Red List: A global inventory assessing the conservation status of species and their risk of extinction.

21. LiDAR (Light Detection and Ranging): Remote sensing technology that uses laser pulses to map landforms, vegetation structure, and habitat features in three dimensions.

22. Net Positive Impact (NPI): A sustainability outcome in which an organization's activities result in an overall gain in biodiversity or ecosystem condition after accounting for all negative and positive impacts. Achieving NPI means that, once mitigation measures, restoration, and conservation actions are applied, the net effect is a measurable improvement in natural systems compared to the baseline state.

23. QA/QC (Quality Assurance / Quality Control): Procedures ensuring data accuracy, reliability, and consistency throughout sampling, laboratory analysis, and reporting. In eDNA workflows, QA/QC includes field blanks, replicates, negative and positive controls, contamination checks, and validation of sequencing outputs to maintain scientific and regulatory credibility.

24. Remote Sensing: Collecting environmental data using satellite or aerial sensors to assess vegetation, habitat extent, and landscape change.

25. Science-Based Targets Network (SBTN): An initiative helping companies set measurable targets to reduce their impacts on nature and contribute to global biodiversity and ecosystem recovery goals.

26. Sector-specific guidance for Oil and Gas (TNFD and GRI): Supplementary documents that adapt the TNFD and GRI frameworks to the specific environmental and biodiversity challenges of the oil and gas sector.

27. STAR (Species Threat Abatement and Restoration metric): A biodiversity metric estimating potential reductions in global extinction risk through threat abatement and habitat restoration.

28. State–Pressure–Response (SPR): A model describing environmental relationships: the condition of ecosystems (State), human drivers of change (Pressure), and management actions (Response).

29. Taskforce on Nature-related Financial Disclosures (TNFD): A global framework guiding organisations on how to assess, manage, and disclose nature-related risks and opportunities.

30. Visual Monitoring: Observation-based methods that use cameras, drones, or direct field surveys to record species visually. Often paired with bioacoustics and eDNA to confirm species identity, estimate abundance, and assess behavioural or temporal patterns.

31. WDPA (World Database on Protected Areas)
A comprehensive global database of terrestrial and marine protected areas managed by UNEP-WCMC and IUCN.

9 Bibliography

This report and the accompanying database were produced using the references listed below, together with internal expertise and proprietary knowledge from NatureMetrics.

Accounting for Nature. Method Catalogue. https://www.accountingfornature.org/method-catalogue

Addison, P. F. E., Stephenson, P. J., Bull, J. W., Carbone, G., Burgman, M., Burgass, M. J., Gerber, L. R., Howard, P., McCormick, N., McRae, L., Reuter, K. E., Starkey, M., & Milner-Gulland, E. J. (2020). Bringing sustainability to life: A framework to guide biodiversity indicator development for business performance management. *Business Strategy and the Environment, 29*(8), 3303–3313. https://doi.org/10.1002/bse.2573

Andruszkiewicz, E. A., Starks, H. A., Chavez, F. P., Sassoubre, L. M., Block, B. A., & Boehm, A. B. (2019). Modeling environmental DNA transport in the coastal ocean using Lagrangian particle tracking. *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2019.00477

Barth, A., Ranacher, L., Hesser, F., Stern, T., & Schuster, K. C. (2025). Bridging business and biodiversity: An analysis of biodiversity assessment tools. *Environmental and Sustainability Indicators, 26*, 100682. https://doi.org/10.1016/j.indic.2025.100682

Biggs, C., & Le Breton, C. (2025). *Comparing the efficacy of conventional survey methods to eDNA in a rapid multi-taxa survey of a tropical rainforest ecosystem.* bioRxiv. https://doi.org/10.1101/2025.08.28.672370

Blackman, R. C. et al. (2022). General principles for assignments of communities from eDNA: Open versus closed taxonomic databases. *Environmental DNA*. https://doi.org/10.1002/edn3.382

Carraro, L., Hartikainen, H., Jokela, J., Bertuzzo, E., & Rinaldo, A. (2018). *Estimating species distribution and abundance in river networks using environmental DNA.* Proceedings of the National Academy of Sciences of the United States of America, 115(46), 11724–11729. https://doi.org/10.1073/pnas.1813843115

CDP. (2025, April). *Full corporate questionnaire — Modules 8–13*. https://assets.ctfassets.net/v7uy4j80khf8/1mbAbAkEaxCT4MMt4ChuYW/f105573f487cd48967cdfdac0ce344ee/Full_Corporate_Questionnaire_Modules_8-13.pdf

Chan, L., Hillel, O., Werner, P., Holman, N., Coetzee, I., Galt, R., & Elmqvist, T. (2021). *Handbook on the Singapore Index on Cities' Biodiversity (City Biodiversity Index)*. Secretariat of the Convention on Biological Diversity & National Parks Board, Singapore. cbd-ts-98-en.pdf

Collins, R. A., Wangensteen, O. S., O'Gorman, E. J., Mariani, S., Sims, D. W. & Genner, M. J. 2018. Persistence of environmental DNA in marine systems. *Communications Biology* **1**, Article 185 https://www.nature.com/articles/s42003-018-0192-6

Doi, H., Uchii, K., Takahara, T., Matsuhashi, S., Yamanaka, H., & Minamoto, T. (2015). *Use of Droplet Digital PCR for Estimation of Fish Abundance and Biomass in Environmental DNA Surveys*. PLoS ONE, 10(3): e0122763. https://doi.org/10.1371/journal.pone.0122763

Duarte S, Vieira PE, Costa FO (2020) Assessment of species gaps in DNA barcode libraries of non-indigenous species (NIS) occurring in European coastal regions. Metabarcoding and Metagenomics 4: e55162. https://doi.org/10.3897/mbmg.4.55162

D Cote, et at. (2023), Comparing eDNA metabarcoding and conventional pelagic netting to inform biodiversity monitoring in deep ocean environments, *ICES Journal of Marine Science*, Volume 80, Issue 10, Pages 2545–2562, https://doi.org/10.1093/icesjms/fsad169

Doi, H., Fukaya, K., Oka, Si. *et al.* Evaluation of detection probabilities at the water-filtering and initial PCR steps in environmental DNA metabarcoding using a multispecies site occupancy model. *Sci Rep* 9, 3581 (2019). https://doi.org/10.1038/s41598-019-40233-1

European Financial Reporting Advisory Group (EFRAG). (2023). *ESRS E4: Biodiversity and ecosystems — Delegated Act (Annex 1)*. https://www.efrag.org/sites/default/files/sites/webpublishing/SiteAssets/ESRS%20E4%20Delegated-act-2023-5303-annex-1_en.pdf

EFRAG. (2024). *ESRS implementation guidance 3: List of ESRS datapoints* [Excel workbook]. https://www.efrag.org/en/projects/esrs-implementation-guidance-documents

EU Business & Biodiversity Platform. (2022). *Biodiversity measurement approaches for businesses and financial institutions: Thematic report — Biodiversity data* (March 2022). https://circabc.europa.eu/ui/group/da655eff-acfa-4b21-a366-2795d0e7de39/library/c0990e0c-6f5b-4503-93fd-be0c87bc656f/details?download=true

Farrell, J. A., et al. 2021. The Promise and Pitfalls of Environmental DNA and RNA Approaches for the Monitoring of Human and Animal Pathogens from Aquatic Sources. *Bioscience*. https://pmc.ncbi.nlm.nih.gov/articles/PMC8083301/

Fediajevaite, J., Priestley, V., Arnold, R., & Savolainen, V. (2021). Meta-analysis shows that environmental DNA outperforms conventional surveys, but warrants better reporting standards. *Ecology and Evolution, 11*(9), 4803–4815. https://doi.org/10.1002/ece3.7382

Ficetola, G. F., Pansu, J., Bonin, A., Coissac, E., Giguet-Covex, C., De Barba, M., Gielly, L., Lopes, C. M., Boyer, F., Pompanon, F., & Taberlet, P. (2015). Replication levels, false presences and the estimation of the presence/absence from eDNA metabarcoding data. *Molecular Ecology Resources, 15*(3), 543–556. https://doi.org/10.1111/1755-0998.12338

Ficetola, G. F., Taberlet, P., & Coissac, E. (2016). How to limit false positives in environmental DNA and metabarcoding? *Molecular Ecology Resources, 16*(3), 604–607. https://doi.org/10.1111/1755-0998.12508

Finance for Biodiversity Foundation. (2024, October 26). *Biodiversity measurement approaches: A practitioner's guide for financial institutions* (4th ed.). https://www.financeforbiodiversity.org/wp-content/uploads/Biodiversity-measurement-approaches_A-practitioners-guide-for-financial-institutions_4th-edition.pdf

Gold, Z., et al. (2021). eDNA metabarcoding as a biomonitoring tool for marine protected areas. *PLoS ONE, 16*(2), e0238557. https://doi.org/10.1371/journal.pone.0238557

Global Reporting Initiative. (2021). *GRI 11: Oil and gas sector 2021*. https://www.globalreporting.org/standards/standards-development/sector-standard-for-oil-and-gas/

Global Reporting Initiative. (2024). *GRI 101: Biodiversity 2024*. https://www.globalreporting.org/publications/documents/english/gri-101-biodiversity-2024-english/

Harrison Jori B., Sunday Jennifer M., and Rogers Sean M. 2019. Predicting the fate of eDNA in the environment and implications for studying biodiversity. *Proc. R. Soc. B* 286: 20191409.https://royalsocietypublishing.org/doi/10.1098/rspb.2019.1409

Halvorsen, S., Korslund, L., Mattingsdal, M. & Slettan, A. (2023). *Estimating number of European eel (Anguilla anguilla) individuals using environmental DNA and haplotype count in small rivers*. Ecology and Evolution, 13, e9785. doi: 10.1002/ece3.9785

Iacaruso, N. J., Reves, O. P., Merkelz, S. J., Waldrep, C. L., & Davis, M. A. (2025). A systematic review evaluating the performance of eDNA methods relative to conventional methods for biodiversity monitoring. *Ecography*, e07952. https://doi.org/10.1002/ecog.07952

IOGP Joint Industry Programme on Environmental Genomics / eDNA (NatureMetrics & ID-Gene contributions). (2024). *Chapter 1: Efficacy of eDNA vs conventional monitoring methods* [Draft report]. https://www.iogp-edna.org/wp-content/uploads/2025/01/Chapter-1-Efficacy-of-eDNA-vs-Conventional-Monitoring-Methods.pdf

IOGP Joint Industry Programme on Environmental Genomics / eDNA (NatureMetrics & ID-Gene contributions). (2024). *Chapter 2: eDNA sampling standards and guidelines* [Draft report]. https://www.iogp-edna.org/wp-content/uploads/2025/01/Chapter-2-eDNA-Sampling-Standards-and-Guidelines.pdf

IUCN. *The IUCN Red List of Threatened Species*. https://www.iucnredlist.org/

ipieca, American Petroleum Institute (API), & International Association of Oil & Gas Producers (IOGP). (2025). *Sustainability reporting guidance for the oil and gas industry* (5th ed.; Module 4: Environment). https://www.ipieca.org/resources/sustainability-reporting-guidance

Kestel, J. H., et at. (2022). Applications of environmental DNA (eDNA) in agricultural systems: Current uses, limitations and future prospects. *Science of The Total Environment*, *847*, 157556. https://doi.org/10.1016/j.scitotenv.2022.157556

Kirse, A. et al. (2021). Unearthing the potential of soil eDNA metabarcoding—towards best practice advice for invertebrate biodiversity assessment. *Frontiers in Ecology and Evolution, 9*. https://doi.org/10.3389/fevo.2021.630560

Lambrechts, S., Deflem, I. S., Sensalari, C., De Backer, S., De Beer, B., Neyrinck, S., & De Vos, B. (2025). *Comparison and evaluation of sampling and eDNA metabarcoding protocols to assess soil biodiversity in Belgian LUCAS Biopoints*. Zenodo. https://doi.org/10.5281/zenodo.1504601

Lodge, D.M., Turner, C.R., Jerde, C.L., Barnes, M.A., Chadderton, L., Egan, S.P., Feder, J.L., Mahon, A.R. & Pfrender, M.E. (2012). *Conservation in a cup of water: Estimating biodiversity and population abundance from environmental DNA*. Molecular Ecology, 21(11), 2555-2558. doi: 10.1111/j.1365-294X.2012.05600.x

Mahon, A. R., Grey, E. K., & Jerde, C. L. (2023). Integrating invasive species risk assessment into environmental DNA metabarcoding reference libraries. *Ecological Applications*, *33*(1), Article e2730. https://doi.org/10.1002/eap.2730

Marques, V. et al. (2021). GAPeDNA: Assessing and mapping global species gaps in genetic databases for eDNA metabarcoding. *Diversity and Distributions*. https://doi.org/10.1111/ddi.13142

Marczylo, E. L., et al. (2021). Metabarcoding of Soil Fungi from Different Urban Greenspaces: A multi-region approach to analyse soil mycobiomes from five urban greenspaces (lawns, parklands, bareground, young forest and old forest). *PMC*, PMC8626400. https://www.ncbi.nlm.nih.gov/articles/PMC8626400/

Mauffrey F, Cordier T, Apothéloz-Perret-Gentil L, Cermakova K, Merzi T, Delefosse M, Blanc P, Pawlowski J. Benthic monitoring of oil and gas offshore platforms in the North Sea using environmental DNA metabarcoding. Mol Ecol. 2021 Jul;30(13):3007-3022. doi: 10.1111/mec.15698. Epub 2020 Nov 3. PMID: 33070453

McGee, K. M. et al. (2019). Gaps in DNA-based biomonitoring across the globe. *Frontiers in Ecology and Evolution, 7*. https://doi.org/10.3389/fevo.2019.00337

NatureMetrics. (n.d.). *Revolutionizing EIAs for Offshore Wind Farms with eDNA: A collaboration between NatureMetrics, EDF Renewables and Natural Power* [Case Study]. Retrieved from https://www.naturemetrics.com/case-study/edf

NatureMetrics. (n.d.). *Nature Intelligence for Extractives: From pit to port – supporting the mitigation hierarchy across supply and logistics chains*. Retrieved from https://www.naturemetrics.com/resources/nature-intelligence-for-extractives

NatureMetrics. (2023). *eDNA Report Interpretation Guide*. https://www.naturemetrics.com/report-interpretation-guide

NatureMetrics. (n.d.). *A Practical Guide to CSRD-E4's biodiversity requirements (ESRS E4)*. Retrieved from https://www.naturemetrics.com/resources/CSRD-E4-biodiversity-requirements-esrs-e4-guide

NatureMetrics. (n.d.). *Download our 6-step guide to TNFD: Get started on your TNFD journey*. Retrieved from https://www.naturemetrics.com/resources/tnfd-journey

NatureMetrics. (n.d.). *Marine Infrastructure for a Nature-Positive Future: A practical guide to meeting tomorrow's biodiversity monitoring and reporting requirements with eDNA*. Retrieved from https://www.naturemetrics.com/resources/offshore-project-leaders-guide-to-edna-monitoring

OECD (Organisation for Economic Co-operation and Development). (1993). *OECD core set of indicators for environmental performance reviews: A synthesis report by the Group on the State of the Environment* (Environment Monographs No. 83; OCDE/GD(93)179). Paris: OECD. https://one.oecd.org/document/OCDE/GD(93)179/en/pdf

Pettorelli, N., Wegmann, M., Skidmore, A., Mücher, S., Dawson, T. P., Fernandez, M., Lucas, R., Schaepman, M. E., Wang, T., O'Connor, B., Jongman, R. H. G., Kempeneers, P., Sonnenschein, R., Leidner, A. K., Böhm, M., He, K. S., Nagendra, H., Dubois, G., Fatoyinbo, T., … Pereira, H. M. (2016). Framing the concept of satellite remote sensing essential biodiversity variables: Challenges and future directions. *Remote Sensing in Ecology and Conservation, 2*(3), 122–131. https://doi.org/10.1002/rse2.15

Preston, M., Fritzsche, M. & Woodcock, P. 2022. Understanding and mitigating errors and biases in metabarcoding: an introduction for non-specialists. JNCC Report No. 699, JNCC, Peterborough, ISSN 0963-8091, https://data.jncc.gov.uk/data/8345b6ce-6099-42f6-903c-32ce1e09e4db/JNCC-Report-699-FINAL-WEB.pdf

Ralston, M. J., et al. (2025). Translating eDNA data into conservation action: Partnerships to support imperiled amphibians in coastal California wetlands. *Conservation Science and Practice.* Advance online publication. https://doi.org/10.1111/csp2.70000

Ruppert, K. M., Kline, R. J., & Rahman, M. S. (2019). Past, present, and future perspectives of environmental DNA (eDNA) metabarcoding: A systematic review in methods, monitoring, and applications of global eDNA. *Global Ecology and Conservation, 17,* e00547. https://doi.org/10.1016/j.gecco.2019.e00547

Sahu, A., et al. (2023). Environmental DNA (eDNA): Powerful technique for biodiversity conservation. *Journal for Nature Conservation, 71*, 126325. https://doi.org/10.1016/j.jnc.2022.126325

Saito, T. & Doi, H. 2021. A Model and Simulation of the Influence of Temperature and Amplicon Length on Environmental DNA Degradation Rates: A Meta-Analysis Approach. *Frontiers in Ecology and Evolution* 9, 623831 https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2021.623831/full

Schenekar, T., Schletterer, M., Lecaudey, L. A., & Weiss, S. J. (2020). Reference databases, primer choice, and assay sensitivity for environmental metabarcoding: Lessons learnt from a re-evaluation of an eDNA fish assessment in the Volga headwaters. *River Research and Applications.* Advance online publication. https://doi.org/10.1002/rra.3610

Schmid, S. et al. (2025). Unlocking natural history collections to improve eDNA reference databases and biodiversity monitoring. *BioScience*. https://doi.org/10.1093/biosci/biaf140

Shu, L., Ludwig, A., & Peng, Z. (2020). Standards for methods utilizing environmental DNA for detection of fish species. *Genes, 11*(3), 296. https://doi.org/10.3390/genes11030296

Stephenson, P. J., & Carbone, G. (2021). *Guidelines for planning and monitoring corporate biodiversity performance*. IUCN. https://portals.iucn.org/library/node/49301

Science Based Targets Network (SBTN). (2024). *Technical Guidance—Step 1: Assess (v1.1)*. https://sciencebasedtargetsnetwork.org/wp-content/uploads/2024/07/Technical-Guidance-2024-Step1-Assess-v1-1.pdf

Science Based Targets Network (SBTN). (2024). *Technical Guidance—Step 2: Prioritize(v1.1)*. https://sciencebasedtargetsnetwork.org/wp-content/uploads/2024/07/Technical-Guidance-2024-Step2-Prioritize-v1-1.pdf

Takahara, T., Minamoto, T., Yamanaka, H., Doi, H., & Kawabata, Z. (2012). *Estimation of Fish Biomass Using Environmental DNA*. PLoS ONE, 7(4): e35868. https://doi.org/10.1371/journal.pone.0035868

Taskforce on Nature-related Financial Disclosures (TNFD). (2023). *Guidance on the identification and assessment of nature-related issues: The LEAP approach* (v1.1). https://tnfd.global/wp-content/uploads/2023/08/Guidance_on_the_identification_and_assessment_of_nature-related_Issues_The_TNFD_LEAP_approach_V1.1_October2023.pdf

Taskforce on Nature-related Financial Disclosures (TNFD). (2023, September). *TNFD Recommendations: final disclosures & metrics framework* (Version 1.0). https://tnfd.global/publication/recommendations-of-the-taskforce-on-nature-related-financial-disclosures/

Taskforce on Nature-related Financial Disclosures (TNFD). (2024). *Additional sector guidance — Oil & gas*. https://tnfd.global/publication/additional-sector-guidance-oil-and-gas/

The Biodiversity Consultancy & NatureMetrics. 2021. *Using Environmental DNA to manage biodiversity risks: Briefing Note*. Cambridge, UK. Retrieved from https://www.thebiodiversityconsultancy.com/fileadmin/uploads/tbc/Documents/Resources/eDNA-and-biodiversity-risk-briefing-note.pdf

U.S. Geological Survey (USGS). (n.d.). *Environmental DNA (eDNA)*. USGS Water Science School. https://www.usgs.gov/water-science-school/science/environmental-dna-edna

United Nations Environment Programme (UNEP). (2022). *Kunming-Montreal Global Biodiversity Framework (GBF)*. https://www.unep.org/interactives/biodiversity-sdgs-tool/global-biodiversity-framework.html

Vasar, M. et al. (2023). Metabarcoding of soil environmental DNA to estimate plant diversity globally. *Frontiers in Plant Science, 14*, 1106617. https://doi.org/10.3389/fpls.2023.1106617

Větrovský, T., *et al.* (2020) GlobalFungi, a global database of fungal occurrences from high-throughput-sequencing metabarcoding studies. *Sci Data* **7**, 228. https://doi.org/10.1038/s41597-020-0567-7

Wilcox, T. M., et al. (2013). Robust detection of rare species using environmental DNA: The importance of primer specificity. *PLoS ONE, 8*(3), e59520. https://doi.org/10.1371/journal.pone.0059520

Xing, K., Lu, et.al,. (2024). Soil eDNA biomonitoring reveals changes in multitrophic biodiversity and ecological health of agroecosystems. *Environmental Research, 262*(Part 2), 119931. https://doi.org/10.1016/j.envres.2024.119931

Xiong, F., et al.,. (2022). Methodology for fish biodiversity monitoring with environmental DNA metabarcoding: The primers, databases and bioinformatic pipelines. *Water Biology and Security*, *1*(1), Article 100007. https://doi.org/10.1016/j.watbs.2022.100007

Xue, K., et al., (2013). Functional gene differences in soil microbial communities from conventional, low-input, and organic farmlands. *Applied and Environmental Microbiology*, *79*(4), 1284–1292. https://doi.org/10.1128/AEM.03393-12

Zhang, Y., et al.,. (2025). *Integrated reanalysis of global riverine fish eDNA datasets shows robustness and congruence of biodiversity conclusions* [Preprint]. bioRxiv. https://doi.org/10.1101/2025.09.16.676481

Environmental DNA and nature reporting

How and when to use molecular data in corporate biodiversity disclosure

November 2025

Purpose

IOGP commissioned NatureMetrics and Stantec to assess the applicability of environmental DNA (eDNA) for supporting corporate nature-related reporting frameworks. This slide summarises Deliverables 1 and 2 under RFP 05. (Deliverable 3 is addressed separately in *"Environmental DNA and Nature Reporting: How and When to Use Molecular Data in Corporate Biodiversity Disclosure Guidance"*.)

Document Structure

Deliverable 1 – Mapping Nature Reporting Frameworks

- Assessment of 280 biodiversity disclosure requirements across 8 reporting frameworks
- Identification of where eDNA may be applicable
- Supporting Excel database provided to enable implementation

Deliverable 2 – Suitability of eDNA for Nature Reporting

- Evaluation of where eDNA best supports nature-related reporting requirements. Primary focus on *state of nature* metrics, which establish baselines for measuring pressures and responses. They represent the most practical and informative entry point for integrating eDNA
- Comparison of eDNA with conventional biodiversity monitoring (efficacy, efficiency, scalability, cost, and sampling)
- Recommendations for embedding eDNA within corporate nature strategy, impact measurement, and reporting

Frameworks Analysed

Mandatory

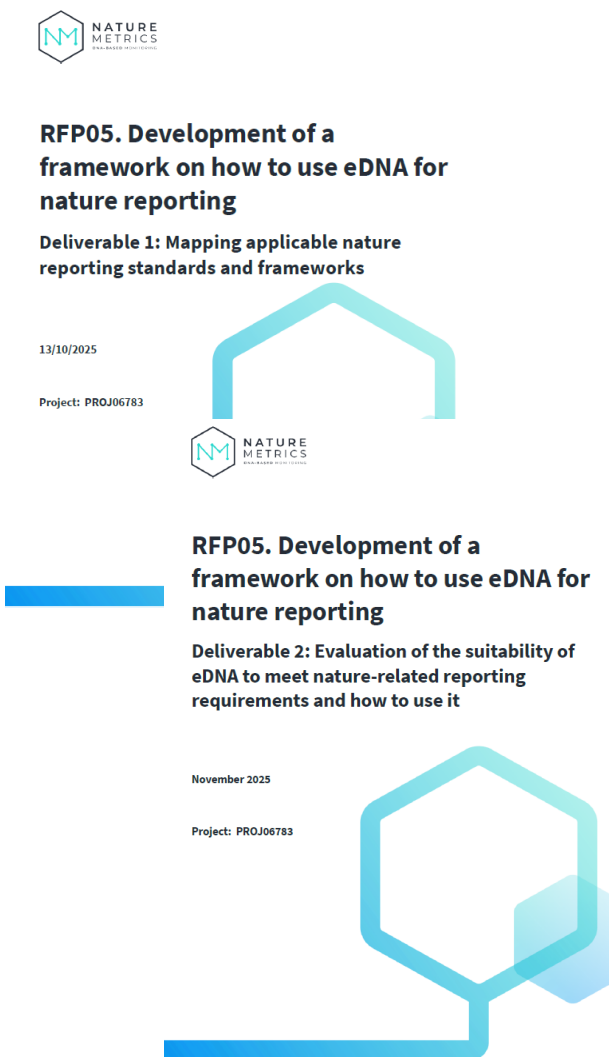
- Corporate Sustainability Reporting Directive (CSRD) – ESRS E4: Biodiversity and Ecosystems

Voluntary

- Taskforce on Nature-related Financial Disclosures (TNFD) – core and additional metrics
- Science-Based Targets Network (SBTN) – Step 1 and 2 requirements
- Global Reporting Initiative (GRI) 304 – Biodiversity
- CDP – Biodiversity

Industry Guidance

- IPIECA – Biodiversity
- Sector-specific guidance for Oil and Gas from TNFD and GRI



Deliverable 1

Deliverable 1. Findings Across Frameworks

We categorised all 280 requirements using the State-Pressure-Response model to provide a structured comparison. Most frameworks (TNFD, GRI, SBTN) use this conceptual model to structure reporting.

State-Pressure-Response (SPR) model

STATE OF NATURE: The condition of the environment (e.g., species richness, ecosystem health, habitat extent).

PRESSURE: Direct stresses from human activities (e.g., land use change, pollution, water consumption).

RESPONSE: Actions taken to prevent or mitigate impacts (e.g., governance policies, restoration projects, mitigation hierarchy).

High-Level Findings: A Snapshot

Category	# of Requirements	Mandatory	Quantitative	Key Focus
State (state of nature)	69	49%	58%	Ecosystem condition, Species Data
Pressure	53	66%	72%	Land Use, Water, Pollution
Response	61	67%	23%	Governance, Policies, Management
N/A	94	68%	5%	Strategy, Methods, Governance

Key Insight: The frameworks show distinct patterns. "Pressure" is highly quantitative, "Response" is highly qualitative, and "State" is a dynamic mix, representing the biggest measurement challenge.

Deliverable 1. The Role of Environmental DNA

Across the SPR model, the State of Nature requirements provided the clearest opportunity for using eDNA to measure progress over time.

The SPR model highlights where eDNA adds most value.

- State of Nature requirements (ecosystem and species condition): The "state" category focuses on the condition of ecosystems and species, such as richness. It is therefore the most compatible with eDNA, as eDNA is a powerful tool for detecting species presence, assessing biodiversity patterns, and providing direct evidence of ecological condition.
- Pressure requirements (impacts like emissions, flows): Highly standardised, prescriptive, and strongly quantitative but largely closed to eDNA because of its focus on physical flows and emissions.
- Response requirements (governance, progress tracking): Dominated by qualitative, governance-driven disclosures where eDNA is not central but can provide evidentiary value.
- N/A requirements: Not all biodiversity requirements fit neatly into SPR. Some clauses focus on governance, strategy, or financial allocation. These total around 94 requirements. Only 3 could be partially addressed using eDNA.

Category	Can eDNA be used?
State of Nature	High Potential (62% - 43 out of 69 requirements)
Pressure	Very Low Potential (15% - 8 out of 53 requirements)
Response	Supporting Evidence Only (21% - 13 out of 61 requirements)
Pressure and response	Supporting Evidence Only (67% - 2 out of 3 requirements)
N/A requirements	Supporting Evidence Only (3%- 3 out of 94 requirements)

Key Insight

eDNA provides biological evidence of State of Nature requirements recommended by nature reporting frameworks

Deep Dive: State of Nature Requirements

Main Findings

Focus: Proximity to sensitive areas, species-level data, and ecosystem condition.
Challenge: This is the most dynamic and open-ended area, with less than half of the requirements prescribing a specific metric.
eDNA's Role:

- Directly applicable for species detection, richness, and community composition metrics.
- Partially supports assessments of ecosystem condition and can validate the "sensitivity" of a location by identifying the presence of threatened species.
- This is the clearest opportunity for eDNA to add value.

Topic	CSRD	TNFD	TNFD GRI O&G	SBTN	GRI	GRI O&G	IPIECA	CDP
Biodiversity sensitive areas	6	*	2	6	6	1	2	2
Species	6	4		7	1	1		
Ecosystem Condition	3	2		2	1			
Ecosystem Extent	2	1		1				
Ecosystem Services		2		2				
Indigenous Peoples			3	2				
Connectivity	3	1						

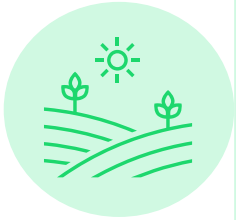
Note: Table shows the number of requirements in each framework. Legend: Light green = Low (1 requirement); Medium green = Medium (2–3 requirements); Dark green = High (>3 requirements).
* This requirement part of the LEAP process and for assessing materiality but note a core or additional metric for disclosure. Thus, is not in the database attached.

Application of eDNA across different ecosystems

eDNA can be applied across terrestrial, freshwater, marine, and coastal ecosystems to provide scalable, standardised biodiversity data that reveals how communities respond to environmental change.

Marine and Freshwater Environments

- Comprehensive baseline assessments for offshore and coastal sites – providing multi-taxa inventories for EIA
- Detection and monitoring of endangered, invasive, commercially important species, cryptic and deep-sea species
- Mapping of community diversity and distribution
- eDNA application in fisheries stock assessments regarding impacts to fisheries from oil and gas activities
- Long-term monitoring to track seasonal and restoration trends
- Because marine environments are logistically expensive to survey, eDNA offers a cost-efficient and repeatable solution that also aligns with future marine biodiversity requirements under CSRD and TNFD.



Terrestrial Environments

- Detection of small mammals, invertebrates, fungi, and microbes invisible to conventional surveys
- Detection and monitoring of endangered, invasive, and commercially important species, cryptic and microfaunal/flora species
- Enables non-invasive tracking
- Measurement of soil biodiversity and microbial health as components of ecosystem condition
- Monitoring of restoration success and invasive species on land
- Survey terrestrial vertebrate communities across large, open spaces, potentially allowing for monitoring of mammals and birds in complex natural settings

Deep Dive: Pressure and Response Requirements

Main findings for pressure requirements

Focus: Highly standardized, quantitative metrics (tonnes, hectares, m^3).

eDNA's Role: Most **requirements focus on physical, chemical, or spatial measurements that fall outside the scope of eDNA monitoring.** For broader requirements, where measurement is not specified (e.g., broadly on biodiversity impacts and open to interpretation), eDNA can provide biological evidence of change that supports, but does not replace, measurement of impact (i.e., physical quantities, geospatial data).

Topic	CSRD-E4	TNFD	TNFD O&G	SBTN	GRI	GRI O&G	IPIECA	CDP
Water		4		7	1			
Land use and land use change	6	3		2				
Pollution		3		4	1			
Supply chain		2			3		1	
Invasive Species	1	1	1		1			
land/freshwater/ocean ecosystem use and use change	1	1			1			
Biodiversity impacts	1					1		1
Air pollution/emissions		1		2				
Ecosystem Services					2			
Waste		1						

Main findings for response requirements

Focus: Qualitative, governance-driven disclosures (policies, plans, commitments). Most response requirements focus on explaining actions taken to reduce impacts

eDNA's Role: Provides **evidentiary value.** While not central, eDNA can be used to provide evidence that response actions (like restoration) are delivering measurable ecological outcomes. In other words, the strength of eDNA lies in the requirements that can be interpreted to include outcome-focused data.

Topic	CSRD-E4	TNFD	TNFD O&G	SBTN	GRI	GRI O&G	IPIECA	CDP
Biodiversity management	9		1		5		6	4
Biodiversity offsets	4				1		1	2
Mitigation hierarchy	1				1	3	1	4
Conservation/ Restoration		1			1			2
Engagement	1							4
Policies	3							
Water		3						
Decommission			2					
Invasive Species	1	1						
Pollution/pollution removal		1						
Sustainable management		1						
Waste		1						

Note: Table shows the number of requirements in each framework. Legend: Light green = Low (1 requirement); Medium green = Medium (2–3 requirements); Dark green = High (>3 requirements).

Interoperability & the Path Forward

Interoperability is key to efficient, credible nature reporting, aligning diverse framework requirements through shared, science-based tools.

- Framework requirements are not one-to-one. They address similar themes but often require different data points (e.g., absolute hectares vs. percentage of footprint).
- Companies need to prioritise core site-level data metrics and tools to meet multiple requirements efficiently.
- The gap between reporting an action and proving an outcome is closing. Tools like eDNA are critical for providing credible, scientific proof of performance

Interoperability of State Requirements

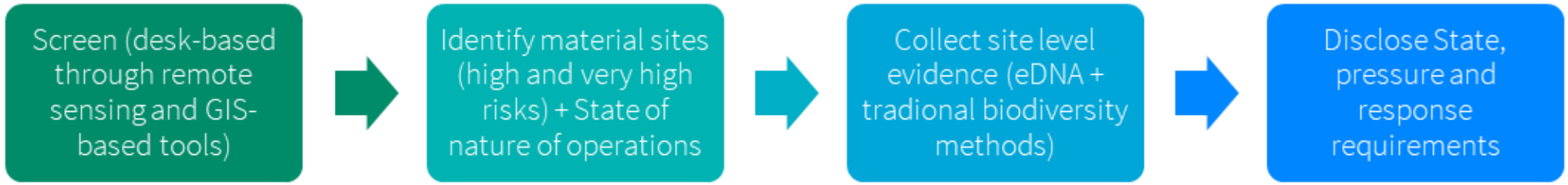
Sub-topic	CSRD	TNFD	TNFD O&G	SBTN	GRI	GRI O&G	IPIECA	CDP
Biodiversity sensitive areas	SBM 3 - 16(a)(iii) ESRS 2 IRO-19(a) - Related AR 7d E4-5 -35 Appendix ESRS 2: IRO -AR 7(b) IRO -AR 7(d) IRO -AR 7(e)	Part of LEAP approach, but not a metric in core or additional disclosures	OG.A1.2 OG.A1.3	Step 1 and 2, Task 9: Biodiversity SoN - State of Nature indicators	101-5a 101-5b (i) 101-5b (ii) 101-5b (iii) 101-5b (iv) 101-5b (v)	304-1	A3; C1	(11.4) (11.4.1)
Connectivity	E4-5 -38(d) E4-5 -38 (e) E4-5 -41(b)(iii)	A5.2						
Ecosystem Condition	E4-5 -41(b)(i) SBM 3 - 16(a)(ii) Appendix ESRS 2: IRO -AR 7(c)	A5.0 C5.0		Step 1& 2, Task 9: Biodiversity SoN indicators Step 1, Task 9: Pressure-sensitive SoN indicators	101-7a			
Ecosystem Extent	E4-5 -38(c) E4-5 -41(a)	A5.1		Step 1, Task 9: Pressure-sensitive SoN indicators				
Ecosystem Services		A6.0 A6.1		Step 1. Appendix 1. SoN Biodiversity indicators- Water Use				
Indigenous Peoples			OG.A1.0 OG.A1.1 OG.C1.0	Step 1& 2, Task 9: Biodiversity SoN indicators				
Species	E4-5 -40(b) E4-5 -40(c) E4-5 -40(d)(i) E4-5 -40(d)(ii) E4-5 -41(b)(ii) SBM 3 - 16(c)	C5.1 A3.5 A5.3 A5.4		Step 1 &2, Task 9: SoN indicators; Step 1. Appendix 1. SoN Biodiversity indicators - Water and land Use, water pollution and soil pollution	101-6b (i)	304-4		

Deliverable 2

Deliverable 2. eDNA's role in nature reporting

Most nature-related frameworks prescribe a similar process for assessing impacts and dependencies on nature. The process from desktop analysis to verifiable evidence, defines where eDNA fits.

General workflow of nature reporting



Screening and Compliance

- Corporate sustainability teams use **global datasets** such as IBAT, GBIF, and national biodiversity inventories to **map potential risk areas**.
- Spatial data, satellite imagery, and ecosystem indices help identify sensitive ecosystems and potential overlap with protected areas.
- These tools efficiently flag proximity risks but cannot verify ecological conditions on the ground, which is recommended by all frameworks.

Transition to Field Evidence

- Once high-risk sites are identified, frameworks require companies to confirm their actual ecological conditions.
- eDNA becomes a **primary measurement tool**, supplying **biological validation** that turns spatial assumptions into measurable outcomes.
- By supporting state of nature requirements, eDNA strengthens disclosures, supports compliance, and provides the biological evidence that desktop screening alone cannot deliver.

Deliverable 2. When and How eDNA Should Be Used

Within state of nature requirements, eDNA has the most potential to be applied for 3 topics: species-related, ecosystem condition and biodiversity sensitive areas.

Topic Area	When eDNA Should Be Used	What It Measures / Delivers	How It Should Be Applied	How It Reports	Complementary Tools
Species	After screening identifies high-risk sites (protected, endemic, cryptic, invasive taxa). Use during baseline and periodic monitoring.	I. Presence of threatened species and invasive species II. Species richness III. Relative abundance trends *(when calibrated)* IV. Indirect population	• Metabarcoding for multi-taxa surveys • Targeted qPCR/ddPCR for key species • Repeat sampling for turnover tracking	• Satisfies species presence/richness indicators • Supports extinction-risk analysis	• Acoustic/camera for abundance and population • Modelling for extinction risk
Ecosystem Condition	When reporting ecosystem health, restoration progress, or management outcomes at material sites.	I. Composition *(species assemblages, trophic structure)* II. Partial function (*microbial & nutrient-cycling taxa)*	• Soil, water, or sediment eDNA for compositional & functional analysis • Use diversity indices and indicator taxa	• Provides biological layer for condition metrics	• Remote sensing for structure • Bioacoustics for function • Retain conventional field surveys for validation
Biodiversity-Sensitive Areas	Where operations overlap or lie adjacent to protected areas, KBAs, high-integrity habitats, or ecological corridors.	I. Current presence of protected or threatened species II. Early detection of compositional change III. Biological validation of mapped sensitivity	• Targeted metabarcoding in and around mapped sensitive areas, linked with GIS layers	• Strengthens sensitive-area disclosures	• GIS/spatial mapping for proximity analysis

Deliverable 2. Comparison of monitoring methods

eDNA consistently delivers superior performance in efficiency, scalability, and cost-effectiveness, while complementary tools fill structural and behavioural data gaps.

Method Type	Efficacy	Efficiency	Scalability	Cost-Effectiveness	Sampling Efficiency
Aquatic eDNA *(marine & freshwater)*	*Very High* confirms species presence, multi-taxa detection, and site sensitivity	*Very High* minimal vessel time, rapid collection, automated lab processing	*Very High* standardised global protocols enable repeatable monitoring	*Very High* reduced field labour, batch lab analysis cuts per-sample cost	*Very High* small water samples, minimal field time
Terrestrial eDNA	*High* strong for invertebrates, microbes, and plants; limited for large vertebrates	*Very High* faster than trapping or transects, requires careful planning	*Very High* consistent when soil types/conditions are similar. Standardised global protocols enable repeatable monitoring	*Very High* reduced field labour, batch lab analysis cuts per-sample	*Very High* small soil samples, short campaigns
AirDNA	*Medium–High* effective for broad biodiversity screening; spatial precision limited	*Very High* passive, continuous or large-area sampling	*Very High* scalable with automated devices.	*High* low setup and lab processing cost	*Very Low* automated or minimal field effort
Remote Sensing / LiDAR	*High* captures ecosystem structure; ideal for spatial analysis, indirect species detection	*Very High* automated data collection at broad scales	*Very High* repeatable global coverage	*High–Very High* free satellite data or low per-site cost after setup	*Very High* entirely remote
Bioacoustics / Visual Monitorinng	*Medium* good for conspicuous/vocal taxa, behaviour; misses cryptic species	*Medium* deployment, retrieval, and data review required	*Medium* scalable with automated AI identification	*Medium* moderate hardware and data-processing costs	*Medium* devices need installation and maintenance
Conventional Ecological Surveys	*High* strong for abundance, behaviour, and ground-truthing	*Low* time-consuming, labour-intensive	*Low* constrained by logistics and expertise	*Low* high personnel and travel costs	*Low* extended field effort required

Deliverable 2. Benefits and Limitations of eDNA

eDNA offers rapid, scalable, and cost-effective biodiversity insight, but its accuracy depends on context and careful design.

Benefits

- ✓ Comprehensive coverage: A single sample can detect hundreds of species across multiple taxa.
- ✓ Early detection: Highly sensitive to low-density or elusive species, including invasives.
- ✓ Scalable: Applicable to thousands of sites using standardised sampling protocols.
- ✓ Non-invasive and safer: Reduces field time, costs, and health-and-safety risks.
- ✓ Data integration: Outputs can be linked to GIS, TNFD "Locate" layers, and CSRD datasets.

Commercial applications across 110+ countries show eDNA detecting up to 70% more fish species and 10× more soil fauna than conventional surveys, while cutting field time by 40–60%.

Limits

eDNA's value depends on rigorous method design:

- ✓ Environmental sensitivity: DNA degradation varies by temperature, pH, salinity, and UV exposure.
- ✓ Sampling bias: DNA from upstream or airborne sources may cause false positives.
- ✓ Incomplete reference databases: Some taxa (e.g., certain invertebrates or tropical flora) are underrepresented.
- ✓ Quantification challenges: Relative abundance indices possible; exact population counts are not.
- ✓ Quality control essential: Replicate sampling, negative controls, and bioinformatics checks are mandatory for defensible data.

Deliverable 2. Conclusion

- eDNA transforms biodiversity reporting from descriptive to evidence-based. It provides the missing biological dimension that turns “impact statements” into measurable outcomes.
- Integrating eDNA with remote sensing, bioacoustics, and field surveys provides full coverage of species, ecosystem structure, composition, and function.
- To align with framework requirements, eDNA data should be:
  - Collected using standardised, accredited protocols.
  - Analysed by certified laboratories with full chain-of-custody documentation.
  - Integrated into internal ESG data systems, ideally geo-referenced.
  - Accompanied by metadata (sampling date, environment, coordinates, sequencing method).
  - This ensures replicability and regulatory defensibility.

Companies that adopt eDNA early will likely be better equipped to meet nature reporting requirements, demonstrate transparency to investors, and measure progress toward a nature-positive future.

Thank you

Isadora Ferreira and Pippa Howard

Head Office
1 Occam Court,
Surrey Research Park,
Guildford, GU2 7HJ
United Kingdom

North American Office
590 Hanlon Creek Boulevard,
Unit 11,
Guelph,
Ontario, N1C 0A1,
Canada

Environmental DNA and nature reporting

How and when to use molecular data in corporate biodiversity disclosure

December 2025

Purpose

This document provides a **practical framework** to guide how and when **environmental DNA (eDNA)** should be applied in nature-related reporting, the **types of metrics** it can credibly support, and how it can be **integrated with other monitoring and assessment tools** to meet the disclosure expectations of 8 frameworks:

1. Corporate Sustainability Reporting Directive - ESRS E4: Biodiversity and Ecosystems (CSRD – E4)
2. Taskforce on Nature-related Financial Disclosures (TNFD) – core and additional metrics
3. Science-Based Targets Network (SBTN) – Step 1 and 2 Requirements
4. Global Reporting Initiative (GRI) – 304 biodiversity
5. IPIECA (Oil & Gas Association) – biodiversity only
6. CDP (Carbon Disclosure Project) – biodiversity only
7. Sector-specific guidance for Oil and Gas from TNFD and GRI was also included.

Under the CSRD, where biodiversity and ecosystems are assessed as material through the double materiality assessment, disclosures under ESRS E4 are compulsory and subject to regulatory scrutiny and assurance, while TNFD, SBTN, GRI 304, CDP, IPIECA and sector-specific oil and gas guidance remain voluntary frameworks that support and strengthen biodiversity risk management and disclosure.

The framework is based on findings from **280 biodiversity-related disclosure requirements** analysed across **eight reporting frameworks**. Each requirement was mapped against the **State–Pressure–Response (SPR)** model to identify where eDNA provides direct or complementary value. A summary of this assessment is presented on **page 20** of this document.

The document is structured in two main parts:

1. **Framework for using eDNA in nature reporting** – outlines decision criteria, applicability boundaries, and examples of integration with other data sources.
2. **Summary of Phase 1 and 2 findings** – synthesises results from the assessment of reporting frameworks (Phase 1) and the evaluation of metric-level applicability (Phase 2).

Glossary of key terms and acronyms

1. α-/β-diversity: Measures of biodiversity: α-diversity refers to species richness within a specific site, while β-diversity compares species composition between sites.
2. CDP (Carbon Disclosure Project): A non-profit platform for environmental disclosure where companies report on climate, water, and biodiversity performance to investors and stakeholders.
3. Corporate Sustainability Reporting Directive – ESRS E4: Biodiversity and Ecosystems (CSRD–E4): EU regulation requiring companies to disclose on a wide range of topics, including climate and environmental data in the EU. ESRS E4 is a sustainability reporting standard under CSRD that requires companies to report on their impacts, dependencies, risks, and opportunities related to biodiversity and ecosystems
4. eDNA (Environmental DNA): Genetic material obtained from environmental samples (e.g. soil, sediment, or water) that can be analysed to identify species present without direct observation or capture.
5. eDNA Metabarcoding: A method that amplifies and sequences multiple DNA fragments from an environmental sample to identify entire biological communities, allowing broad biodiversity assessments.
6. eDNA qPCR/ddPCR (Quantitative / Digital Droplet Polymerase Chain Reaction): Techniques used to detect and quantify specific target species in an environmental sample. qPCR measures DNA concentration in real time, while ddPCR partitions samples into thousands of droplets for higher sensitivity and precision.
7. GBIF (Global Biodiversity Information Facility): An open-data platform that provides access to global species occurrence records collected from museums, research institutions, and citizen science initiatives.
8. GIS (Geographic Information System): Technology used to capture, store, analyse, and visualise spatial and geographic data for environmental assessment and decision-making.
9. Global Reporting Initiative (GRI): An international standard for sustainability reporting that includes biodiversity indicators within its environmental disclosures.

Glossary of key terms and acronyms

10. IBAT (Integrated Biodiversity Assessment Tool): An online platform providing access to global biodiversity datasets, including the IUCN Red List, Key Biodiversity Areas (KBAs), and protected areas, to support risk screening and conservation planning.
11. IPIECA (Oil & Gas Association): The global oil and gas industry association for advancing environmental and social performance, including biodiversity and ecosystem guidance.
12. IUCN Red List: A global inventory assessing the conservation status of species and their risk of extinction.
13. LiDAR (Light Detection and Ranging): Remote sensing technology that uses laser pulses to map landforms, vegetation structure, and habitat features in three dimensions.
14. Science-Based Targets Network (SBTN): An initiative helping companies set measurable targets to reduce their impacts on nature and contribute to global biodiversity and ecosystem recovery goals.
15. Sector-specific guidance for Oil and Gas (TNFD and GRI): Supplementary documents that adapt the TNFD and GRI frameworks to the specific environmental and biodiversity challenges of the oil and gas sector.
16. STAR (Species Threat Abatement and Restoration metric): A biodiversity metric estimating potential reductions in global extinction risk through threat abatement and habitat restoration.
17. State–Pressure–Response (SPR): A model describing environmental relationships: the condition of ecosystems (State), human drivers of change (Pressure), and management actions (Response).
18. Taskforce on Nature-related Financial Disclosures (TNFD): A global framework guiding organisations on how to assess, manage, and disclose nature-related risks and opportunities.

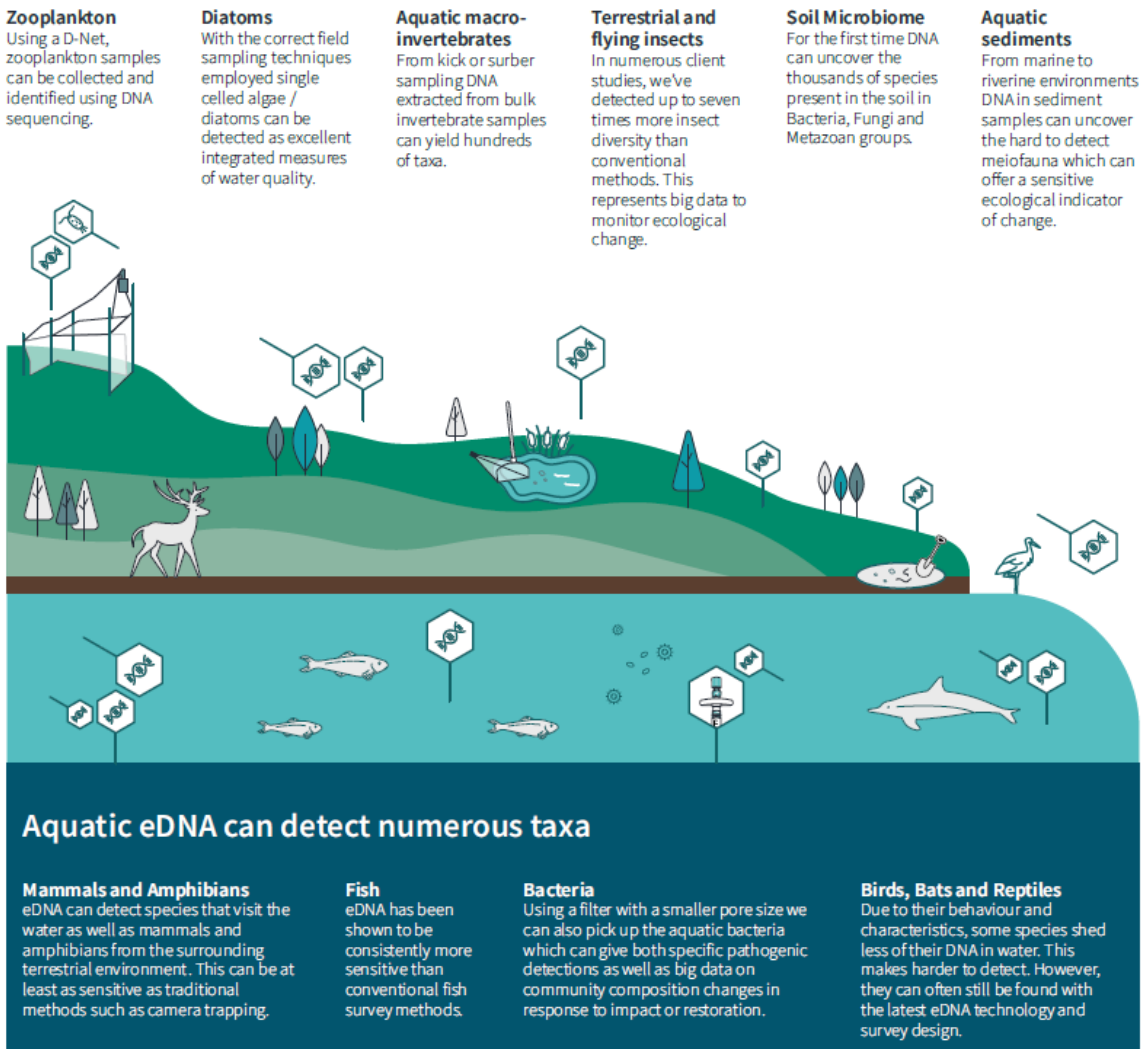
Framework for using eDNA across nature reporting

Why eDNA Matters

eDNA converts biodiversity from a qualitative concept into a measurable, repeatable dataset, linking corporate activity to ecological reality.

eDNA consists of microscopic fragments of genetic material shed by organisms into their surroundings, soil, water, sediment or air.

By collecting and sequencing these traces, we can identify which species are or were recently present in an ecosystem.



Why it matters for reporting

- **Comprehensive:** DNA is ubiquitous to all life, thus all life is detectable via eDNA, assuming all forms of life are detectable in all environments.
- **Direct biological evidence:** Supports several *states* of nature requirements at the site level, something GIS or chemical data cannot.
- **Early detection:** Reveals threatened, endemic or invasive species before visible change occurs.
- **Standardised and scalable:** Enables consistent biodiversity data across global portfolios.
- **Cost-effective verification:** Reduces fieldwork while producing auditable, digital records compatible with nature reporting frameworks.

Step 1.Identify the SPR Category

Determine where your reporting need sits within the State-Pressure-Response (SPR) model. This screens whether eDNA can be the primary, complementary, or limited-use method.

Reporting category	Framework question	Topics covered in each category	eDNA role	Other tools	How eDNA can be used
State of Nature*	What is the current condition of biodiversity or ecosystems? What species are present?	**Species**: Threatened and invasive species presence, species richness **Ecosystem condition**: composition and partial function	Primary	Supporting	Provides direct biological evidence of ecological condition by detecting species presence, richness and community composition across microbes, invertebrates and vertebrates. It reveals changes in ecosystem integrity, functional groups and overall biodiversity status with high sensitivity.
		Species: Extinction risk, abundance, population size **Ecosystem condition**: structure **Biodiversity sensitive areas** **Other topics:** connectivity, ecosystem services	Supporting	Primary	
		Ecosystem extent and overlap with indigenous land	Limited applicability	Primary	-
Pressure	What human activities impact biodiversity?	Land conversion, emissions, pollution, etc.	Limited applicability	Primary	Detects shifts in soil, water and habitat communities that signal disturbance, degradation or pollution. Loss of sensitive taxa, proliferation of tolerant species and altered microbiome structure provide early evidence of anthropogenic pressures. Comparative designs (reference vs impact) strengthen attribution to specific pressure.
Response	What actions and results have been used to mitigate impacts?	Restoration, offsets, ecological recovery, etc.	Supporting	Primary	eDNA enables verification of whether mitigation or restoration actions are producing measurable biodiversity outcomes. By tracking species return, community recovery and functional improvements over time, eDNA converts management actions into demonstrable ecological evidence. This supports adaptive management and proof of performance for TNFD and CSRD reporting.
Governance Strategy	What policies are in place and What methods have been used?	Baseline validation and progress tracking	Supporting	Primary	

Note: *A summary of this assessment is presented from page 20 of this document.

Step 2a. Assess applicability for State of Nature requirements – Species

Determine the topic within State of Nature requirements to identify where eDNA adds the most value.

Step 1: What is the topic covered?	Step 2: What is the main method to use to measure the requirement topic?	Step 3: What are the supporting tools?	Step 4. What metrics can be derived from eDNA? (non-exhaustive)
Presence and Richness	Use eDNA to detect multiple taxa simultaneously, including rare, nocturnal, or cryptic species, IUCN Threatened Species, invasive species.	You may use visual and acoustic monitoring for behavioural context; conventional surveys for morphological verification.	• **Presence/absence:** confirms if a species is currently or recently present at a site • **Species richness:** counts the number of distinct taxa detected, indicating biodiversity level and local ecological quality.
Population Change and Community Turnover	Use eDNA metabarcoding to assess species composition across sites or time periods to track biodiversity change.	Combine with field or acoustic surveys to validate ecological shifts; integrate with GIS or environmental data to interpret drivers.	• **Community diversity (α-/β-diversity):** compares species composition within and between sites to detect ecological turnover or disturbance. • **Functional group composition:** identifies trophic or ecological roles (e.g., pollinators, decomposers, predators) to infer ecological balance or stress.
Abundance or Population Size	Use acoustic/visual monitoring and conventional surveys to determine population size, range, and abundance.	You may use eDNA to provide relative abundance indicators (semi-quantitative). Use alongside calibration datasets or acoustic/visual monitoring to interpret trends.	• **Relative abundance (semi-quantitative):** eDNA read counts or DNA concentration give a semi-quantitative signal of species dominance, and in soils this often reflects true relative abundance more reliably.* • **Biomass proxy:** In enclosed systems, eDNA concentration can act as a proxy for biomass, indicating population size or biomass trends.
Extinction Risk or Range	Modelling tools and frameworks (e.g. IUCN Red List, STAR, persistence score models) for assessing extinction risk and range.	You may use eDNA to confirm current species occupancy in historical or modelled ranges, validating presence within extinction-risk models or persistence indices. eDNA can be used for species mapping across catchments.	• **Extinction-risk score:** combines eDNA detections with IUCN or STAR indices to validate risk level.

*Because soil holds DNA in place, read counts more closely reflect the actual proportion of each taxon.

See next slide for metrics derived from other tools that can also be applied here.

Step 2a. Assess applicability for State of Nature requirements - Ecosystem Condition

Determine the topic within State of Nature requirements to identify where eDNA adds the most value.

Step 1: What is the topic covered?	Step 2: What is the main method to use to measure the requirement topic?	Step 3. What are the supporting tools?	Step 4. What metric can be derived from eDNA? (non-exhaustive)	Step 5. What metrics can be derived from other tools? (non-exhaustive)
Composition	eDNA provides direct biological evidence of which species are present and how biodiversity is changing.	• Visual and acoustic monitoring complement eDNA by adding temporal and behavioural insight. • Conventional surveys can support eDNA detections and provide context.	• Same metrics from slide 5	Visual/Acoustics • *Vocal Species Richness*: Identifying the number of bird, bat, amphibian, or insect species by their calls. • *Temporal Activity Diversity Index*: Understanding when species are active (day vs. night). Conventional Survey • *Population Density & Abundance*: Estimating the number of individuals, not just their presence. Remote Sensing • *Habitat Suitability*: Correlating specific habitat types with the likely presence of certain species communities • *Range distribution*: Built from species occurrence data, including eDNA, visual records, or trapping, then interpolated spatially. The mapping step uses GIS, but the underlying data are biological detections. • *Persistence index*: Derived from repeated presence observations across time to estimate the probability a species remains in a site.

Step 2a. Assess applicability for State of Nature requirements - Ecosystem Condition

Determine the topic within State of Nature requirements to identify where eDNA adds the most value.

Step 1: What is the topic covered?	Step 2: What is the main method to use to measure the requirement topic?	Step 3. What metric can be derived from eDNA? (non-exhaustive)	Step 4. What metrics can be derived from other tools? (non-exhaustive)
Function	• Remote sensing provides a macroscopic view of ecosystem function (i.e. measures large-scale processes) • Bioacoustics adds a temporal and behavioural layer • eDNA reveals the hidden functions performed by microbial communities. • Conventional surveys remain essential for direct measurement of key functions	• Functional diversity index: measures the diversity of genes or taxa performing ecological processes (e.g. nutrient cycling). • Microbial or benthic assemblage integrity: tracks the condition of soil or aquatic communities driving key biogeochemical functions. • Pollution indicator taxa: detects functional groups linked to degradation or recovery (e.g. hydrocarbon degraders).	Remote Sensing • *Gross Primary Production*: Measuring the rate of photosynthesis and carbon uptake over large areas. • *Water Cycling*: Assessing evapotranspiration rates and surface water dynamics. • *Phenology*: Tracking the timing of seasonal events like leaf-out and senescence. Visual/Acoustics • *Acoustic Complexity Index*: A proxy for the health and complexity of the soundscape. A vibrant, complex soundscape often indicates a functioning ecosystem. • *Pollinator Activity*: Detecting the buzzing frequencies of bees and other flying insects. Conventional surveys • *Water Quality Parameters*: Measuring levels of nitrates, phosphates, and dissolved oxygen. • *Soil Carbon Content*: Directly quantifying carbon stored in the soil.

Step 2a. Assess applicability for State of Nature requirements - Ecosystem Condition

Determine the topic within State of Nature requirements to identify where eDNA adds the most value.

Step 1: What is the topic covered?	Step 2: What is the main method to use to measure the requirement topic?	Step 3. What are the supporting tools?	Step 4. What metric can be derived from eDNA? (non-exhaustive)	Step 5. What metrics can be derived from other tools? (non-exhaustive)
Structure	Remote sensing (LiDAR, multispectral imagery), habitat mapping, and environmental sensors for canopy structure, connectivity, and productivity.	eDNA plays a supporting role: while it cannot measure physical structure directly, it provides complementary biological context by revealing how community composition varies across structural gradients. This is key when generating ecosystem condition indicators	• β-diversity (Community Turnover Index): Measures the difference in species composition between sites (e.g., forest edge vs interior, or disturbed vs intact plots). Helps interpret whether structural change affects biological integrity. • Native–Non-Native Ratio: proportion of native vs. alien taxa detected. Indicates structural disturbance or fragmentation, a higher non-native ratio often aligns with reduced structural complexity or edge effects.	Remote Sensing • Habitat Extent & Fragmentation: Measuring the size and connectivity of natural habitats. • 3D Vegetation Structure (from LiDAR): Metrics include canopy height, vertical complexity, and vegetation density. • Normalised Difference Vegetation Index (NDVI): A proxy for vegetation health and photosynthetic activity. Conventional Survey • Ground-Truthed Tree Height & Diameter (DBH): Validating LiDAR-based biomass models. • Understory & Ground Cover Assessment: Providing detail that satellites cannot see.

Step 2a. Assess applicability for State of Nature requirements: Biodiversity sensitive areas

Determine the topic within State of Nature requirements to identify where eDNA adds the most value.

Step 1: What is the topic covered?	Step 2: What is the main method to use to measure the requirement topic?	Step 3. What are the supporting tool(s)?	Step 4. What metric can be derived from eDNA? (non-exhaustive)	Step 5. What metrics can be derived from other tools? (non-exhaustive)
Biodiversity Sensitive Areas	GIS-based mapping (IBAT, WDPA, KBA datasets, protected-area layers) for identifying overlap with high-biodiversity areas.	You may use eDNA to verify the presence of threatened or endemic species in or near mapped sensitive sites, strengthening classification and supporting compliance reporting.	• Presence of threatened or endemic taxa: confirms if mapped sensitive areas host priority species. • Species richness: counts the number of distinct taxa detected, indicating biodiversity level and local ecological quality. • Biodiversity sensitivity index: ranks sites based on species composition and rarity-weighted richness to verify ecological value.[1]	There is no metric here. Use spatial intersection and buffering in GIS to quantify how much of your site overlaps or lies near protected or biodiversity-sensitive areas.

Note 1: There is no widely recognised, off-the-shelf "Biodiversity Sensitivity Index" that universally ranks sites based on species composition and rarity-weighted richness under that precise terminology. However, companies may develop a bespoke biodiversity sensitivity index by aggregating site-level species data and applying recognised conservation weightings (e.g. IUCN Red List status, endemism or range restriction) to rank ecological value. While not a prescribed ESRS metric, such indices are acceptable under CSRD where methodologies, assumptions, data sources and limitations are transparently documented and used to inform impact, risk and opportunity assessment.

Step 2a. Assess applicability for other topics included in State of Nature

Determine when eDNA is the most suitable tool to measure or verify the topic within the State of Nature requirements of the specific framework.

Step 1: What is the topic covered?	Step 2: What is the main method to use to measure the requirement topic?	Step 3. What are complementary / supporting tool(s)?	Step 4. What metric can be derived from eDNA? (non-exhaustive)	Step 5. What metrics can be derived from other tools? (non-exhaustive)
Connectivity	GIS, habitat and corridor modelling for landscape-scale ecological connectivity.	• eDNA validates biological connectivity by detecting shared or genetically linked taxa between sites. • eDNA can partially measure functional connectivity by detecting species across multiple sites, analysing genetic variation and comparing turnover between patches	• Functional Connectivity Index: Measures biological continuity between sites by detecting the same taxa or shared DNA signatures across multiple locations. A higher index suggests species are using corridors or that gene flow persists between habitats. • Community Overlap Score: Quantifies similarity in community composition between adjacent or linked habitats. Declining overlap indicates reduced functional connectivity.	• Structural Connectivity (Corridor Index): Quantifies how physically connected habitats are based on spatial continuity, patch proximity, or resistance to movement. Reflects the potential connectivity. • Habitat Permeability Map: Models ease of species movement across the landscape, integrating barriers • Corridor Effectiveness Ratio: Compares actual biological use (from eDNA detections or tracking) with mapped corridor area. Indicates whether corridors function as intended.
Indigenous Peoples and Local Communities	GIS-based mapping for identifying the overlap of operations with areas where Indigenous Peoples are present or affected by activities of the organisation.	eDNA not applicable.	eDNA not applicable.	There is no metric here; overlay sites with area maps to measure proximity

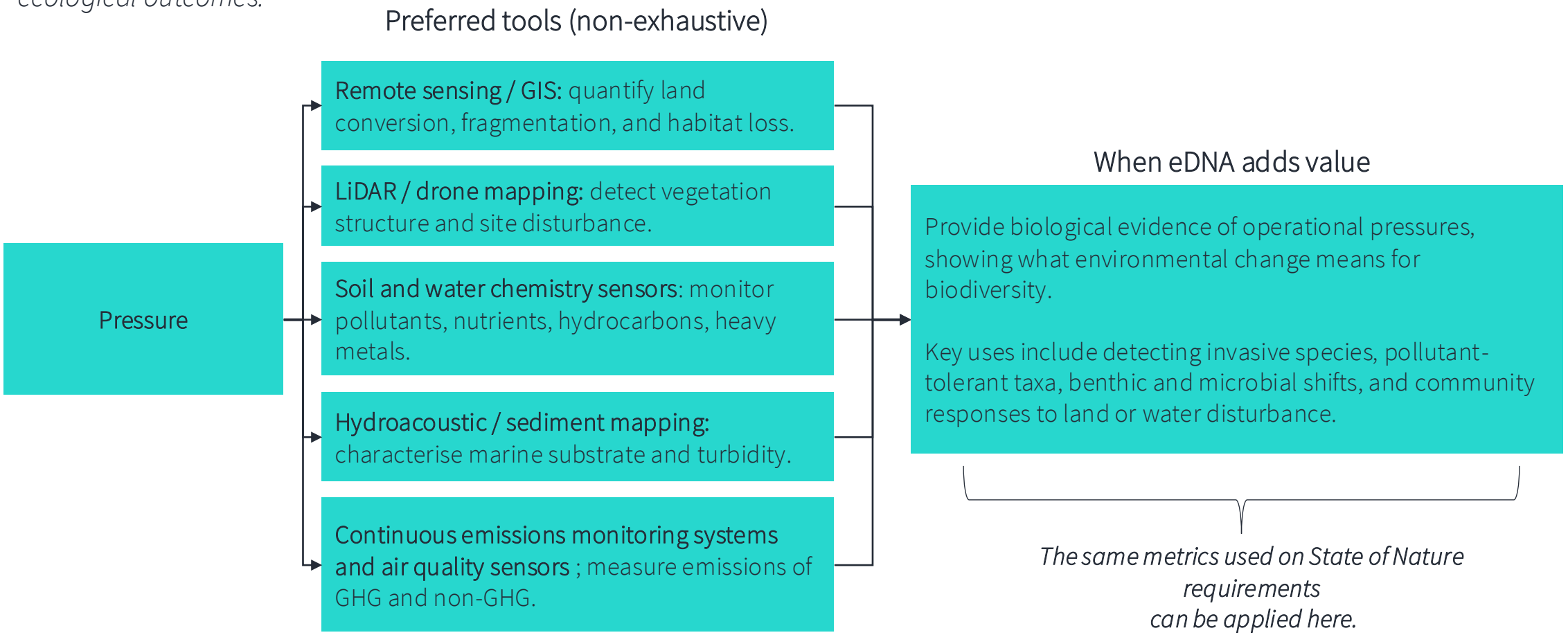
Step 2a. Assess applicability for other topics included in State of Nature

Determine when eDNA is the most suitable tool to measure or verify the topic within State of Nature requirements of the specific framework.

Step 1: What is the topic covered?	Step 2: What is the main method to use to measure the requirement topic?	Step 3. What are complementary / supporting tool(s)?	Step 4. What metric can be derived from eDNA? (non-exhaustive)	Step 5. What metrics can be derived from other tools? (non-exhaustive)
Ecosystem Extent	Spatial datasets (satellite imagery, land-use/land-cover maps) for measuring area, fragmentation, and land-cover change.	eDNA not applicable.	eDNA not applicable.	• Habitat Extent (ha/km^2): total area of each ecosystem type. • Land-Cover Change Rate (%/year): expansion or loss relative to baseline. • Habitat Fragmentation Index: number and size of patches, edge density.
Ecosystem Services	Ecosystem service models (InVEST, ENCORE, ARIES) and spatial data on service flows and beneficiaries.	eDNA identifies key biotic contributors (pollinators, decomposers, microbial communities) influencing service delivery and ecosystem function.	• Functional Group Richness: diversity of taxa contributing to key services (pollinators, decomposers, nitrogen fixers). • Microbial Functional Index: relative abundance of genes/taxa linked to nutrient cycling or pollutant breakdown. • Pollinator Presence Metric: detection of pollinator DNA in soil, air, or water.	• Ecosystem Service Flow Models: Estimates the amount of a service delivered (e.g., water filtration) based on ecosystem extent and condition. • Vegetation Productivity (NDVI, GPP): Measures photosynthetic activity and biomass accumulation, a proxy for provisioning and regulating services.

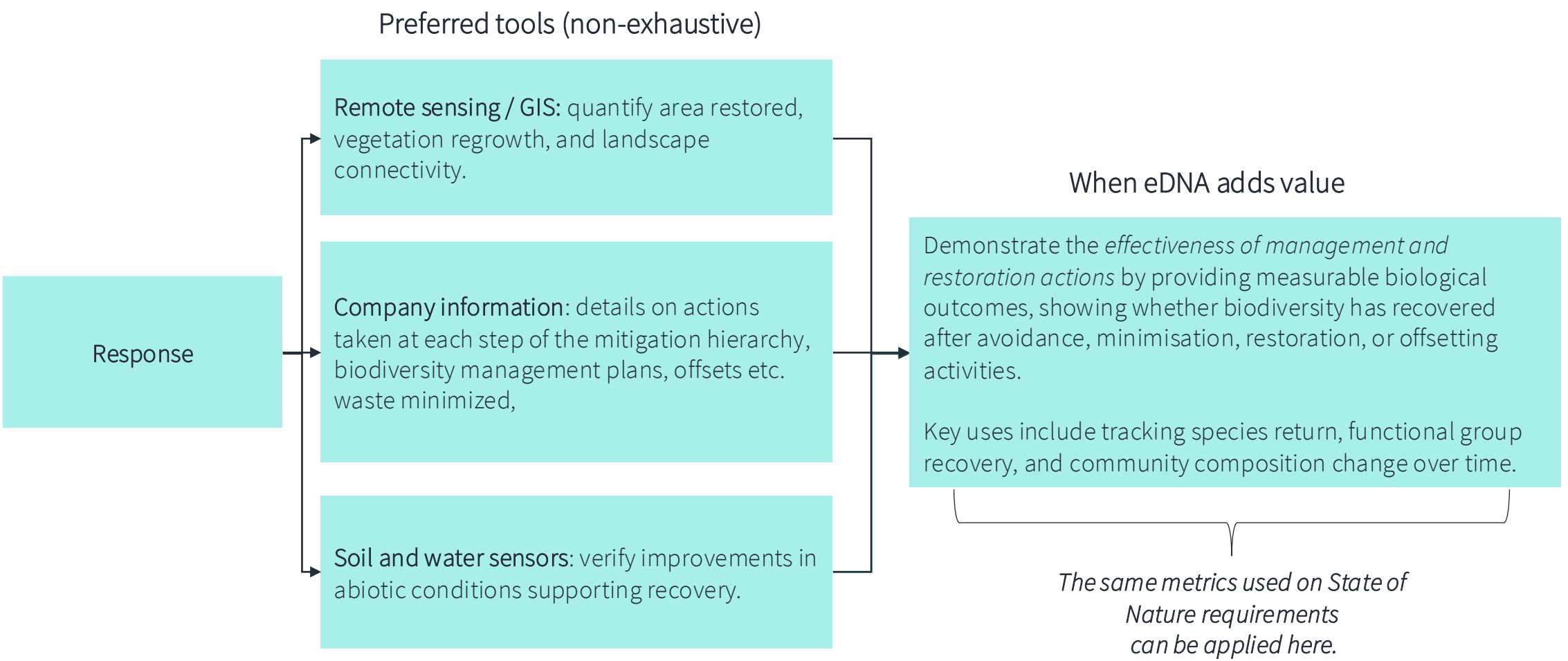
Step 2b: Assess applicability for pressure requirements

Define the circumstances under which eDNA can support, but not replace, physical, chemical, or management data for other disclosure categories. eDNA enhances the robustness of reporting by providing biological evidence that links environmental pressures to observed ecological outcomes.



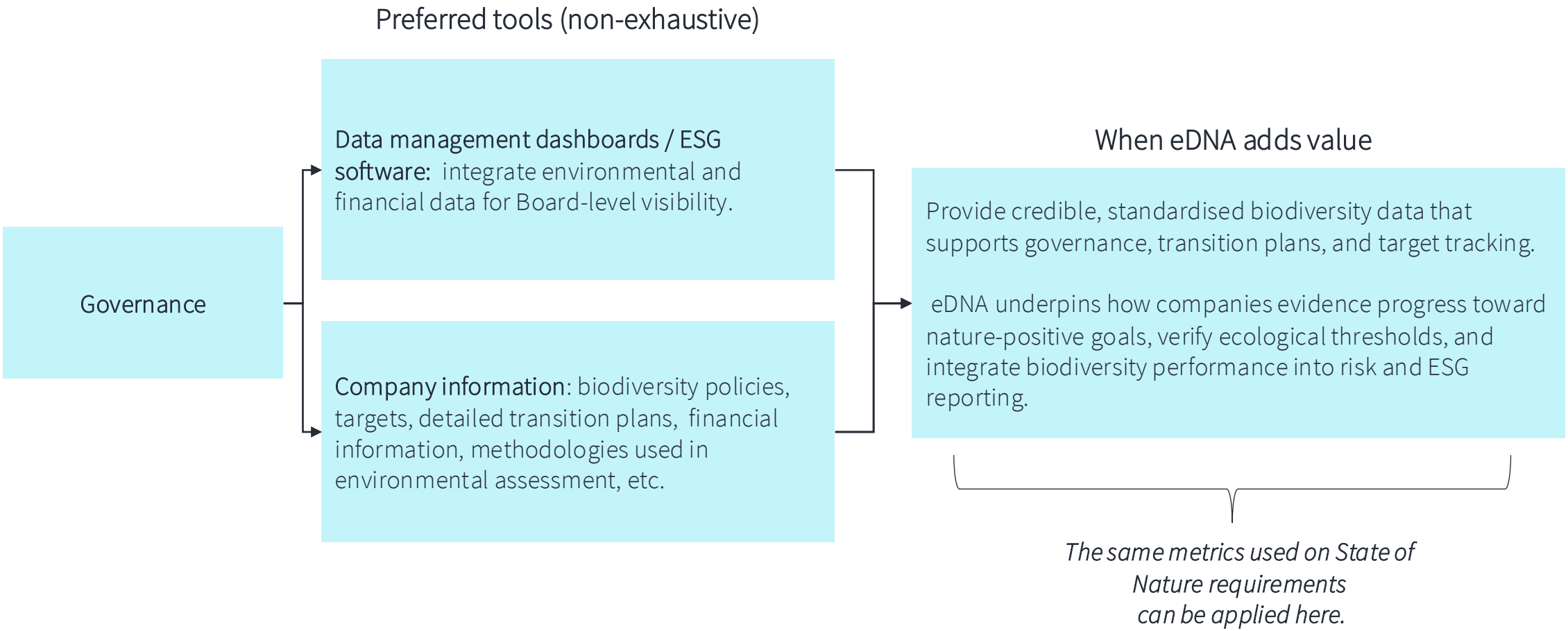
Step 2b: Assess applicability response requirements

Define when eDNA can support evidence for response requirements. eDNA moves reporting from listing actions to demonstrating ecological results, providing evidence of biodiversity recovery.



Step 2b: assess applicability governance and strategy requirements

Define when eDNA can support evidence for response requirements. eDNA moves reporting from listing actions to demonstrating ecological results, providing evidence of biodiversity recovery.



Recommendations for State of Nature requirements

Embedding eDNA within corporate environmental management and disclosure processes can support a shift from compliance-focused reporting towards more evidence-based assessment of nature-related performance.

Integrated approach for species-related requirements:

- Use eDNA to confirm the presence of threatened and invasive species and species richness.
- Use acoustic/visual monitoring and conventional surveys to determine population size, range and abundance.
- Use models such as STAR or species persistence scores for ecosystem risk.
- Use remote sensing if contextual habitat/ phenology data are needed

Integrated approach for biodiversity sensitive areas requirements:

- **Primary:** GIS-based mapping (IBAT, WDPA, KBA datasets, protected-area layers)
  for identifying overlap with high-biodiversity areas.
- **Supporting:** Use eDNA to validate biological significance

Integrated approach for ecosystem condition requirements:

- Use eDNA as the compositional core
- Leverage remote sensing for structural data
- Integrate bioacoustics for functional insight
- Retain conventional field surveys for validation

Integrated approach for other requirements:

- **Extent**: Use GIS and remote sensing to measure extent, area, fragmentation etc.
- **Connectivity**: Use GIS and habitat modelling for landscape-scale ecological connectivity; eDNA confirms biological functionality of corridors.
- **Indigenous People**: Use participatory mapping and socio-environmental data
- **Ecosystem Services**: Use ecosystem service models (InVEST, ENCORE, ARIES). Integrate eDNA functional taxa data with modelled or remote-sensed service flows for combined functional and spatial outputs.

Recommendations for pressure, response, strategy & governance requirements

Use conventional metrics to measure impact, then use eDNA to prove what those impacts mean for nature.

1. Start with conventional tools

- The frameworks analysed, such as CSRD, TNFD, and GRI, currently require physical, spatial, and chemical data — hectares, tonnes, cubic metres, concentrations for pressure requirements and descriptions of response and governance actions.
- Use first remote sensing, GIS, emissions monitoring, water and soil sensors, and internal company information to answer these requirements.
- These must remain the foundation of reporting.

2. Use eDNA as a complementary validation layer:

- Once physical data are collected, apply eDNA to confirm whether reported actions or pressures translate into *real ecological outcomes*.

3. Why go beyond current requirements

Even if not yet mandatory, integrating eDNA provides:

- Credible scientific proof linking corporate activity to biodiversity change.
- Future-readiness for upcoming TNFD, SBTN, and CSRD updates focusing on nature outcomes.
- Reputational and regulatory resilience, moving from compliance to evidence-based leadership.

Sampling standards and guidelines

To ensure data quality, reproducibility, and regulatory credibility, consistent field protocols are needed. Here we provide current best practices and offers baseline recommendations suitable for oil and gas contexts.

Key Principles for eDNA Sampling

Contamination control is essential at all stages—from field collection through to laboratory processing.

Sampling design must align with monitoring objectives, taking into account habitat characteristics and target taxa.

Standardisation of procedures supports cross-project comparisons and regulatory engagement.

Metadata recording is integral to data interpretation and auditability

For more information pleaser refer to IOGP – Genomics Publications/ Chapter 1 and 2

eDNA sampling standards and guidelines

To ensure data quality, reproducibility, and regulatory credibility, consistent field protocols are needed.
Here we provide current best practices and offers baseline recommendations suitable for oil and gas contexts.

General Recommendations for Field Sampling (Part 1)

Planning and Preparation

- **Clear objectives:** Define species or communities of interest and intended ecological insights (e.g., presence/absence vs. community structure).
- **Reference sites:** Incorporate baseline or control sites where possible to interpret temporal or impact-related changes.
- **Replicates:** Use biological and technical replicates to ensure robustness, especially in heterogeneous environments.

Sample Collection

- Use **sterile, single-use equipment** wherever possible.
- Minimise sample handling and exposure to reduce risk of cross-contamination.
- Ensure **appropriate preservation** methods are used immediately after collection (e.g., freezing, ethanol, buffer solutions).

Contamination Prevention Measures

Field protocols

- Collect samples upstream or upwind of any disturbance.
- Process negative controls in the field (e.g., blank filters, sterile water).
- Clean or change gloves and tools between each sample.

Personnel training

- Ensure that all team members involved in sampling understand contamination risks and follow procedures consistently. This does not require an ecology background or formal education.

Equipment

- Use pre-sterilised containers and filtration units.
- Avoid re-use of field gear unless validated cleaning protocols are in place.

For more information pleaser refer to IOGP – Genomics Publications/ Chapter 1 and 2

eDNA sampling standards and guidelines

To ensure data quality, reproducibility, and regulatory credibility, consistent field protocols are needed.
Here we provide current best practices and offers baseline recommendations suitable for oil and gas contexts.

General Recommendations for Field Sampling (Part 2)

Sample Preservation and Transport

- Preservation methods should be selected based on sample type and analysis timeline.
- Options include: immediate freezing (preferred where feasible); ethanol or DNA preservation buffer for field conditions without refrigeration.
- Labelling and documentation must be clear, consistent, and linked to field metadata and chain-of-custody records.
- Transport logistics must maintain sample integrity (e.g., cold chain), especially for marine or remote locations.

Sampling Design Considerations

- Spatial replication: Helps account for local variation, particularly in patchy habitats.
- Temporal sampling: Should align with biological cycles (e.g., breeding seasons, migration) and project phases.
- Volume and filtration:
  - Larger volumes may increase detection likelihood, but must balance with filter clogging risk
  - The guidance suggests filtering 1–5 litres of water per sample in typical applications.

Metadata and Documentation

- A consistent approach to metadata is vital for the interpretation and reuse of eDNA datasets. Recommended information includes:
  - GPS location, date, time, habitat descriptors
  - Environmental conditions (e.g., temperature, salinity, turbidity)
  - Sample type, volume, preservation method
  - Equipment used and any deviations from standard protocol

For more information pleaser refer to IOGP – Genomics Publications/ Chapter 1 and 2

eDNA sampling standards and guidelines

To ensure data quality, reproducibility, and regulatory credibility, consistent field protocols are needed. Here we provide current best practices and offers baseline recommendations suitable for oil and gas contexts.

Sample Types by Habitat

Environment	Typical Sample Types	Notes
Marine	Water, sediment	Use depth-integrated or discrete samples depending on objectives
Freshwater	Water, sediment, biofilm	Flow conditions and turbidity affect sampling strategy
Terrestrial	Soil, bulk arthropods, surface swabs	Heterogeneity requires spatial replication

Caution: Survey design, sample size, and frequency depend on each site's habitat type, climate, hydrology, and operational footprint. A fixed framework such as this cannot prescribe these parameters without compromising scientific validity. **Sampling design must be developed case by case** by technical experts or accredited providers, following ISO standards and local regulatory requirements.

For more information pleaser refer to IOGP – Genomics Publications/ Chapter 1 and 2

Conclusion

eDNA transforms biodiversity reporting from measuring activity to proving ecological performance, a crucial step toward credible, nature-positive business practice.

As frameworks evolve toward nature-positive performance, early adoption of eDNA positions companies ahead of regulatory and investor expectations.

eDNA is a scalable and credible biodiversity measurement tool

It delivers reliable biological data that meet evolving TNFD, CSRD-E4, and SBTN disclosure needs across species, ecosystem condition, and biodiversity-sensitive areas.

Build interoperability into reporting systems

Integrating eDNA with remote sensing, bioacoustics, and field surveys provides full coverage of species, ecosystem structure, composition, and function.

eDNA accelerates and strengthens biodiversity assessment

Faster baselines, earlier detection of critical habitats, and clear evidence of restoration outcomes, particularly valuable for sectors like oil and gas.

Moves companies from compliance to performance

Embedding eDNA in management and reporting systems links actions to measurable ecological outcomes, improving transparency and accountability.

Thank you

Isadora Ferreira and Pippa Howard

Head Office
1 Occam Court,
Surrey Research Park,
Guildford, GU2 7HJ
United Kingdom

North American Office
590 Hanlon Creek Boulevard,
Unit 11,
Guelph,
Ontario, N1C 0A1,
Canada

ENVIRONMENTAL GENOMICS RESEARCH PROGRAMME

An IOGP programme

International Association of Oil & Gas Producers

IOGP Headquarters

3 Moorgate Place, London, EC2R 6EA, United Kingdom
T: +44 20 4570 6879
E: reception@iogp.org

IOGP Europe

T: +32 2 210 94 40
E: reception-europe@iogp.org