

Strengthening eDNA Biomonitoring in Remote Australia

Research Report



Executive Summary

This report investigates the use of environmental DNA (eDNA) for biodiversity monitoring in remote contexts. eDNA enables species detection through genetic traces in water, soil, and air, offering a non-invasive tool for conservation. While widely applied, its effectiveness in the field is limited by challenges of reliability, usability, and logistics.

A mixed-methods approach was adopted, combining a survey of 21 experts with interviews involving 4 practitioners and specialists. This triangulation provided both quantitative patterns and qualitative depth, revealing where processes break down and where design opportunities exist.

Findings show that delays, difficulties, and risks to reliability cluster at three critical workflow stages: collection, preservation, and transport. Environmental conditions such as heat, humidity, and turbidity, together with fragile logistics like cold-chain transport, often degrade samples. Contamination was identified as a recurring risk in both field and laboratory stages. Usability also emerged as a barrier, with current workflows described as fragmented and difficult for non-specialists to integrate into demanding schedules.

Opportunities for design include robust transport systems, climate-resilient preservation methods, and more practical, integrated workflows that reduce time and training demands. Innovation pathways were also identified; airborne eDNA as a frontier for expanding applications, automation to lower costs and broaden participation, and improved data-sharing to build transparency and trust.

Overall, the study highlights that the greatest opportunities for design-led solutions lie not in sequencing technologies but in addressing the bottlenecks of reliability, workflow integration, and adoption. By focusing on these areas, future tools can strengthen the accessibility, scalability, and impact of eDNA monitoring in remote and resource-limited contexts.



Acknowledgement

This report acknowledges Aboriginal and Torres Strait Islander peoples as the first inhabitants of Australia and the Traditional Custodians of the lands on which this work was undertaken. Respect and recognition is paid to Elders past, present, and emerging, and to their enduring connection with land, waters, and culture.

Authenticity Statement

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Introduction

Australia’s ecosystems are among the most diverse in the world, encompassing a wide range of landscapes, habitats, and species. Protecting these environments is a national priority, requiring accurate ecological knowledge and collaboration to inform management and conservation decisions. Environmental DNA (eDNA) has emerged as a valuable tool for ecological monitoring, offering new opportunities to assess biodiversity and ecosystem health in a non-invasive manner. Unlike traditional survey methods that rely on direct capture or observation, eDNA can detect species from genetic traces shed into water, soil, or air (Taberlet et al., 2018). This enables the identification of rare, elusive, and invasive species that might otherwise go undetected, while reducing disturbance to ecosystems and minimising resource demands (Gold et al., 2021; Holman et al., 2019).

At a time of rapid environmental change, eDNA offers a critical means of generating large-scale biodiversity knowledge. Australia faces particularly urgent challenges, with one of the highest rates of mammal extinction globally and continuing loss of habitat across ecosystems (Ward et al., 2021; Woinarski et al., 2015). In this context, rapid and reliable monitoring methods are essential for informing conservation strategies, managing invasive species, and assessing climate change impacts (Beng & Corlett, 2020). However, the application of eDNA in remote contexts remains constrained by persistent challenges. Technical issues such as contamination, degradation, and inconsistent protocols intersect with logistical barriers including transport, preservation, and training requirements (Granqvist et al., 2025; Wee et al., 2023; Zinger et al., 2019).

The aim of this project is to investigate how these challenges manifest in practice and to identify design opportunities that can strengthen eDNA monitoring. Through secondary research, surveys, and interviews, the study examines vulnerabilities across eDNA workflows and highlights innovation pathways to support more effective ecological monitoring.



Project Structure



Background

Overview

eDNA provides a non-invasive means of detecting species through genetic traces present in water, soil, and air. The effectiveness of eDNA remains constrained by contamination, protocol inconsistency, and environmental degradation, particularly in remote contexts where preservation and transport are challenging. Advances in automation and airborne eDNA present opportunities to enhance accessibility and broaden the applications of ecological monitoring.

eDNA Biomonitoring

Since the mid-2000s, advances in next-generation sequencing have driven a sharp rise in eDNA research. First applied to microbial studies in the 1980s and to macroorganisms in the early 2000s, eDNA offers a sensitive, non-invasive alternative to traditional biodiversity surveys such as trawls or tissue biopsies, which are costly, invasive, and prone to error (Jayasankar, 2017; Ogram et al., 1987). It enables the recovery of genetic material from water, soil, and air, allowing species detection without direct observation (Gold et al., 2021; Holman et al., 2019). Its applications now span widely such as ecology, biomonitoring, conservation, and invasion biology. Particularly transformative in aquatic contexts, eDNA improves detection of rare or low-abundance species often missed by conventional methods, reinforcing its importance for ecosystem monitoring in a time of accelerating environmental change.

Methods

The process of eDNA analysis generally involves collecting samples from the environment, filtering or concentrating the material, and extracting DNA in the laboratory. The extracted DNA is then amplified and sequenced using molecular methods such as polymerase chain reaction (PCR) or next-generation sequencing (NGS) (Ruppert et al., 2019; Sahu et al., 2025). These methods allow researchers to match recovered DNA fragments with reference databases to identify species present in the sampled environment. This workflow, from field sampling through to laboratory analysis, has been refined over the past decade and is now an established component of ecological monitoring programs. See Figure 2 for a summary of the eDNA process.

Inform, Educate, Act

Environmental Decisions

Analyse, Interpret and Report

Data

Extract, Amplify and Sequence DNA

Laboratory

Collect, Filter, Preserve samples

Field

Figure 2: Overview of eDNA process

Challenges

There are several challenges in the eDNA process that affect the reliability of results (Figure 3). Effective monitoring requires specialist expertise, fieldwork, and detailed laboratory analysis, yet the capacity to meet these demands is unevenly distributed worldwide, creating geographical gaps in biodiversity data. Another major limitation is the lack of consistency across workflows, with differences in survey design, field equipment, and laboratory protocols, making results difficult to compare across studies (Granqvist et al. 2025; Wee et al. 2023). Errors can also arise both from procedural steps, such as sampling, preservation, DNA extraction, and sequencing, and from natural variability in the spatial and temporal distribution of DNA (Zinger et al. 2019; Wee et al. 2023).

Environmental factors further complicate reliability. Water temperature, turbidity, pH, salinity, microbial activity, and ultraviolet radiation all influence DNA degradation, while poor preservation can exacerbate sample loss (Beng & Corlett, 2020; Mynott et al., 2019; Lamb et al., 2022; Tzafesta & Shokri, 2025). Such conditions are often amplified in remote locations, where maintaining sample integrity is more difficult. Since no single sampling technology can address all contexts, instrument design generally reflects trade-offs between usability, performance, and cost (Yamahara et al., 2025). Finally, contamination remains a persistent risk throughout eDNA workflows where DNA from external sources can be introduced during field sampling, laboratory processing, or equipment reuse, leading to false positives and misinterpretation of results (Beng & Corlett, 2020; Ke et al., 2025; Wee et al., 2023).

Emerging Topics

Automation is emerging as a key area of development in eDNA monitoring. Semi-to-fully autonomous devices now enable in-field sampling, filtration, and preservation, reducing reliance on laboratory infrastructure. Portable, low-cost tools are being developed for community science, while higher-capacity systems support long-term monitoring. New approaches such as digital PCR, and portable nanopore sequencing offer potential for rapid, sensitive analysis in remote settings, though many remain at early stages of validation (Yamahara et al., 2025). Airborne eDNA is an emerging approach with the potential to complement aquatic and sediment surveys (Johnson et al., 2021). Its ability to capture the airborne metagenome across taxa also presents widening applications for ecosystem monitoring, pest and pathogen surveillance, aeroallergen detection, and even industrial or agricultural uses (Bohmann et al., 2014; Tanaka et al., 2019).

Summary

eDNA is a powerful tool for biomonitoring, yet its full potential is often constrained in remote contexts. Distinct logistical and environmental challenges in these settings undermine the reliability of results and, by extension, the conservation decisions that depend on them. This research investigates these technical and contextual issues in greater depth to identify pathways for improvement.



Figure 3: Effect of challenges on eDNA process

Benchmarking

Overview

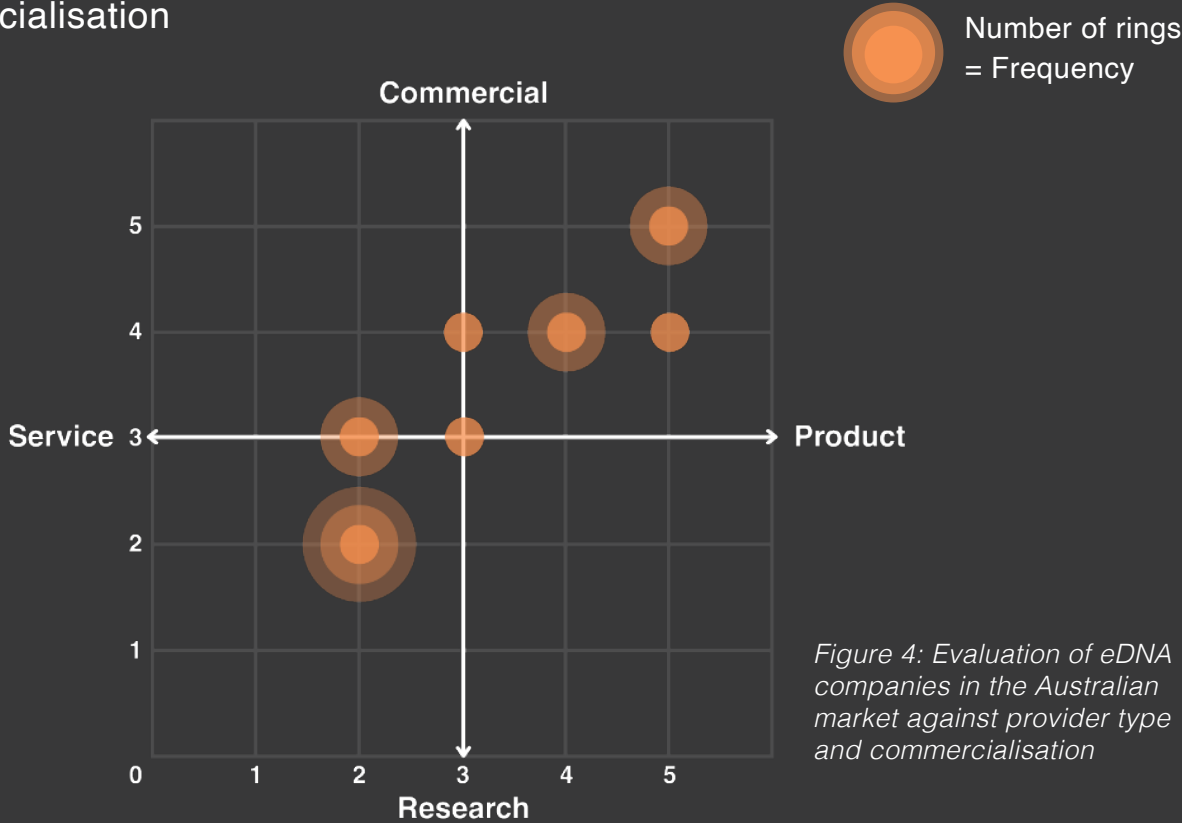
Benchmarking provides insight into the current market landscape to inform design decisions. Given the broad applications of eDNA, both a company-level scope of the Australian market and a product-level scope were conducted. This involved comparing companies by service versus product orientation and products by usability and workflow integration. From this overview, a selection of products was chosen for more detailed analysis. Refer to the appendix for assessment criteria.

Market Scope

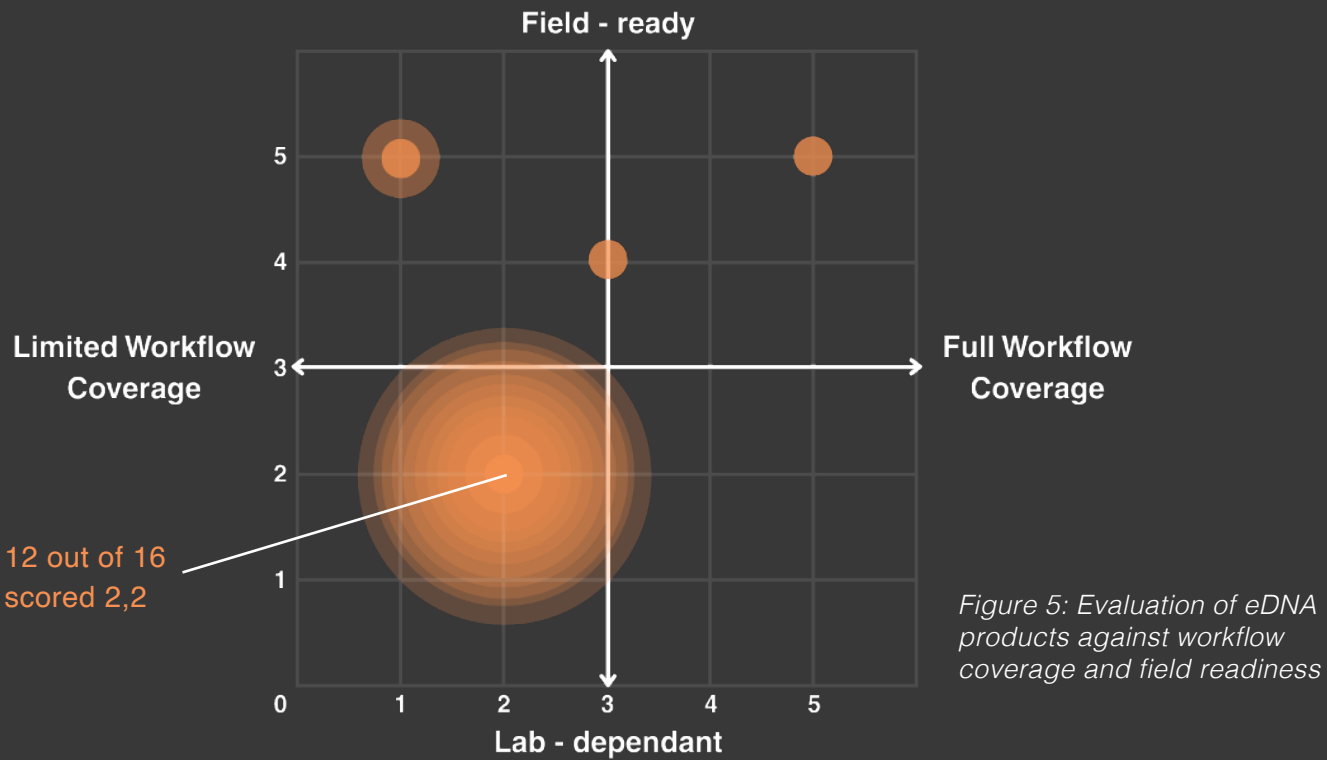
Many eDNA providers remain closely linked to laboratory services, reflecting the field's ongoing dependence on lab-based workflows. In the Australian market, eleven leading companies were identified and evaluated according to provider type and commercial versus research orientation (Figure 4). Separately, sixteen nationally and internationally available eDNA products were assessed based on the workflow stages they cover, and their field readiness (Figure 5).



Comparison of eDNA companies against provider type and commercialisation



Comparison of eDNA products against workflow coverage and field readiness



Product Matrix

Table 2 evaluates products selected from the previous product scope graph against a series of criteria, including functionality, durability, innovation, and ease of use see in Table 1. Functionality and Data Quality were weighted double in the scoring to better reflect their critical and influential role in the eDNA process.

A	B	C	D	E	F	G
Functionality (x2)	Portability/Field Readiness	Ease of Use	Durability	Innovation	Cost and Accessibility	Data Quality (x2)

Table 1: Product Matrix Criteria

Competitor	A	B	C	D	E	F	G	Total
EnviroDNA Water Sampling Kit	4	4	4	3	1	4	6	26
JonahVentures JonahAir	4	4	3	2	4	2	6	25
Smith-Root Sampler Backpack	6	4	3	3	2	3	8	29
Ocean Diagnostics Ascension Sampler	6	4	1	4	3	2	8	27
Hexsor eDNA 100P	6	4	3	3	3	3	8	30
Biomeme Franklin qPCR Thermocycler	4	4	4	3	4	3	8	30
Oxford Nanopore MinION	2	4	3	3	4	3	4	23
DNAIR Sampler	4	3	3	3	4	2	6	25

Table 2: Evaluation of existing eDNA products and devices against criteria

Opportunities and Gaps

The combined analysis of company scope, product scope, and detailed product matrix, highlights several key opportunities and persistent gaps within the eDNA monitoring field (Figures 4, 5 and Table 2). Company mapping reveals a clear divide between research-oriented service providers and commercially oriented product developers, with few organisations bridging both domains. This indicates a gap in translating laboratory-based expertise into scalable, field ready solutions. Product scope analysis reinforces this trend where an abundance of devices cluster at low to moderate process coverage and remain lab-dependent, with only a small number approaching full field readiness or integrated workflows. This uneven distribution underscores the lack of tools that can reliably function end to end in remote or resource limited contexts.

The product matrix provides further resolution, showing that while devices such as the Hexsor eDNA 100P and Biomeme Franklin qPCR score highly in data quality and functionality, they are offset by moderate portability, durability concerns, and relatively high cost. Conversely, simpler tools like the EnviroDNA water sampling kit and JonahAir sampler achieve high portability but offer limited functionality and innovation. Across all products, the most consistent weaknesses are standardisation, ease of use, and durability under variable environmental conditions, particularly relevant for remote operations.

Summary

Together, these figures point to an opportunity space for hybrid solutions. Devices that integrate greater workflow coverage while remaining portable, robust, and user-friendly. For this project, these findings establish a baseline against which primary research can be compared, highlighting alignment or divergence between practitioner identified needs and market provision. The literature has emphasised cost-effectiveness, standardisation, and sample integrity as barriers to uptake. The scoping here suggests these remain largely unresolved. Addressing these gaps, particularly usability and durability in remote contexts, emerges as a critical direction for design led innovation.

Research

Overview

Following secondary research to identify existing gaps, primary research was undertaken to validate these findings, explore them further, and reveal additional issues. This section outlines the research methodology, presenting the overarching approach and rationale guiding the study, along with the specific data collection methods employed to ensure transparency and validity.

Methodology

A triangulation approach was adopted to provide a more comprehensive understanding of the research issues, specifically through methodological and data triangulation. This strategy helps to minimise bias, leverage different perspectives, reduce the likelihood of error, and strengthen the reliability of results, which is particularly valuable in qualitative research where subjectivity and context play significant roles (Hassan, 2024; Rashid, 2025). The methods deployed in this project included a survey and semi-structured interview sessions, producing both quantitative and qualitative data. The strength of qualitative research lies in its capacity to capture depth, context, and participant voice, offering insights that may be overlooked in numerical analysis. However, its limitations include reduced generalisability, dependence on the skill and knowledge of the researcher and susceptibility to researcher bias (Lim, 2024).

Participant Recruitment

This study generated 21 survey responses and involved 4 participants across 3 semi-structured online interviews. The survey, designed in Qualtrics, was distributed via email to eDNA experts across Australia, including scientists, academics, and researchers, using a single-stage probability sampling design (Goodfellow, 2023). Interview participants were recruited purposively to capture relevant expertise across eDNA research, conservation practice, and technological innovation. See summary of methods and participants involved in Table 3.

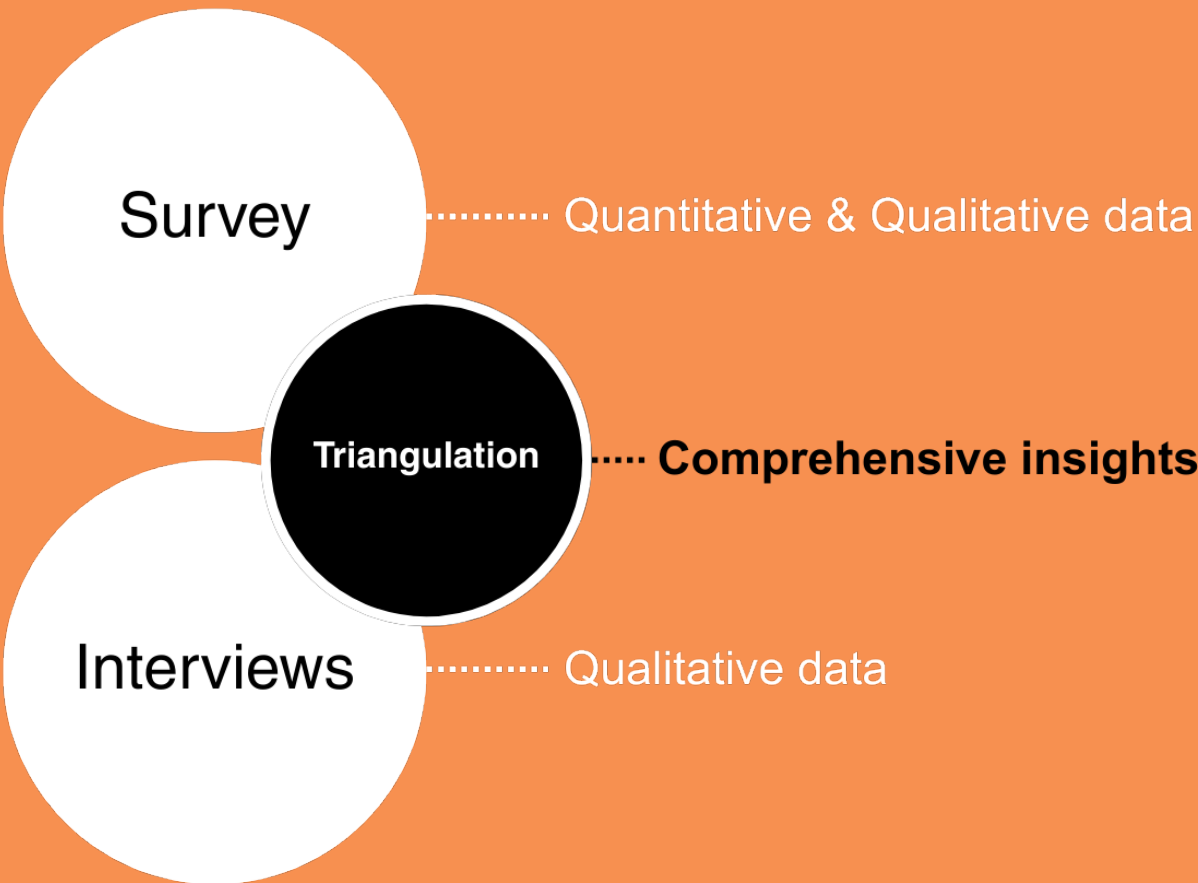


Figure 6: Diagram of methodology

Method	Recruitment	Participants	Breakdown
Survey	Over 100 emails sent directly to experts	21 Responses	eDNA experts (Academics, Researchers, Scientists) across Australia
Interviews	Emails sent directly to experts	4 Participants	P1 eDNA Scientist from TropWater
			P2 QUT Academic and Researcher, Head of School (Earth and Atmospheric Sciences)
	Followed up from survey		P3 Team Leader at CSIRO
			P4 Research Project Officer at CSIRO

Table 3: Summary of methods and participants involved

Methods I Surveys

Surveys provide a systematic method for gathering information from a large population, offering quantitative, qualitative, or mixed-method descriptions of patterns, problems, and predictions (Salmons, 2024). This project’s survey included 9 quantitative response questions and 3 short-answer questions designed to capture qualitative insights. A mixed-method approach was employed to maximise the strengths and minimise the weaknesses of each type of data (Creswell et al., 2013).

Limitations

Limitations of survey research include sampling bias and response bias. Sampling bias reduces the generalisability of results and occurs when the sample selection does not adequately represent the broader population. This may be evident in the present study, as the sample was not randomised, which could introduce potential bias (Chen et al., 2021). Response bias, which occurs when participants answer questions inaccurately or misleadingly, was addressed by designing neutral and balanced survey items to reduce the likelihood of leading responses (Menachemi, 2010).

Methods I Interviews

Semi-structured interviews were employed as they facilitate the collection of open-ended data and enable in-depth exploration of participant experiences and expertise, balancing methodological rigour with the flexibility to elicit nuanced insights beyond what structured methods allow (Adams, 2015; DeJonckheere & Vaughn, 2019). 4 participants were interviewed, including eDNA researchers and collaborators and a technology specialist, located across North Queensland, Brisbane, and coastal Tasmania.

The process was iterative, with survey findings and earlier interviews shaping subsequent lines of inquiry. This sequencing allowed the interviews to progressively refine focus and ensured that both system-level considerations and specialised perspectives were addressed. Each participant was recruited to provide specific insights and values relevant to the study (Table 4).

Participant	Project Value	Duration
P1	Overview of eDNA processes, the broader system, and the challenges of conducting remote fieldwork.	45 minutes
P2	Perspectives on how eDNA supports conservation practice and provided field-based reflections on its application.	50 minutes
P3	Expertise on current technologies and data accuracy, highlighting emerging opportunities for improving eDNA workflows.	1 hour
P4	Additional depth on eDNA processes, reinforcing and expanding on earlier discussions.	

Table 4: Breakdown of Interviews

Limitations

Limitations of these interviews include the reduction of social cues inherent to online communication and the potential for subconscious bias. As all 3 interviews were conducted virtually, reliance on asynchronous communication limited the ability to observe body language and non-verbal signals that may enrich data collection (Opdenakker, 2006). Another limitation relates to the inherent power dynamic of interviews. The interviewer assumes authority as the ‘seeker of knowledge’, while the participant is positioned as the ‘privileged knower.’ These roles can shape responses, influence interpretation, and introduce bias at both the data collection and analysis stages (Alsaawi, 2014; Alshenqeeti, 2014).

Summary

This study employed a mixed-methods approach combining surveys and semi-structured interviews to triangulate data and strengthen reliability. 21 survey responses and 4 interview participants provided both quantitative patterns and qualitative insights into eDNA practices, challenges, and innovation opportunities. While this approach enabled depth and breadth, limitations such as sampling bias, response bias, and reduced social cues in online interviews were acknowledged.

Analysis & Findings

Overview

Data analysis was undertaken to interpret the information collected and generate meaningful insights. Survey responses were examined using univariate and bivariate methods, while qualitative data from both surveys and interviews were analysed through thematic coding. This process identified key concepts and themes that underpin the findings and inform the design implications presented later in this report.

Quantitative Data

Survey

Quantitative survey data was analysed using descriptive statistics to identify overall response patterns and distributions. Univariate and multivariate analyses were conducted to examine individual variables and relationships between them. This included overall experience with eDNA and relationships between delays and areas of innovation potential. The Qualtrics survey platform was used to generate visualisations such as pie charts and graphs, which supported the interpretation and presentation of findings. All qualitative results were exported from Qualtrics and imported into coding software NVivo to manually add codes to the responses.

Survey demographics

Survey participants reported varied levels of experience with eDNA processes, with the majority indicating more than ten years of involvement. Respondents represented a wide range of engagement across the eDNA workflow, from sample collection through to data interpretation. Water was identified as the most commonly used sample type, followed by soil and, to a lesser extent, air. The primary purposes of eDNA application were biodiversity assessment and general ecosystem monitoring.

Delays, Reliability and Innovation in eDNA Workflows

A series of survey questions examined three aspects of the eDNA process; common points of delay and difficulty, the most critical factors influencing the reliability of results, and the areas with the greatest potential for innovation. A Likert scale was used to capture participant responses. Field sampling equipment design received notably high ratings, with all participants scoring it 3 or above (on a scale where 1 indicated the lowest potential for innovation and 5 the highest).

A multivariate analysis showed that the most critical factors identified by respondents align with the points at which delays and difficulties are most often reported, and these same areas were also recognised as having the strongest potential for innovation. The findings are presented and visualised in Figure 7. Refer to appendix for detailed survey results.

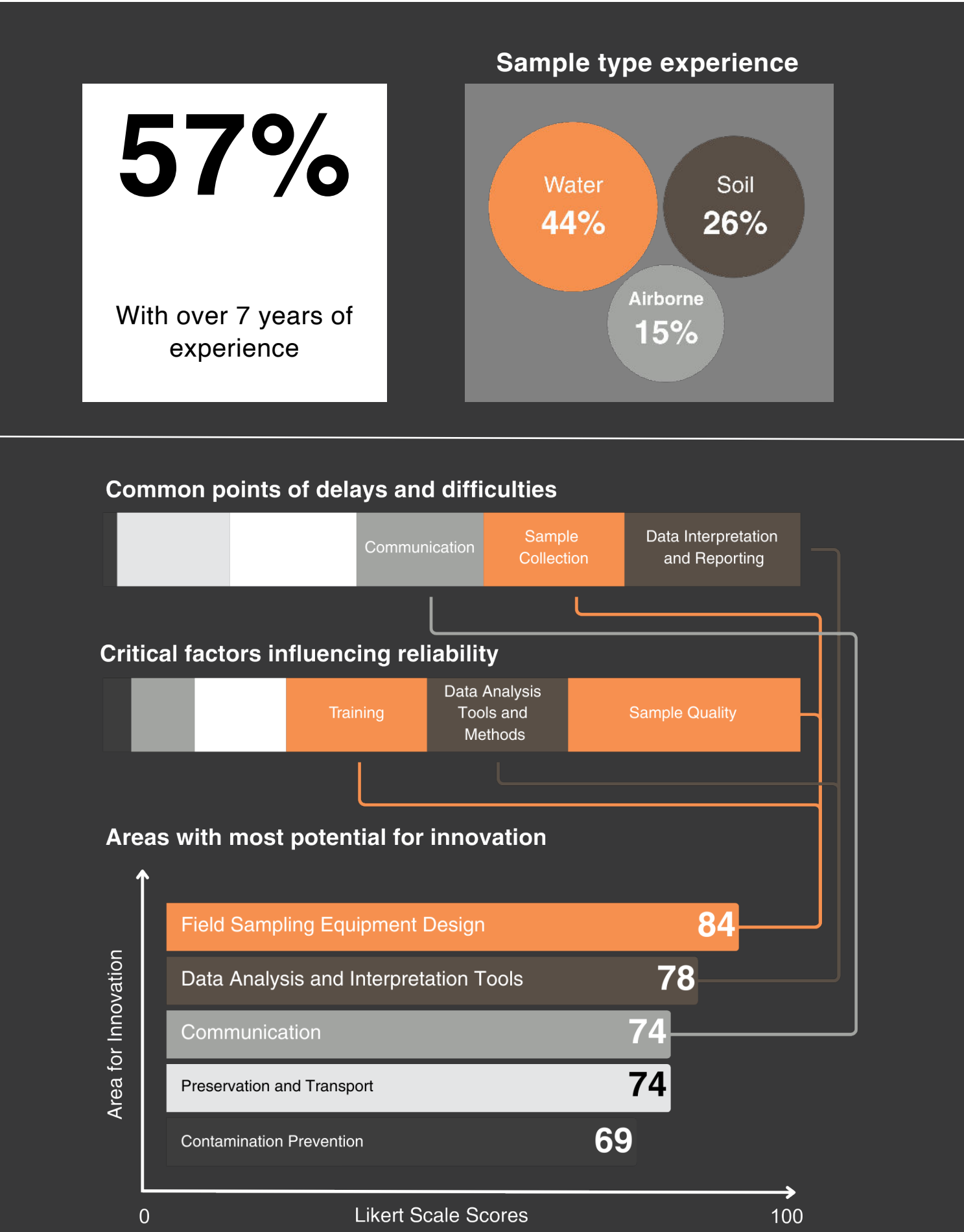


Figure 7: Results from Q9, Q10 and Q11 from survey and relationships between them

Qualitative Data

Survey and Interviews Analysis

An inductive thematic analysis was conducted to allow themes to emerge directly from the data. The process was guided by Braun and Clarke’s six-phase framework, ensuring sustained engagement with the material and the development of meaningful insights (Braun & Clarke, 2008). Transcripts were first imported into Miro, where key quotes and ideas were captured on digital sticky notes and iteratively clustered in an open, exploratory manner to examine potential relationships. In the second stage, a more systematic affinity diagramming approach was applied to refine clusters, consolidate overlaps, and organise codes into broader categories. This process led to the identification of overarching themes represent recurring patterns across the dataset.

A total of 4 themes, 15 sub-themes, and 23 codes were identified. Remote Fieldwork was the most frequent theme, accounting for 8 sub-themes and 120 references. This was followed by Cultural Knowledge and Respect, Innovation, and Collaboration. The most relevant themes to this research are outlined below.

eDNA Integrity

eDNA integrity was referenced 73 times across all 4 data sets. Within this sub-theme, participants described the influence of climate conditions, contamination, data accuracy, and training or skill level. Reports of high temperatures, humidity, and turbidity highlighted how environmental conditions affected sampling. Concerns about contamination focused on equipment cleanliness and cross-contamination between sites. Training and skill levels were also raised, particularly in relation to citizen scientists and the need to follow processes to ensure accurate data.

Logistics

Logistical challenges were raised in relation to electricity, transport, and handling processes. Electricity was noted as essential for maintaining cold chain transport and operating equipment requiring a power source. These issues were closely linked with transportation, as samples often required cold chain shipping to laboratories. Some participants also described instances where freight companies mishandled samples, resulting in breakages or DNA degradation.

Workflows and Innovation

Participants referred to the integration of eDNA sampling into existing workflows, noting the need for methods that are quick, straightforward, and practical for those with demanding field schedules. Innovation was most frequently associated with air eDNA and automation. Air eDNA was highlighted as an underexplored area, while automation was linked to reducing cost and time and enabling broader community participation. In relation to engagement, the communication of data to both communities and the scientific sector was highlighted as an area requiring improvement to support wider adoption of eDNA processes. Data distribution was specifically mentioned as a barrier to effective communication.

Summary

Data analysis combined statistical methods with thematic coding to examine survey and interview responses. Four themes were identified; Remote Fieldwork, Cultural Knowledge and Respect, Innovation, and Collaboration. Key sub-themes included eDNA integrity, logistics, and workflow integration, with participants highlighting challenges in sampling conditions, contamination, training, electricity, transport, and opportunities in air eDNA, automation, and communication.

Example quotes

“for our remote field work, high humidity and heat can accelerate DNA degradation, while freezing using dry ice etc may preserve DNA but complicate sampling logistics (cant always get access to dry ice).” - eDNA researcher

“Experience is the most beneficial factor to reducing contamination.” - eDNA researcher

“Issues include cross-contamination during field sampling from equipment or handlers, introduction of foreign DNA in lab environments through reagents or surfaces, and airborne or human DNA contamination during processing.” - eDNA researcher

“Remote locations often lack immediate access to proper storage (e.g., refrigeration or ethanol), increasing the risk of contamination or degradation before processing.” - eDNA researcher

“I think air EDNA would be the way to go because it’s a relatively recent field and people are still doing a lot of trialing” - Senior Research Officer at JCU

“having something that can give all the results immediately would be useful because then you do away with all the issues of transport, preservation, you do away with issues of biosecurity, you do away with issues of a lot of data sharing things” - Team Leader at CSIRO

“And that’s one of the challenges we’re addressing with our project is how do we package that EDNA data so that it’s more familiar and usable.” - Team Leader at CSIRO

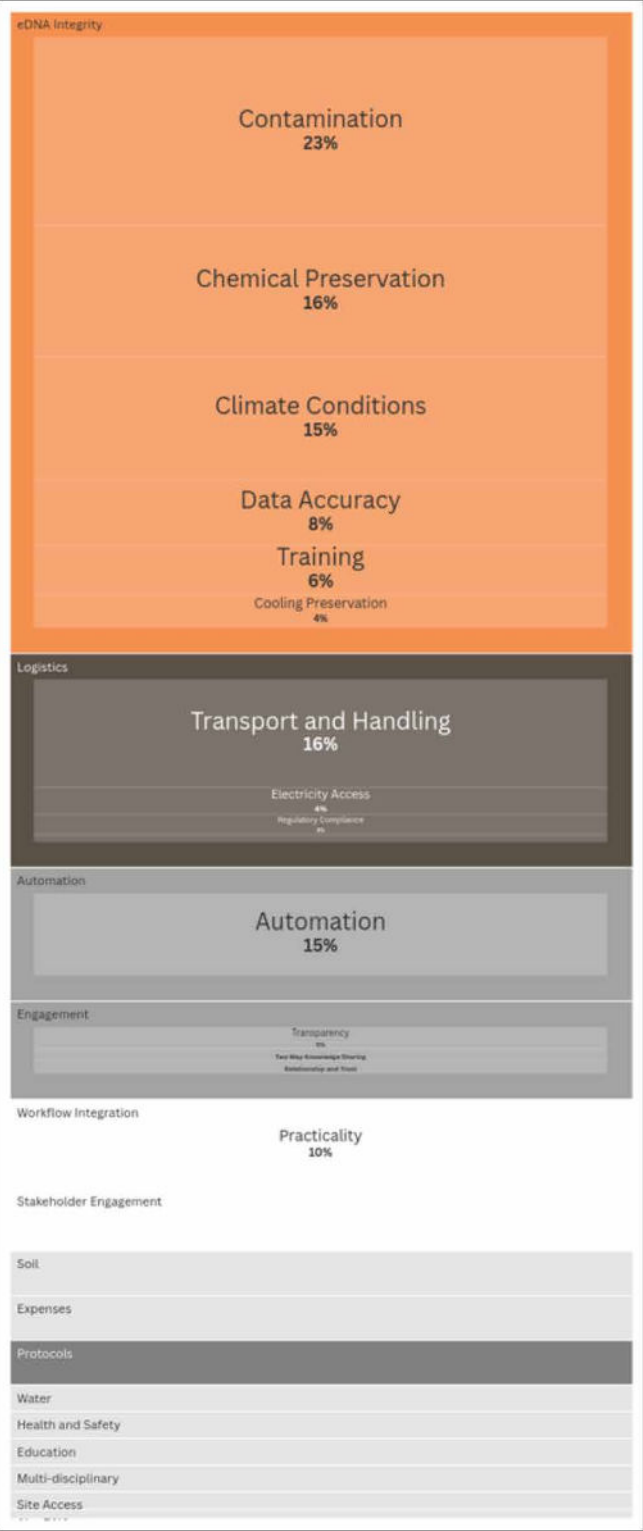


Figure 8: Treemap representing frequency of codes made in Flourish

Discussion

Overview

This study addresses a gap in the literature by examining how eDNA challenges arise in remote field contexts, where logistics, usability, and workflow integration intersect. Previous research has mainly highlighted technical barriers such as sample degradation, contamination, and inconsistent protocols (Beng & Corlett, 2020; Zinger et al., 2019; Granqvist et al., 2025). While these remain important, the findings show that technical, logistical, and human factors converge in practice, and together they strongly influence the reliability of results. Figure 9 provides an overview of insights found analysis and findings.

Key insights	Details
eDNA Integrity	Climate conditions and its affect on DNA degradation
	Logistics issues and its affect on DNA degradation
	Preventing contamination from field to lab
Converging Points	Delays and difficulties cluster at critical stages where reliability is most at risk and innovation most needed.
Innovation	Automation as a means to reduce costs and increase accessibility
	Air eDNA offers to expand applications and fundamentally reshape eDNA practices
	Encouraging eDNA adoption through awareness and data sharing

Not revealed in literature

Figure 9: Overview of key discussion insights from analysis and findings

eDNA Integrity

Participants described how climate conditions, mishandling during transport, and the need for adequate training directly influence sample integrity. Unlike earlier studies that highlight preservation as a limitation (Beng & Corlett, 2020), some participants noted that the use of chemical buffers has reduced its significance, with these methods already tested and available. This suggests that preservation challenges may be less acute than often presented in the literature, though they remain relevant where cold chain logistics are impractical. Contamination, by contrast, was consistently described as a recurring threat during both sampling and laboratory processing, echoing concerns raised by Wee et al. (2023) and Ke et al. (2025).

Converging points

The quantitative analysis revealed a critical insight that the stages of sample collection, preservation, and transport are not only where delays and difficulties most frequently occur but also where reliability is most at risk and innovation is most needed. This overlap extends existing knowledge by showing that the same points in the workflow concentrate multiple challenges. In contrast, the literature often treats these issues in isolation, discussing degradation, contamination, or workflow variability as separate barriers (Beng & Corlett, 2020; Zinger et al., 2019). By demonstrating their convergence, this study highlights the need for integrated solutions that address technical, logistical, and training related factors together. This shifts the discussion of reliability beyond laboratory methods alone and underscores that in remote contexts, improvements must also consider usability, transport logistics, and the effective communication of results.

Innovation

The findings also engage with emerging innovation pathways. Automation was identified as an area of innovation consistent with the literature, where it is positioned as a frontier for improving efficiency and reducing costs (Yamahara et al., 2025). However, this study extends that framing by highlighting automation’s potential to engage communities more directly, lowering technical barriers and supporting participation in eDNA monitoring. Airborne eDNA was likewise recognised as having strong potential for innovation, aligning with Johnson et al. (2021) and Bohmann et al. (2014), who emphasise its ability to complement aquatic and sediment surveys. Beyond these areas, participants raised a distinct issue not commonly addressed in the literature regarding the communication and distribution of eDNA data to both communities and scientific practitioners. This emphasis on data sharing as a condition for wider adoption underscores that innovation in eDNA is not only technical but also social, requiring tools and systems that facilitate accessibility and trust across different user groups.

Summary

Overall, this study confirms many barriers identified in existing research while contributing new insights into how they intersect. By evidencing that technical, logistical, and innovation challenges converge at the same workflow stages, it extends current knowledge and offers a sharper framing for where design-led solutions may have the greatest impact.

Design Implications

Overview

The findings of this study highlight design problems and opportunities that are most pronounced at the fieldwork stage. While much of the literature identifies technical barriers such as degradation or protocol variability, the evidence gathered here points to the importance of logistical, usability, and adoption-focused considerations. Together, these insights define priority areas for future design interventions (Figure 10).

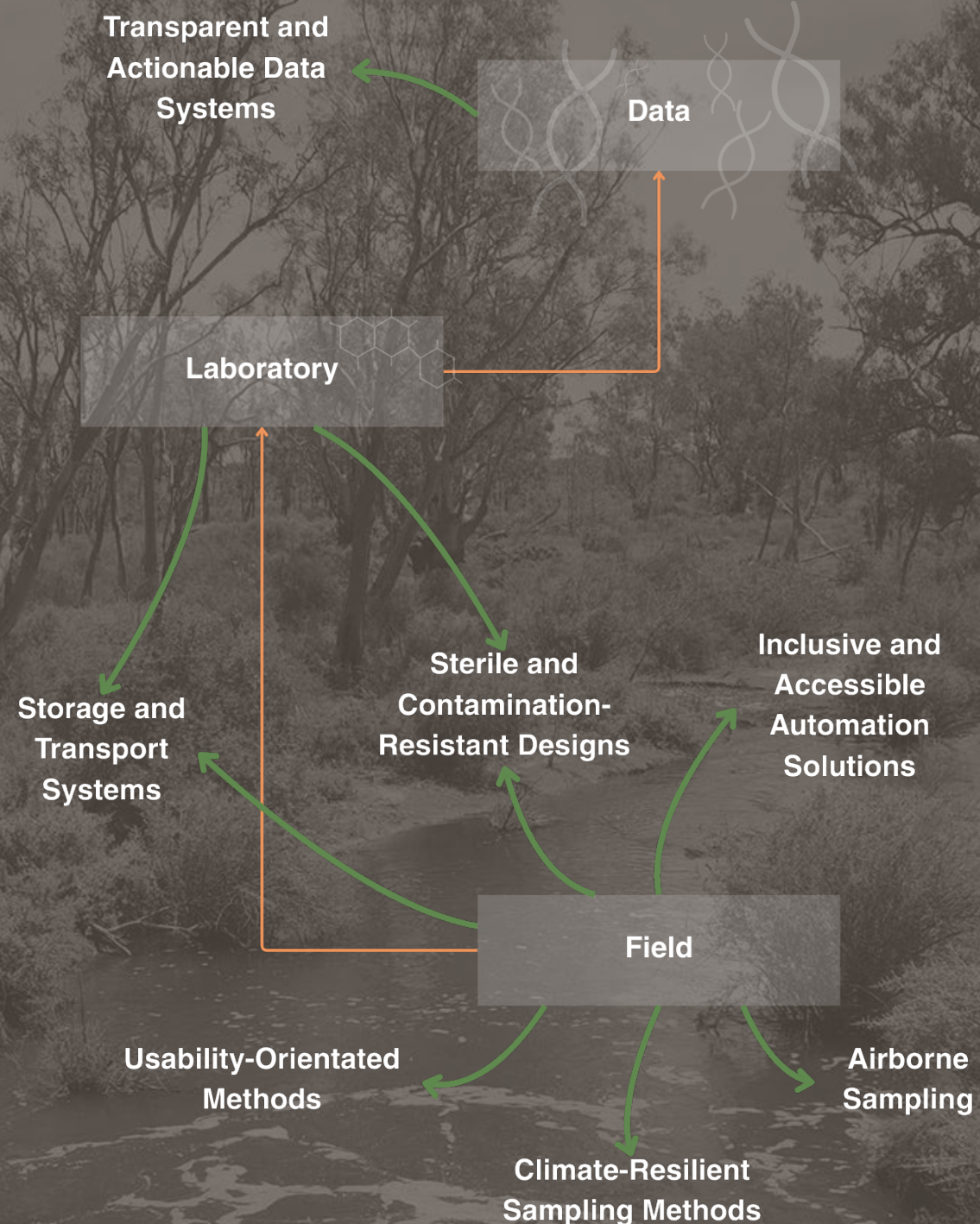


Figure 10: Overview of design implications and intervention areas

Reliable Storage and Transport Systems

Reliability emerged as a recurring concern, with participants emphasising the fragility of eDNA samples across multiple stages of the workflow. Transport was described as a particular pressure point, with breakages, mishandling, and the inability to guarantee cold chain logistics leading to degraded or unusable samples. This suggests a design opportunity for more robust, protective transport systems that minimise dependency on external freight providers and maintain sample integrity under fluctuating conditions.

Sterile and Contamination-Resistant Designs

Contamination was another prominent challenge, occurring both at field and laboratory stages. Since small amounts of exogenous DNA can distort results, there is scope for equipment and consumables specifically designed to reduce transfer risk, whether through disposable components, self-contained workflows, or field kits that integrate sterilisation protocols.

Climate-Resilient Sampling Methods

Although buffers and preservatives have improved the resilience of samples, the findings indicate that climate conditions such as heat, humidity, and turbidity, continue to undermine sample quality during fieldwork. This highlights the need for portable, low-energy preservation solutions tailored to extreme environments. Designs that reduce reliance on electricity or refrigeration could provide value in remote operations where infrastructure is limited.

Usability-Orientated Methods

Another consistent theme was the difficulty of integrating eDNA sampling into existing fieldwork schedules. Respondents stressed the need for methods that are quick, straightforward, and require minimal training, particularly where citizen scientists or non-specialists are involved. Current workflows are often fragmented, with separate stages for collection, filtration, and storage, increasing both time and error risk. This creates a design opportunity for more practical, integrated workflows that combines steps while maintaining scientific rigour. Portability and ease of use should be prioritised, reducing the cognitive and technical burden placed on practitioners in demanding field conditions.

Section Three

Expansive Solutions through Airborne Sampling

Air eDNA represents a clear opportunity to widen the applications of existing methods. Designing for this space means not only improving the technical reliability of airborne sampling but also exploring entirely new avenues where air eDNA could add value, such as early pest detection, urban biodiversity mapping, or climate resilience monitoring. This requires tools that are flexible enough to operate across varied contexts yet robust in capturing and analysing airborne DNA.

Inclusive and Accessible Automation Solutions

Automation, meanwhile, carries implications that extend beyond efficiency. By reducing dependence on laboratories which is a major source of cost and logistical barriers, automation can make eDNA more accessible to smaller organisations, community groups, and citizen scientists. This reframes the design challenge to how automated systems that are portable, low-training, and affordable, enabling participation at a wider scale, can be created. In this sense, automation is not just a technical pathway but a social one, opening doors for more inclusive, distributed models of biodiversity monitoring.

Transparent and Actionable Data Systems

Finally, a novel opportunity lies in the distribution and communication of eDNA data. While most literature focuses on methods of collection and analysis, this study identified the flow of data to communities, practitioners, and sceptical scientists as a barrier to adoption. Tools or platforms that make eDNA results more transparent, accessible, and interpretable could enhance trust and accelerate uptake. This points to a design space beyond equipment alone, into interfaces and systems that support the translation of eDNA into actionable knowledge.

Summary

Taken together, these implications highlight that the greatest opportunities for design are not in high-end sequencing technologies but in addressing the bottlenecks of reliability, workflow integration, and adoption. By improving transport and contamination control, simplifying workflows, and advancing innovation in air sampling, automation, and data distribution, future solutions can bridge the gap between laboratory promise and field-based practice. These directions define where design-led interventions may have the most significant impact on the accessibility, reliability, and scalability of eDNA monitoring.

Section Three

Conclusion

This report examines how environmental DNA (eDNA) biomonitoring processes in remote areas of Australia can be strengthened to support conservation outcomes. With Australia facing some of the world's highest extinction rates and rapid habitat loss, the need for reliable and scalable biodiversity insights is urgent.

Drawing on secondary research, a survey of 21 experts, and four in-depth interviews, the study explored both the barriers and opportunities shaping eDNA application. Benchmarking shows that the Australian eDNA market remains largely research-oriented, with few products offering full field readiness. Most tools continue to rely on laboratory processing, while field devices often compromise on durability or usability. The findings reveal that reliability is most vulnerable during collection, preservation, and transport, where contamination, degradation, and fragile logistics converge. Current workflows were also described as fragmented and difficult for non-specialists, limiting broader adoption. At the same time, innovation pathways show clear potential. Automation can reduce costs and expand participation, airborne eDNA opens new frontiers in ecosystem and climate monitoring, and improved data-sharing platforms can build trust and accelerate uptake. Findings suggest that intervening at the fieldwork stage offers the greatest opportunity to enhance system reliability and, in turn, support more effective environmental decision-making.

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