1st Dutch National eDNA Workshop: Report

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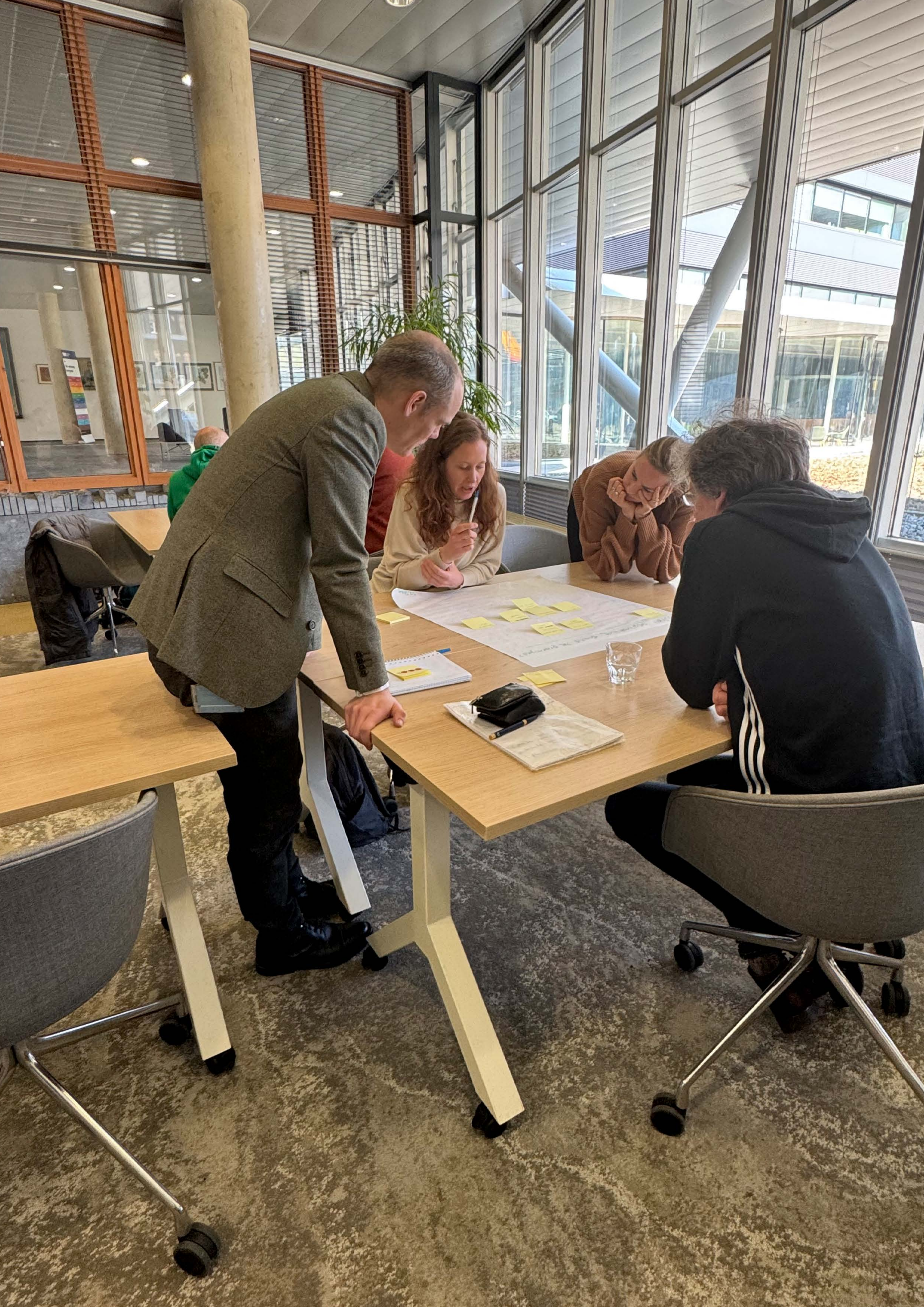

1st Dutch National eDNA Workshop: Report

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Executive Summary

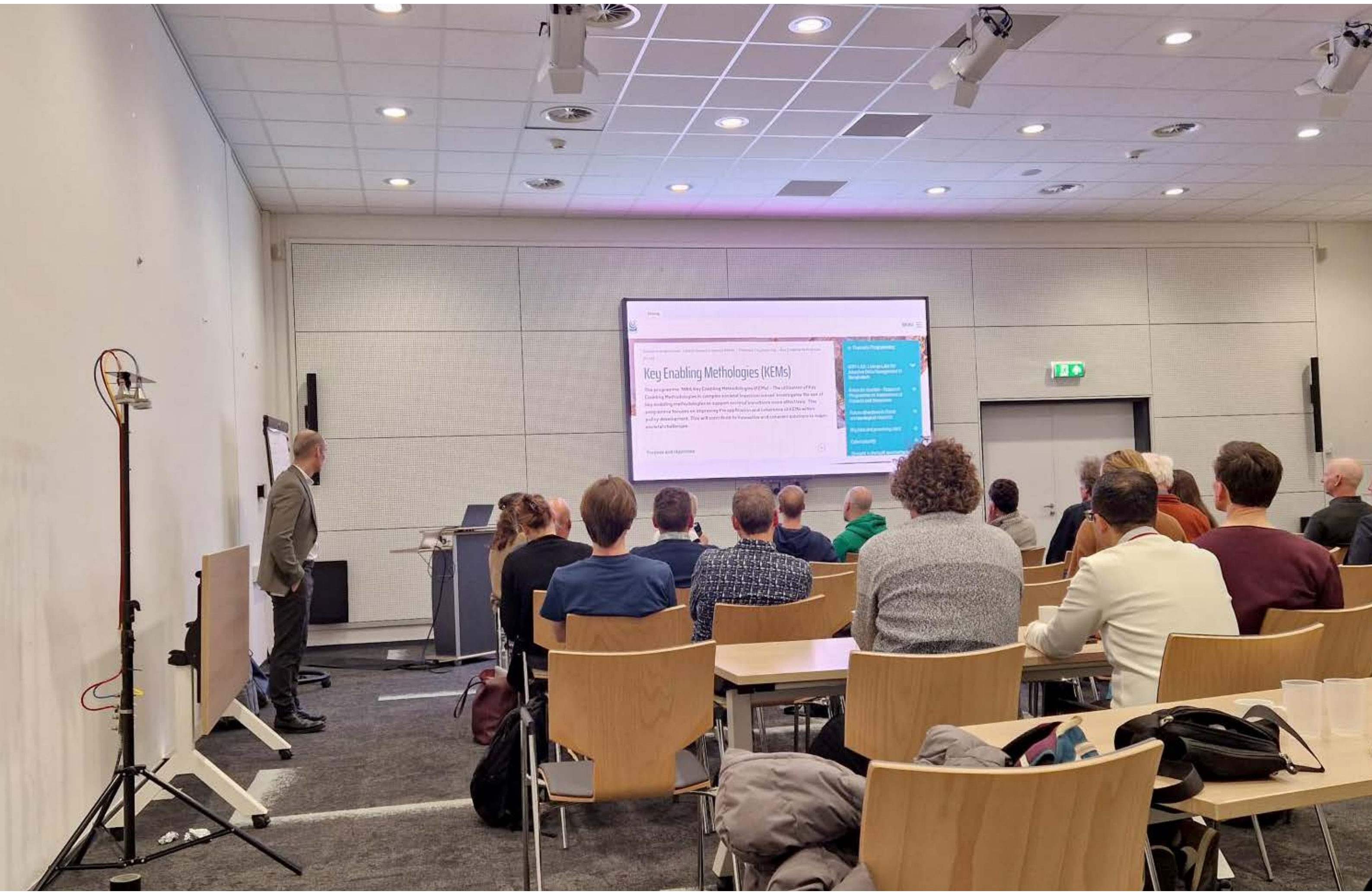
Environmental DNA (eDNA) refers to genetic material shed by organisms into their environment—found in water, soil, air, or surfaces—and can be used to detect presence, diversity, and dynamics of species without direct observation or capture. It offers a powerful, non-invasive tool for monitoring and action.

The first Dutch National eDNA Workshop, held on March 5, 2025, marked a milestone in the collective effort to integrate environmental DNA (eDNA) into the country's biodiversity monitoring and decision-making frameworks. This report consolidates the key insights, perspectives, and outcomes of the workshop, and serves as a launchpad document for the Dutch national eDNA working group.

This document includes a collective overview of the perspectives from leading institutes and a synthesis of the two main topic sessions on standardization and national roadmap development, and concludes with actionable next steps. Together, these contributions outline a shared ambition: to create a robust, inclusive, and future-proof eDNA infrastructure that informs national policy, supports global leadership, and fosters long-term collaboration across sectors.

The newly established Dutch national eDNA working group will use this report as a launchpad document to coordinate next actions, facilitate continued stakeholder engagement, and secure funding for the Netherlands eDNA Initiative (NEDI).

The Dutch National eDNA Workshop 2025 has clearly demonstrated that the Netherlands holds the expertise, motivation, and collaborative capacity to take a leading role in the future of eDNA-based monitoring and decision-making.

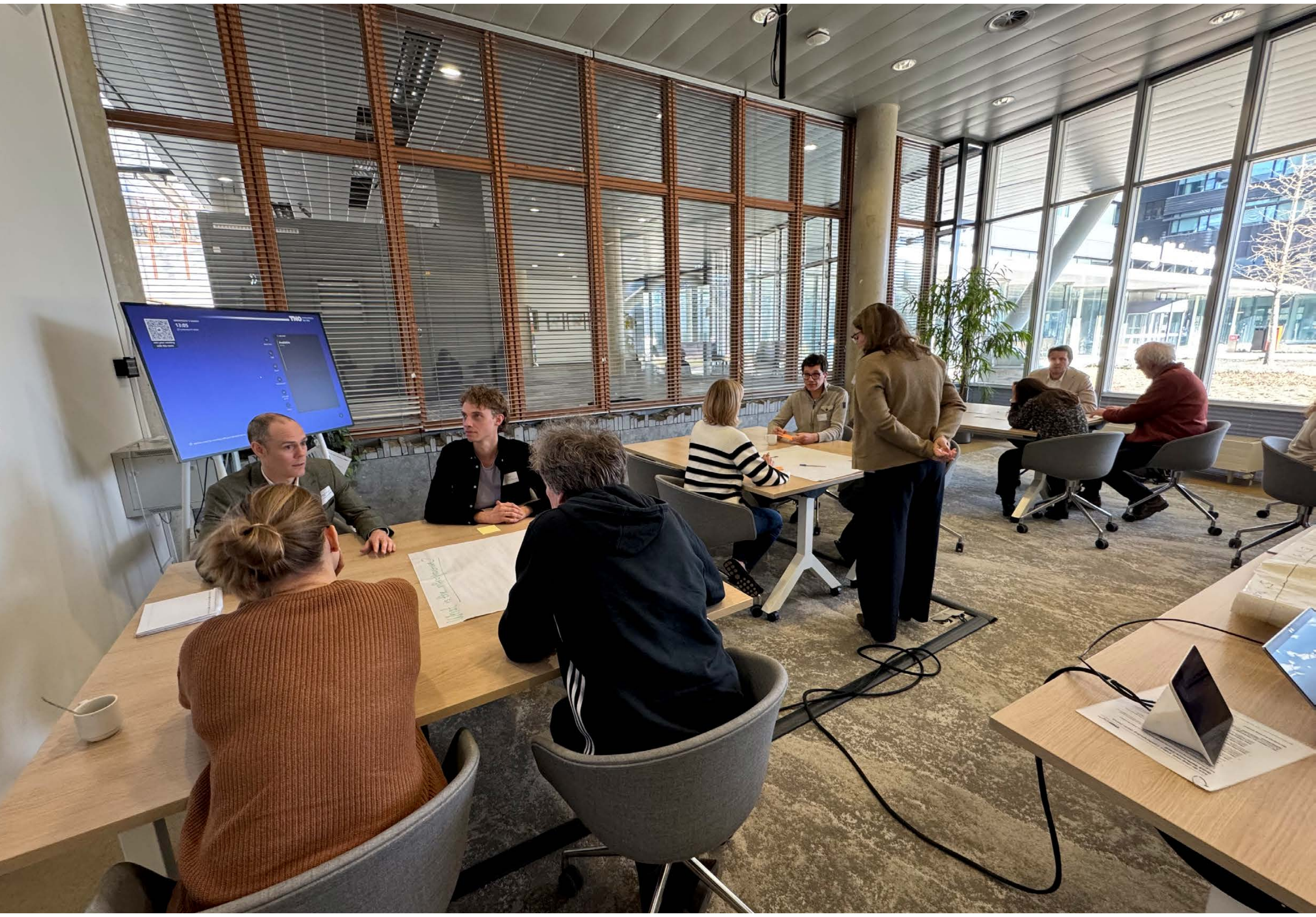


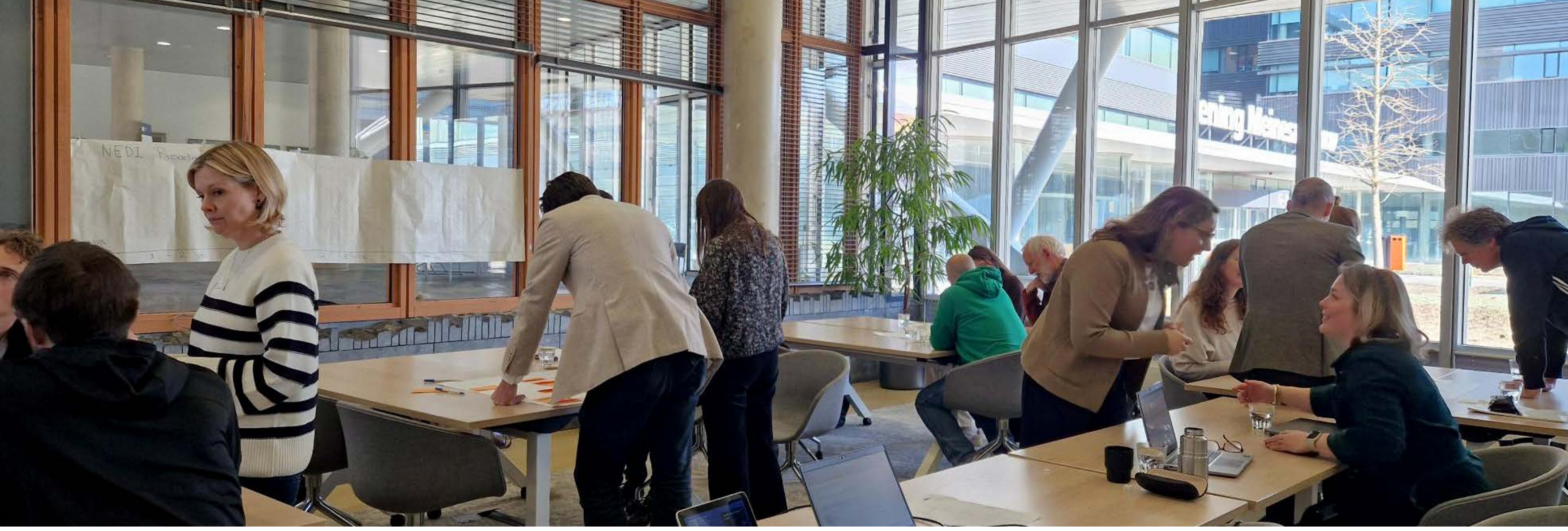
1. Introduction

Environmental DNA technologies are rapidly transforming how we understand, monitor, and protect ecosystems. From biodiversity and invasive species tracking to public health and regulatory applications, the potential for eDNA in decision-making is vast and will be essential to guide a transitioning society, responding to the 'triple planetary crisis' of climate change, biodiversity loss and pollution. eDNA utility spans water quality and pollution assessment, biosecurity, national defense, and health surveillance, crime scene analysis, the detection of illegal wildlife trade, and even offers unique 'time travel'-insights into responses of ancient ecosystems to changes in conditions, man-made or natural. Positioned as a powerful cross-sectoral tool, eDNA can help to shape evidence-based policies across environmental, societal, and economic domains.

This report captures the momentum of the first Dutch national eDNA workshop by:

- Presenting institutional and thematic perspectives from key national actors
- Documenting the discussions and decisions from the workshop's two topic sessions
- Proposing a roadmap and set of priorities for the national eDNA working group





2. Perspectives

2.1. eDNA research and its ecological significance

CML / Leiden University // Kat Stewart

The Institute of Environmental Sciences (CML) at Leiden University is a leading center for eDNA research in the Netherlands, with over ten principal investigators integrating eDNA into their work. Research at CML spans from developing cutting-edge eDNA toolkits—such as novel samplers and analytical pipelines—to advancing our fundamental understanding of eDNA behavior, degradation, transport, and ecological significance. This work extends into applied fields, including agriculture and horticulture (e.g., antimicrobial resistance, plant-pollinator dynamics, soil health) and water systems (e.g., biodiversity impacts from pesticides, invasive species, vector transmission). For this, CML is equipped with advanced infrastructure like qPCR, ddPCR, SNP lines, and sequencing technologies to support such work. Given the growing importance of eDNA in biodiversity monitoring, there is an increasing need for strong links between research, practice, and policy. Meeting this demand requires robust capacity building, large interdisciplinary networks of practitioners, and research that spans methodological innovation, standardization, and application. To foster this network of end-users and research collaboration, CML launched the first nationwide eDNA hub, e3DNA.com—a grassroots community that hosts bi-monthly meetings connecting researchers, stakeholders, and students. These meetings include hands-on workshops, student presentations, and talks from international experts across marine, freshwater, and terrestrial domains. Ultimately, CML aims to make eDNA sampling a rapid, accessible tool to address urgent sustainability and biodiversity challenges while ensuring that research outcomes can inform and shape evidence-based policy.

2.2. A DNA metabarcoding facility for rapid identification and monitoring of biodiversity

Naturalis / eDentity // Vincent Merckx

As we are currently witnessing substantial declines and shifts in biodiversity and a serious movement towards understanding and mitigating these impacts for a biodiversity-positive future, there is a considerable and urgent need for monitoring biodiversity in much greater detail and more frequently than ever before. National, regional, and local government, industry and society need more data and more readily available information of the current state of biodiversity to provide future reliable policy frameworks on climate change and to mitigate biodiversity loss.

Naturalis has the ambition to generate biodiversity data with an unprecedented breadth, at a rate previously unattainable, and at a fraction of the cost. This data is urgently needed to characterise the dynamics of biodiversity in space and time at granular levels conforming to the urgent demand to monitor the state of our biodiversity. As part of this ambition, Naturalis is building eDentity: a large infrastructure to allow for biodiversity monitoring through high-throughput genetic identification of species from environmental samples.

This infrastructure focusses on eDNA to address several current taxonomic, spatial, and temporal gaps in biodiversity monitoring that presently prevent us from tracking progress toward agreed biodiversity targets. The resulting fine-scale understanding of trends and drivers of biodiversity change in soil, water and air, while enabling large-scale high-throughput monitoring, is key for evidence-based national, regional, and local biodiversity policy targets aimed at fighting the biodiversity crisis.

2.3. eDNA-Metabarcoding for Fish Monitoring under the Water Framework Directive

RAVON // Jelger Herder

Fish are a key biological quality element for assessing ecological health of waterbodies under the Water Framework Directive (WFD). Conventional methods like electrofishing and seine fishing are used to calculate Ecological Quality Ratios (EQRs) based on standardized protocols. eDNA-metabarcoding offers a promising alternative with higher sensitivity, lower costs, and less invasive sampling. A comprehensive project in the Netherlands, in collaboration with STOWA and waterboards, evaluated eDNA-metabarcoding as a substitute for traditional WFD fish monitoring. From 2016 to 2020, 81 waterbodies—including streams, rivers, lakes, canals, and brackish waters—were sampled using both methods. Sampling strategies were developed. Mixed water samples from three transects provided accurate results at reduced costs. Additionally, eDNA data were also incorporated into WFD indices, producing comparable EQRs for streams and linear waters, though weaker correlations were found in lakes.

A large follow-up project with many partners is now underway and aims to expand the eDNA dataset by sampling additional waterbodies in the Netherlands and reference sites across Europe, generating a robust dataset from which eDNA-based indices can be developed. The project will compare methodologies across labs to establish a standardized protocol, ensuring reproducibility and building lab capacity for widespread implementation.

2.4. eDNA as asset for human health and biodiversity protection, assessment and management

RIVM // Leo Posthuma, Elmer Swart & Elisa Beninca

eDNA is considered as promising asset for the domains where RIVM has tasks regarding protecting, assessing and restoring human health and environmental quality. In this vein, RIVM is generally investing a substantial strategic budget in the context of the ASSET-program, which encompasses dedicated environmental measurements as well as a versatile 'omics'-street and associated data-science developments. The ASSET-investment is the strategic investment that is made next to specific projects, which address specific human health and environmental quality aspects.

The core tasks of RIVM are to protect, and when needed restore, human health problems and environmental quality. The close association of those, via e.g. ecosystem services, is recognized. Hence, the strategic investments as well as specific projects aimed to develop relevant novel techniques such as eDNA for three potential purposes at the conceptual level: diagnosis (1): is there a problem (e.g., a biodiversity reduction due to environmental stress), where does it occur, and what is the magnitude; diagnosis (2): what likely causes the problem (diagnosis of dominant pressures), and understanding (3): how is the impact mechanistically induced (understanding).

Specific for RIVM's efforts is the combination of development of in-depth, innovative scientific approaches with an critical look at validation and practical application. The work of RIVM adds to the efforts of others, for example by combining the large efforts to describe spatio-temporal variation in biodiversity with the diagnostic- and policy-oriented focus of RIVM, which allows to make these data useful to 'bend the curve of biodiversity loss' and protect human health. A characteristics aspect of RIVM's focus is the consideration of pressure and effect data for both human health and environmental quality / biodiversity protection, assessment and mitigation in tandem.

2.5. Biodiversiteit in Beeld

Witteveen+Bos // Marcel Klinge and Frederike Bijlmer

Biodiversity monitoring is essential for the preservation of ecosystems and the sustainable development of our society. Without accurate and reliable data on the state of biodiversity, policymakers, researchers, and businesses cannot make informed decisions to prevent the loss of species and habitats. However, current methods for biodiversity monitoring have significant limitations. They require specialized knowledge, are labor-intensive and costly, and sample only a limited number of species. Additionally, the focus on different indicator species, sampled at various times and with diverse methods, complicates the interpretation of results. This leads to inconsistent and fragmented data, making it difficult to obtain a comprehensive and accurate picture of the biodiversity status.

Environmental DNA (eDNA), in combination with other existing techniques such as remote sensing, camera traps, and acoustic monitoring, has the potential to provide a more complete picture of biodiversity components (Essential Biodiversity Variables, ESVs). However, these techniques have not yet sufficiently reached end users. Large organizations and companies will soon be required to report their impact on biodiversity in accordance with various European directives, such as the Corporate Sustainability Reporting Directive (CSRD), but they still do not know how to approach this effectively and cost-efficiently.

Therefore, we have initiated 'Biodiversiteit in Beeld', a collaboration between Witteveen+Bos, Deltaris, Naturalis, Wageningen University & Research (WUR), and the International Union for Conservation of Nature (IUCN). Our objective is to develop a national strategy for biodiversity monitoring for end users. We will review and assess all existing traditional and innovative methods based on aspects such as ESV focus, completeness, scalability, and cost-efficiency. Simultaneously, we will inventory the needs, goals, and questions of a wide range of end users. In the next phase, we will collaborate closely with various end users to test and determine which techniques are best implemented, where, and when, following a learning-by-doing approach that fosters close cooperation between science and end users. We will continue to follow international developments and establish connections with global biodiversity monitoring strategies such as GeoBon, Biodiversa+ and DNAquaNet, as well as national developments like the national biodiversity discovery infrastructure investments from the OCW-GWI program ARISE and the RVO-FTO program eDentity.

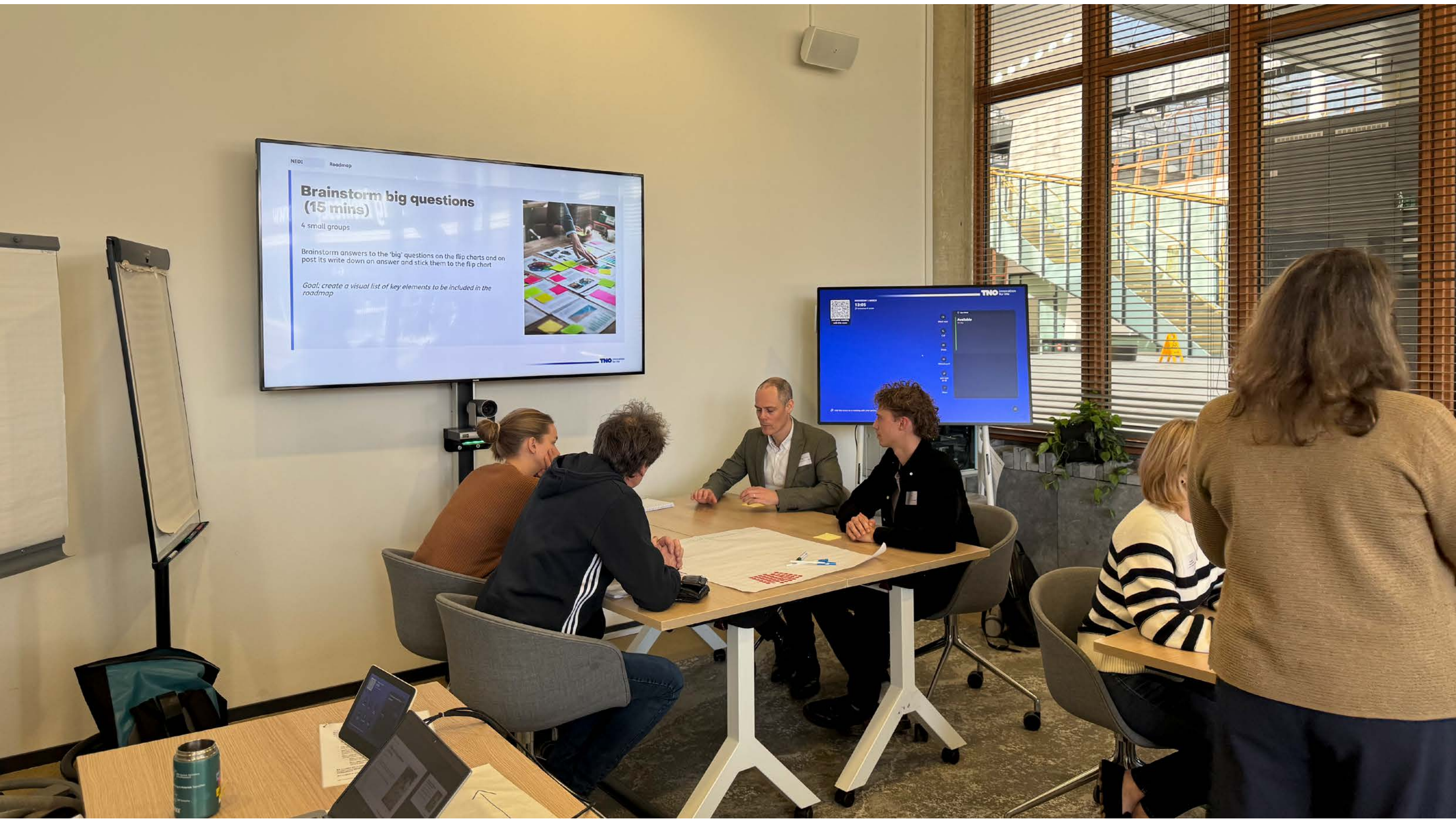
Our ultimate goal is to provide end users with clear guidelines, for example, in the form of a decision tree, to achieve high-quality and continuous monitoring. By using appropriate innovative techniques correctly and at the right time, companies can not only comply with regulations and reporting obligations, but also proactively contribute to biodiversity conservation by responding promptly to changes in ecosystems. Moreover, continuous monitoring by companies generates valuable public data, which scientists can analyze to better understand trends and patterns in biodiversity.

2.6. eDNA and biosecurity

TNO // Hans Leeuwen

Innovations in eDNA analysis extend beyond biodiversity monitoring of plants, insects, and vertebrates. These techniques can also detect and identify pathogens such as fungi, bacteria, and viruses - often as unintended bycatch in environmental samples from soil, water, and air.

Water and air, in particular, are potential reservoirs for human, plant, and animal pathogens, making their identification crucial for early outbreak detection and prevention. Early pathogen warning systems enable timely interventions such as quarantine, treatment, or culling. Many pathogens are airborne and can be effectively captured using air collectors. Strategically placing these collectors at potential outbreak hotspots, such as hospitals, airports, schools, and farms, could enhance disease surveillance and containment efforts. In this context, eDNA analysis shifts towards epDNA (environmental pathogen DNA), focusing specifically on pathogen detection in the environment.



Detecting pathogens via eDNA requires a fundamentally different approach compared to traditional biodiversity assessments. Pathogens exist in millions of species, and distinguishing between pathogenic and non-pathogenic strains often depends on just a few nucleotide differences. This highlights the necessity for 1 Highly accurate base calling to detect minute genetic variations and 2 Well-curated reference databases to distinguish between harmless and potentially dangerous strains with high confidence.

A major challenge lies in developing and optimizing aerosol collection methods capable of efficiently capturing airborne DNA. Different collection techniques, such as filters, liquid traps, and foam-based collector, vary in effectiveness depending on factors like airflow speed and environmental conditions. Additionally, DNA isolation techniques is critical to ensuring high-quality samples for downstream analysis.

Beyond sample collection, the choice of sequencing and analysis approaches significantly impacts pathogen detection. The use of shotgun sequencing versus targeted amplification, selection of sequence analysis software, and database optimization are all crucial factors. For pathogenic eDNA analysis, RNA detection must also be incorporated, as many viruses have RNA genomes. This RNA requirement is less relevant for standard biodiversity assessments but is essential for comprehensive pathogen monitoring.

Pathogenic eDNA detection demands exceptional accuracy to minimize false positives and false negatives, often down to the strain level. The methodologies developed for hotspot outbreak monitoring, designed for high sensitivity and specificity, can significantly benefit other eDNA applications. By advancing precision techniques for pathogen detection, this work contributes to both Dutch and international eDNA efforts, reinforcing environmental monitoring, public health, and biosecurity initiatives.

2.7. Marine community composition analyses via eDNA

Royal NIOZ // Judith van Bleijswijk

Royal NIOZ, Netherlands Institute for Sea Research has facilities in Yerseke and on Texel. The institute's mission is Knowing the Seas to safeguard our future, which implies sea research for climate to biodiversity. NIOZ runs several (long term) monitoring series but many of these still rely on catches and counts of the actual organisms.

eDNA based analyses will become highly relevant because these allow high frequency measurements, high spatial coverage, can cover complete ecosystems (from bacteria to marine mammals), and allow for autonomous sampling. The methods are also cheaper and more sustainable (no catches needed).

NIOZ will use eDNA analyses to measure changes in marine community composition (biodiversity); Food chain length and food web structures (predator-prey relations, healthy food, PUFAs); Specific species information (pathogens, invasive species, valuable key species); Effects of climate change (physio/chemical parameters, temperature, light, nutrients, suspended matter), and effects of direct human activities (vibrations, sounds, pollution). We envision that a National eDNA Program with an integrated approach for land, water and air monitoring, will speed up the scientific output and lead to better understanding of (marine) ecosystems, their sustainable use, protection and restoration.

2.8. eDNA and its promise

Ecopulse // Willem van Strien

eDNA is one of the most promising technologies of the 21st century. Not because of the tool itself, but what it potentially could unlock. With millions of species yet to be discovered and a patchwork of different biodiversity metrics driving national & international policies we are walking closely along a cliff, blindfolded. We do not have a good idea when we go over a catastrophic biodiversity tipping point and urgently need data to steer us away from the cliff and police a safer 'planetary boundary' with ample natural buffers.

Applying eDNA at scale has the potential to provide a much needed global biodiversity baseline metric with the most complete taxonomic coverage, and resulting in actionable insights. Some see eDNA as yet another metric, arguably it could be the glue that binds us to many techniques.

To achieve eDNA at scale we need a healthy network of academic- and research-institutes to sink their teeth into the most pressing questions and work on the key enablers. However, an equally urgent need is a healthy commercial ecosystem of SME's, start-ups and multinationals to scale eDNA. We need to link up the innovation with a service delivery system so we can withstand short-term initiatives and (geo)political shifts. This will also enable new funding mechanisms for eDNA research and not largely have to rely on government grants.

Lastly, if we only develop our eDNA capability for The Netherlands we miss a huge opportunity. Exporting knowledge and technologies for biodiversity metrics should be seen as a strategic objective. If we envisage and believe in a green, healthy, safe & thriving planet, the Dutch should look beyond their borders and aim to play a key role in enabling such vision globally. Only with a strong commercial sector operating in the eDNA space we have a chance to contribute or even enable the global green economy.

2.9. Airborne eDNA, potential applications and current challenges

TNO // Henrik Cornelisson van de Ven

Airborne eDNA is an emerging field, compared to the more established domains of water and soil. It holds the potential to revolutionize terrestrial ecosystem monitoring, offering high-resolution, non-invasive biodiversity assessments across landscapes. Its applications extend to precision agriculture (tracking crop health, soil microbiomes, and pest presence), natural resource management (monitoring impacts, recovery, and resilience), outbreak monitoring (early detection of zoonotic pathogens, airborne disease surveillance, and antimicrobial resistance tracking), biosecurity (detecting invasive species, tracking allergenic pollen and fungal spores), and environmental forensics (tracing pollutants, industrial emissions, and ecological disturbances). To name a few.

A currently commonly cited challenge of airborne eDNA is signal locality, or more generally, where does the DNA I'm sampling come from? At TNO, extensive expertise in airborne pollutant dispersion modeling provides a strong foundation for addressing this issue. With minor adjustments, these models appear to be highly applicable to airborne eDNA transport, offering a way to spatially resolve eDNA signals. By integrating these modeling approaches, airborne eDNA can become spatially explicit, significantly enhancing data interpretation, mapping accuracy, and real-world applicability. Such a breakthrough would increase confidence in airborne eDNA results, drive greater adoption of the technology, and unlock new possibilities for biodiversity monitoring, environmental surveillance, and regulatory applications. TNO is preparing airborne eDNA sampling campaigns to collect data for modeling. Potential collaborators are welcome to join these field campaigns.

2.10. Leveraging airborne eDNA/eRNA for enhanced biosecurity and pandemic preparedness

IRAS, Utrecht University // Alex Bossers & Lidwien Smit

One Health is an approach that recognizes that the health of people is closely connected to the health of animals and our shared environment. The One Health Microbial group of the Institute for Risk Assessment Sciences (Utrecht University) employs a comprehensive approach to pathogen detection and risk assessment using pathogen-targeted and pathogen-agnostic strategies in a One Health context.

We focus on relatively underexamined total repertoire of airborne environmental nucleic acids (eNA)—including both environmental DNA (eDNA) and RNA (eRNA)—to identify the full spectrum of eukaryotes, prokaryotes, and viruses. This includes the diverse microbial repertoire and its hosts. Our aim is to evaluate biosecurity risks and strengthen infectious disease preparedness by studying potential crossing-over points between humans, domestic animals, and wildlife. eNA approaches allow the extension of current risk assessment models and besides detecting eukaryotic hosts, should also target the detection of microbes and pathogens. These pathogen-agnostic approaches such as metagenomics and metabarcoding leverage our broad understanding of microbial presence and transmission dynamics in multi-species environments.

Recently, we demonstrated potential airborne transmission of highly pathogenic avian influenza (HPAI) from wild waterbirds into poultry houses, using eDNA as a proxy for the actual HPAI agent. This study served as a proof-of-principle for the successful application of eDNA in biosecurity research. Building on this, we now apply eNA to investigate the intersection between humans, domestic animals and wildlife more broadly in the context of improving infectious disease and pandemic preparedness.

Studies and models can only be as good as the methods and data they use. A current limitation in eDNA research is the lack of high-quality annotation databases. Therefore, we are actively contributing to developing and curating marker gene databases and refining (unifying) laboratory protocols. Moreover we are extending the utility of eNA, for instance through the integration of eDNA linked to our long-standing expertise in particle-size dispersion modelling from fractionated active air sampling, to estimate microbial travel distances. We also explore the use of eDNA/eRNA ratios as indicators of sample age, to gain insights into the temporal dynamics of environmental signals. These efforts together shape our vision to advance early detection, improve biosecurity, and help to tune response strategies at critical One Health crossing-over sites.

3. Topic Sessions

3.1. Standardization

Marcel Klinge, Frederike Bijlmer and Arjen Speksnijder

During the workshop 'Standardization,' Marcel Klinge and Frederike Bijlmer from Witteveen+Bos, together with Arjen Speksnijder from Naturalis/Leiden University of Applied Sciences, were invited to present the project 'Biodiversiteit in Beeld' and lead an open discussion on the (inter) national standardization of eDNA methodologies. The initiative 'Biodiversiteit in Beeld', described in the summary of Marcel Klinge's presentation during the first session of the workshop, emphasizes the implementation of eDNA technology with a focus on end-user application. However, the open discussion in the workshop centered on scientific perspectives, with representatives from various institutes. This document provides an overview of the topics discussed regarding the standardization of eDNA methodologies from a scientific viewpoint.

Environmental DNA (eDNA) is increasingly applied both nationally and internationally in water, air, and soil research. As with other techniques, various methods are employed. Examples of varying issues include: Where is sampling conducted? How much is sampled? Which filter and buffer are used? What extraction method, primers, PCR settings, sequencing methods, and equipment are employed? What bioinformatics pipeline, quality filters, and cut-offs are applied? Which reference database is utilized? Comparing obtained results can be challenging due to differences in methods. For achieving consistent, comprehensive, and comparable data, (inter)national standardization of methods would be ideal. However, the practical feasibility of this remains a point of discussion. The central question posed to the consortium was: What can, should, or needs to be standardized?

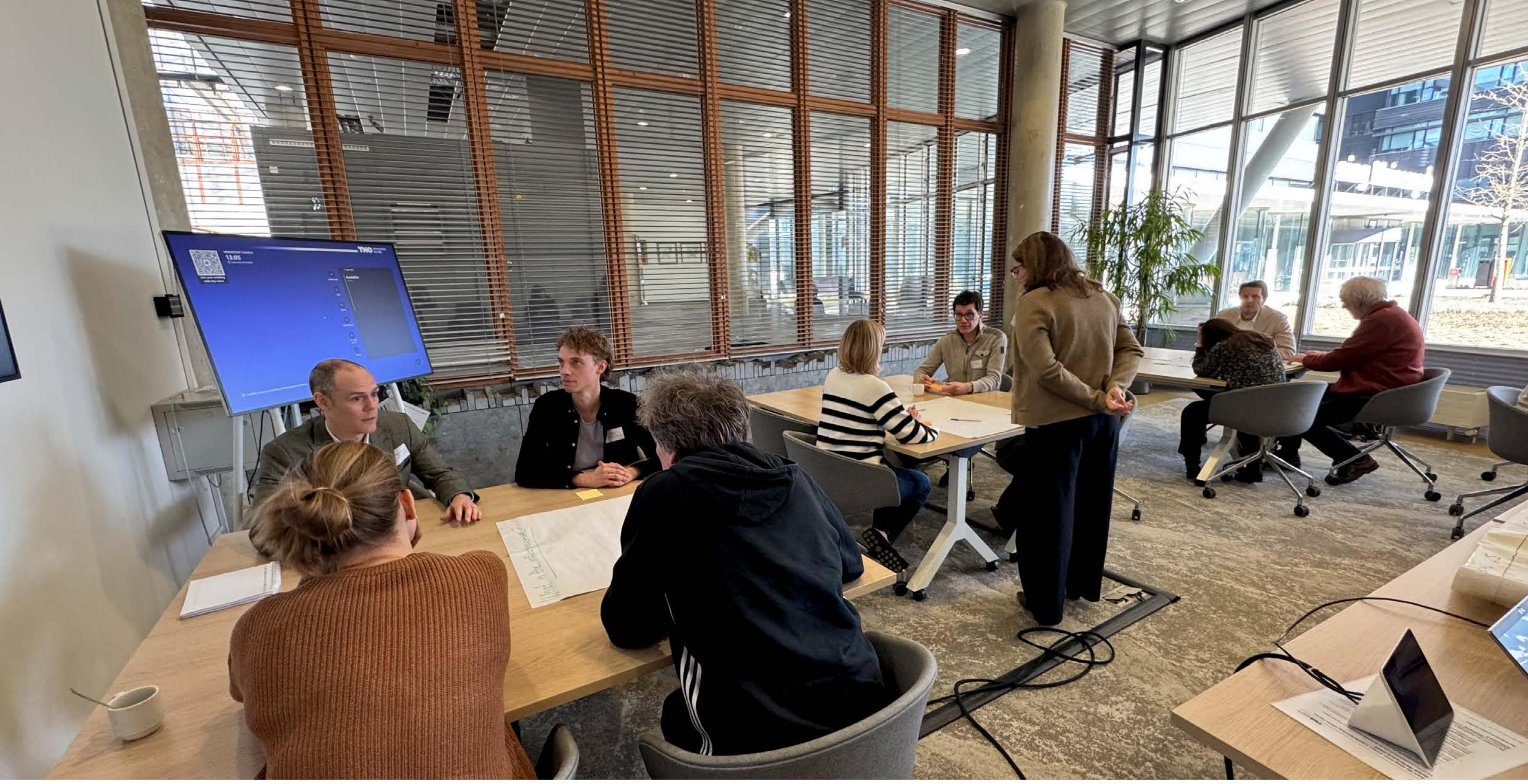
Initial reactions from attendees ranged from full standardization to minimal standardization, underscoring the complexity of the issue. It was acknowledged that differences in results are inevitable, even when using similar techniques. Conversely, different techniques can sometimes yield similar results. A proposed solution is to establish a 'deviation baseline,' where differences between results obtained by different methods are limited to a certain percentage. A control system for this could involve 'ring tests', where identical samples are sent to each laboratory for inter-laboratory comparison. External quality control via quality control panels and reference laboratories were suggested to evaluate these tests. Additionally, international standards can be used to standardize parts of the methodology. Examples of international standards supporting quality management include ISO9001 and ISO17025. The NEN-EN17805:2023 standard specifically addresses the standardization of eDNA sampling, filtering, and preservation in water. However, a NEN standard for metabarcoding was withdrawn.

Workshop participants responded positively to the standardization of the sampling procedure but were less enthusiastic about ring tests and quality control panels, expressing resistance to the 'validation' of a laboratory. While there was some support for ring tests, which are common practice in diagnostic laboratories, concerns were raised about the costs associated with organizing such a sustainable quality system.

The discussion also underscored the necessity of minimal reporting requirements, sample storage for reassessment, and the standardization of bioinformatics and primers to ensure data reliability and transparency. Additionally, ongoing calibration of new technologies against established methods is crucial for maintaining data integrity and comparability between studies.

The preliminary consensus appears to favor the standardization of sampling and minimal reporting requirements, while harmonization of laboratory analyses and bioinformatics is preferred. However, the approach to achieving this remains an open question, as it involves potentially proprietary knowledge of service laboratories. This discussion marked a constructive beginning in identifying the pain points and disagreements among scientists. Deliberate decisions must be made regarding what aspects should be standardized. If standardization is desired, it must be determined which standards will be adopted, how they will be implemented, and how they will be monitored. We seek a flexible standard that can adapt to rapid developments in this field while ensuring results that can be compared internationally.

To achieve this goal, a productive collaboration between scientists, service laboratories and end-users is essential. Their shared goal is to obtain accurate and reliable data through continuous large-scale eDNA monitoring. Moreover, these data must be publicly accessible and interoperable (FAIR) to enhance the understanding of trends and patterns in biodiversity.



3.2. National Roadmap Development

Ilke Adriaans, Jorien Strijk, and Henrik Cornelisson van de Ven

This section summarizes the contributions and insights from the Roadmap topic session during the Dutch National eDNA Workshop, serving as a collaborative launchpad for ongoing structuring of the national eDNA landscape. The session focused on aligning the eDNA community around shared priorities, identifying gaps, and outlining a phased pathway forward for research, collaboration, standardization, and integration of eDNA into national decision-making.

3.2.1. Vision and Motivation

The session began by reaffirming the core motivation behind the national eDNA effort: enabling more accurate, efficient, and inclusive decision-making across domains such as biodiversity monitoring, public health, agriculture, and environmental regulation. Participants emphasized that eDNA should not remain a tool of isolated expertise, but must be embedded into policy frameworks and regulatory procedures to drive tangible impact. The roadmap aims to build shared infrastructure, standards, and governance to make this transition possible.

3.2.2. Stakeholder Landscape

Participants mapped a broad spectrum of relevant stakeholders, including ministries, research institutes, regulatory agencies, water boards, commercial laboratories, NGOs, municipalities, farmers, and citizen scientists. Key actors such as Rijkswaterstaat, LVVN, STOWA, RIVM, and the European Commission were identified as critical to future coordination and scale-up, given their current involvement in eDNA technology adaptation. The discussion emphasized the importance of stakeholder-specific communication, recommending tailored value propositions to build alignment and commitment, particularly when engaging groups not yet familiar with or using eDNA. A successful example of such collaboration is the regulatory acceptance of eDNA for bat detection in the Netherlands, illustrating the potential for integration. However, participants also noted ongoing skepticism among users of more traditional methods, highlighting that education and awareness are vital for the successful implementation of eDNA in established domains.

3.2.3. Infrastructure and Standards

The need for a cohesive national infrastructure was a recurring theme. Discussion focused on standardizing sampling, transport, sequencing, and reporting protocols across domains, as well as the practical side of avoiding 'double work and costs'. Participants emphasized the importance of metadata, accessibility, and shared databases for both raw and processed data. A common reporting format was seen as essential to building trust among data users. The ARISE and eDentity projects at Naturalis are recognized as world-class infrastructure initiatives and are expected to play a large role in accelerating eDNA uptake across the Netherlands.

3.2.4. Funding and Enabling Conditions

Whilst the ‘triple planetary crisis’ (of climate change, biodiversity loss and pollution) offers a strong motive for an all-society effort, participants acknowledged that scaling the eDNA ecosystem will require a mix of short-, medium-, and long-term funding from both industrial and governmental sources. Opportunities were identified across funding instruments such as NWO, PPS, EU Horizon programs, CSRD-linked private sector investment, and even pension fund–backed sustainability vehicles. Strategic alignment with governmental missions and private sector sustainability targets was recognized as a key enabler.

There was a shared sense that the burden of initiating consortia and securing funding currently falls disproportionately on researchers, many of whom do not see this as part of their core scientific role. A key next step for the Dutch national eDNA working group will be to build a broader coalition beyond the eDNA research community and bringing in stakeholders who also recognize the value of implementing eDNA in decision-making contexts and can help carry this effort forward.

3.2.5. Stakeholder Engagement and Influence

Using an influence/interest mapping exercise, the session highlighted actors with both the power and interest to accelerate implementation. These included water authorities, LVVN, RIVM, and some private labs. Other groups, like nature organizations, citizen science groups, and provincial governments, were marked as key allies requiring targeted outreach to activate their involvement. Stakeholder engagement can be founded on the motivation embedded in the triple planetary crisis, due to which many stakeholders feel a need to act.

3.2.6. Prioritization

The roadmap session highlighted a strong desire to shift from research to practical application of eDNA. Participants emphasized the need for real-world use cases that connect to policy, regulation, and monitoring, especially in areas where legal or environmental goals already exist.

Standardizing sampling methods and reporting were identified as essential to building a scalable and trustworthy infrastructure. Supporting elements (like data storage, logistics, and sequencing) were noted as important but secondary priorities.

Stakeholders from policy, research, education, and implementation roles were all seen as essential to the ecosystem. Inclusive engagement, including citizen participation, was also viewed as valuable.

In terms of funding, a blended model combining public and private sources was favored. Strategic alignment with broader environmental missions and practical needs will be key to securing long-term support.

3.2.7. Roadmap Timeline

The workshop concluded with a collaborative construction of a phased timeline that outlines the key steps over a 5+ year horizon. The aspirational goal of the Roadmap is the implementation of eDNA for decision-making across sectors. To achieve this, several technological, organizational, and funding challenges and opportunities have been identified.

Given the diversity and number of end users and stakeholders, effective coordination is essential. This coordination will enable the fastest possible progress while ensuring the optimal use of available resources.

0-1 years

- Formalize national eDNA working group
- Conduct inventor of priority applications
- Coordinate and support active pilot projects
- Submit initial funding proposals

1-3 years

- Develop and test a governance model
- Initiate eDNA integration into decision making pipelines for government
- Develop metadata and reporting standards
- Demonstrate validated use-cases

3-5 years

- Expand eDNA intergration across additional sectors
- Define and formalize an entity for longterm
- Participate in pan-EU and global national initiatives for international cooperation

5+ years

- Secure longterm structural funding
- Expand collaberation at the EU level and beyond
- Scale infrastructure and automation efforts
- ...

4. From idea to action

The Dutch National eDNA Workshop 2025 has clearly demonstrated that the Netherlands holds the expertise, motivation, and collaborative capacity to take a leading role in the future of eDNA-based monitoring and decision-making. Overall, the session reinforced that eDNA's success will depend on coordinated application, reliable infrastructure, and strong stakeholder collaboration. In addition, other molecular monitoring methods should be included where appropriate, such as eRNA.

With perspectives shared by researchers, policy advisors, and infrastructure providers, and with foundational work begun on standardization and the national roadmap, we now have a shared vision and the start of a strategic path forward.

We call on everyone who contributed to this first edition, those present and those yet to be involved, to remain connected, share progress, and help shape the future of this initiative. The success of the Dutch eDNA framework will depend on our ability to maintain open communication, embrace multidisciplinary collaboration, and ensure that the tools we develop are both scientifically robust and societally relevant.

We would also like to acknowledge the support of the Finnish Environmental Institute and the U.S. Geological Survey Wetland & Aquatic Research for presenting key motivational messages to the participants.

The following next steps were identified as priorities:

1. Formalize the national eDNA working group structure, including defined task areas (e.g., governance, pillars, outreach, funding).
2. Align with ongoing national initiatives related to eDNA technology.
3. Develop an inventory of eDNA use cases, stakeholders, and ongoing projects.
4. Initiate strategic stakeholder engagement, using targeted messaging to build commitment from non-eDNA stakeholders and regulatory bodies.
5. Help coordinate and synthesize pilot projects.
6. Plan the second Dutch National eDNA Workshop, with a focus on stakeholder integration, decision-making pipelines, and applied outcomes.
7. Align with other national eDNA initiatives in EU and worldwide.

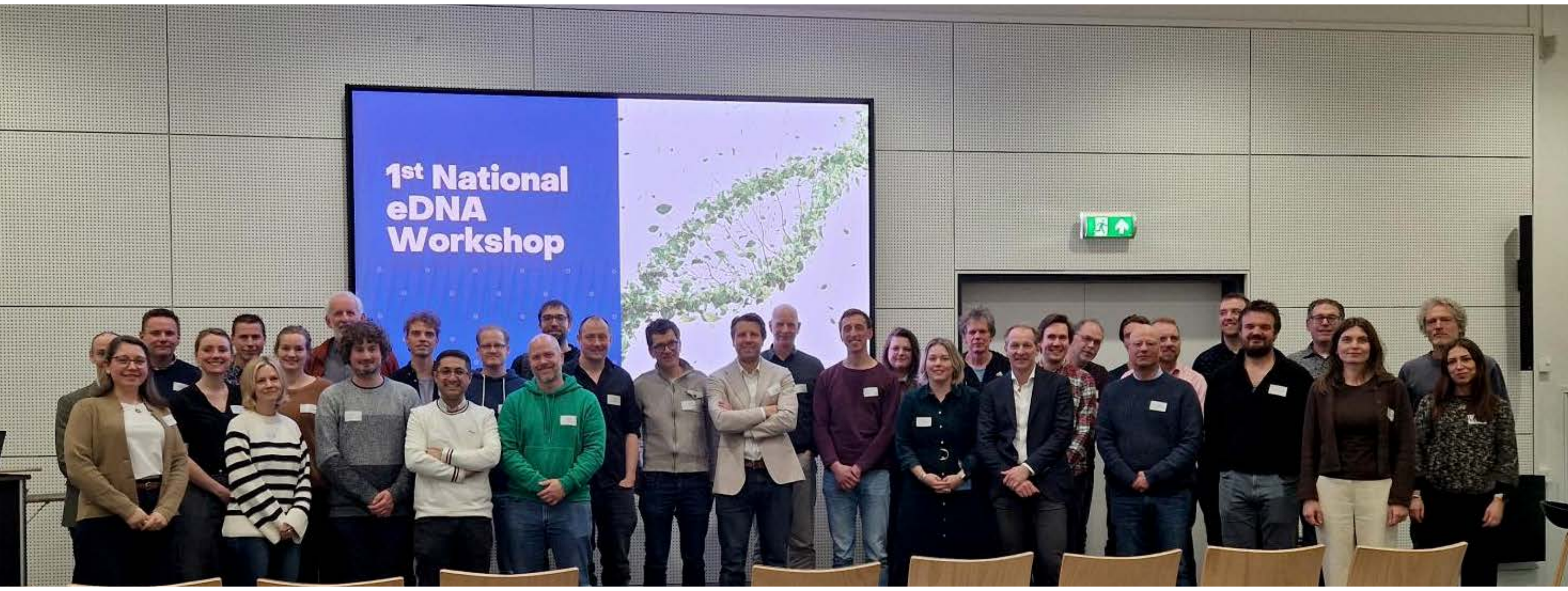


Figure 1 Members of the 1st National eDNA workshop held in Utrecht, March 5th 2025