Environment Agency

Evidence

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# Using DNA-based methods for environmental monitoring and decision-making

## What's this document about?

This document sets out the Environment Agency's view on accepting DNA-based methods for environmental monitoring and decision-making in the absence of a regulated framework to validate the methods.

## Who does this apply to?

It applies to academics, private and public sector laboratories, consultants and any other organisations developing DNA-based methods for application to regulatory and management decision-making.

## Background

The Environment Agency is the competent monitoring authority for EU directives including the Water Framework Directive, Marine Strategy Framework Directive, Bathing Waters Directive and Environmental Quality Standards. Monitoring informs work to protect and improve the environment. Monitoring data, and the information we derive from it, direct our priorities and activities, and help to justify investment decisions.

We are working closely with the research community to develop new ecological monitoring methods and tools that seek to provide us with greater insight into the makeup of biological communities and to improve our current monitoring of individual species.

We hope to deliver novel DNA-based, operationally valid monitoring methods that address some of the challenges faced by traditional methods and could save us money in the future. As well as their anticipated cost-effectiveness, the other advantages of DNA-based methods over traditional monitoring include their ability to be standardised, their sensitivity and the fact that they offer alternatives to more invasive techniques. These methods will use DNA to identify individual species or communities of interest.

We are currently working on two approaches. One targets DNA extracted directly from the organisms themselves. The other uses environmental DNA (eDNA) which is released from an organism via faeces, urine, slime, skin and so on into environmental samples such as water, soil and sediments.

## Why now?

Two recent advances have made it feasible to use these methods to measure the state of the environment more directly. The first advance is that the genetic identification of species has benefitted from international 'DNA barcoding' campaigns which have created large online databases, such as the International Barcode of Life, which link species taxonomies to diagnostic DNA sequences. If necessary, these repositories can be augmented by user-created DNA databases for particular taxa. The second advance is that technology now allows us to perform high-throughput Next Generation Sequencing at a tiny fraction of the cost that had previously precluded advances in the field of ecological monitoring.

Such developments mean that DNA-based methods can now be used to:

- identify and estimate the abundance of single, target species via quantitative polymerase chain reaction (PCR) and/or standard sequencing
- assess whole ecological communities via meta-barcoding/shotgun sequencing (that is, identification en masse) to a higher level of taxonomic resolution, at lower cost and faster than many traditional methods that are based on morphological taxonomy

In summary, new technologies provide the power to measure the environment more directly by detecting unanticipated, individual species and by assessing ecological communities. This has the potential to:

- broaden our understanding of the distribution of biodiversity
- make it easier to analyse the factors that drive change in biodiversity and ecosystem functions and services
- detect new invasive species and pathogens

## Where are we looking to use DNA methods?

Different DNA-based methods come with their own strengths and weaknesses; there is no 'one size fits all' solution to our needs. We are looking to develop DNA methods to support our decision-making. However, these methods must be able to offer a similar level of precision to traditional ones, at a lower cost.

Where possible, they should provide additional benefits with respect to the ecological information offered, for example, to unlock taxonomic information in a form that can be used for ecological assessments.

Areas where we are looking to develop DNA-based methods include the following.

**Monitoring community composition of different biological taxa for ecological assessment of water quality**

We currently use the community composition of different biological taxa in rivers, lakes and transitional waters (including phytobenthos, macro invertebrates, phytoplankton, fish and aquatic vegetation) as part of a suite of ecological methods to inform decision-making associated with EU and UK legislation (for example, the Water Framework Directive, Marine Strategy Framework Directive, Urban Wastewater Treatment Directive and Habitats Directive). Current biological assessment uses morphology-based identification. This is a time-consuming process requiring highly skilled individuals to both analyse and interpret data. We are looking to develop cost-effective DNA-based methods that offer comparable levels of accuracy.

**Monitoring and surveillance of single species**

Two important areas for the application of DNA-based methods include invasive non-native species (INNS) and protected species surveillance, primarily in marine (marinas and ballast water screening) and freshwater environments.

We need to assess the presence/absence, spread and impact of INNS to meet the requirements of national and EU legislation such as the Water Framework Directive, the GB INNS Strategy and the EU Regulation on Invasive Alien Species. Because INNS have a negative impact on ecosystem integrity and native biodiversity, there will be implications for achieving required ecological status under Water Framework Directive objectives due to the presence of some INNS.

The cost of mitigation and management once INNS are established means prevention by early detection would be more cost effective than post management. Methods based on eDNA have great potential to improve our current approach to INNS monitoring and surveillance.

**Pollution source tracking**

We are also exploring the use of DNA-based methods to inform decision-making in other areas such as for pollution source tracking in bathing waters and for monitoring different bioaerosol components from air emissions from regulated industry.

## Method validation: from research to regulatory decision-making

DNA-based methods have moved from just being a fundamental research tool, through proof-of-concept, to full development and application in regulatory decision-making.

For example, the eDNA method is among those listed in the guidance from Natural England on carrying out surveys to assess the impacts of development projects on great crested newts (www.gov.uk/guidance/great-crested-newts-surveys-and-mitigation-for-development-projects).

The adoption of DNA-based methods in regulations will give a paradigm shift to ecological assessment. For this DNA-based paradigm to emerge and to enable us to make appropriately informed regulatory and management decisions, we need to be confident that the information generated is reliable, highly specific and can accurately indicate the presence of the target organism(s) in the test water body.

As demonstrated by our investment in their development, we recognise the potential of DNA-based methods. However, developers need to provide us with evidence of the accuracy and reliability of their methods through validation. This would greatly increase our confidence in applying them to regulation to enhance decision-making and to demonstrate to those we regulate that they provide the reliability, accuracy and confidence appropriate to their use.

A formal regulated framework has not yet been established for validating and approving DNA-based methods, although a formal position on the framework for this and the standards required is under discussion by the regulatory agencies of England, Scotland and Wales. Until such as framework is agreed, we will need to assess the suitability of DNA-based methods for application, either alongside traditional methods or as a replacement, on a case-by-case basis.

Although publication of a method in a peer-reviewed journal is a means of evaluating its scientific credibility, it does not equate to a method being judged or considered to be validated. There will still be a need to determine a method's performance characteristics and limitations to ensure it is fit for purpose and to demonstrate that the results produced can be relied on. Inaccurate information can be costly and the consequence(s) of trusting unvalidated methods could be extremely damaging. This is particularly important when, for example, surveying and monitoring INNS and protected species.

Assays designed to detect the presence/absence of single species will need to be reliably species-specific because of the consequences of false results.

If developers want their DNA-based method to be considered for regulatory use, they will need to submit a detailed technical report, together with any supplementary information, to provide the evidence underpinning the development and rigorous testing of the method. We will submit this report and supporting information for independent peer review.

Subject to a satisfactory peer review, we will then take an informed business decision on whether or not to implement a particular DNA-based method. If we decide to implement a method, we will work with the developer to produce a Standard Operating Procedure (SOP) that sets out the standards required for field and laboratory approaches to give a consistent approach to sampling and analysis.

## Future direction

We recognise that a regulated framework for the validation of DNA-based methods needs to be established to enable decision-makers to have confidence in applying these methods. We are working with others to develop this framework. We would also like to work towards laboratory performance testing and eventual laboratory accreditation so that we can benchmark both the method and the performance of individual laboratories.

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