Using eDNA to trace ivory provenance to help tackle the illegal wildlife trade

Environmental DNA from ivory tusks can be matched back to environmental DNA obtained from wild elephant families living in Africa to understand the origin of the ivory tusk or product. The accuracy of these techniques means that the origin of the tusk can be traced back not only to the exact region that the elephant was from, but even to the exact elephant family.

This type of provenance information is vital for those aiming to identify the global trade routes and supply chains of illegal products. For example, research has shown that tusks from the same elephant are often separated and turn up in ivory markets on different continents – highlighting the complexity of these investigations in terms of tracing perpetrators back along the chain.

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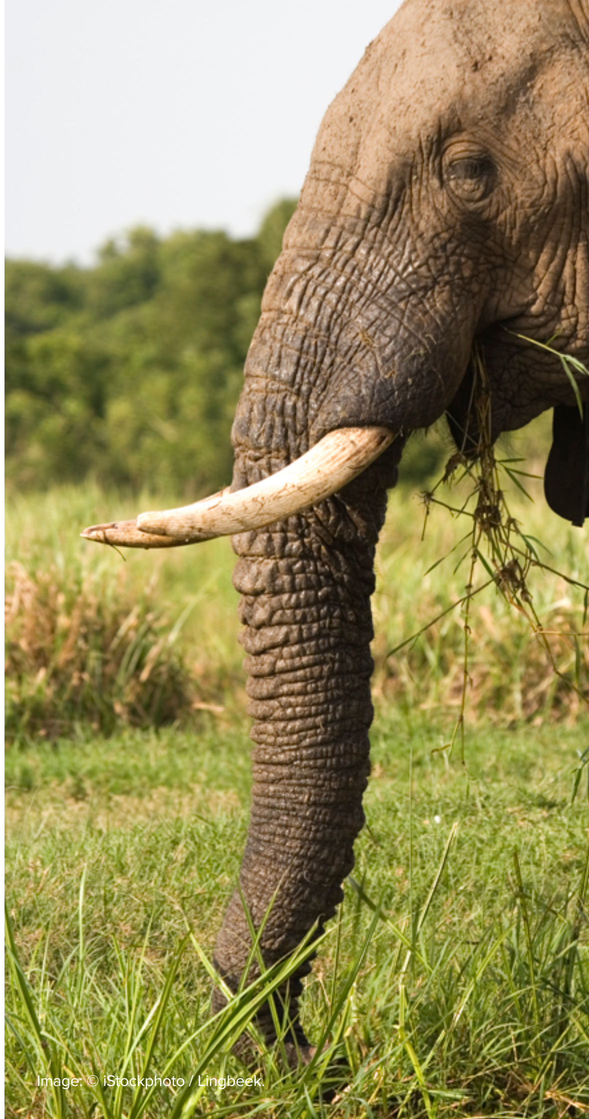

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Using environmental DNA to detect and track COVID-19 in wastewater

In 2020, researchers began repurposing environmental DNA techniques to track the spread of COVID-19. While scientists were using eDNA techniques for pathogen detection prior to the pandemic, the rapid spread of COVID-19 precipitated a significant scaling-up of their use. Scientists were able to detect fragments of viral genetic material in wastewater – in the case of SARS-CoV-2, RNA – allowing public health authorities to detect and monitor new outbreaks.

SARS-CoV-2 RNA can be detected in environmental samples several days before its detection via clinical surveillance. This makes it a useful technique for providing early warnings of new clusters or outbreaks, and for monitoring trends over time.

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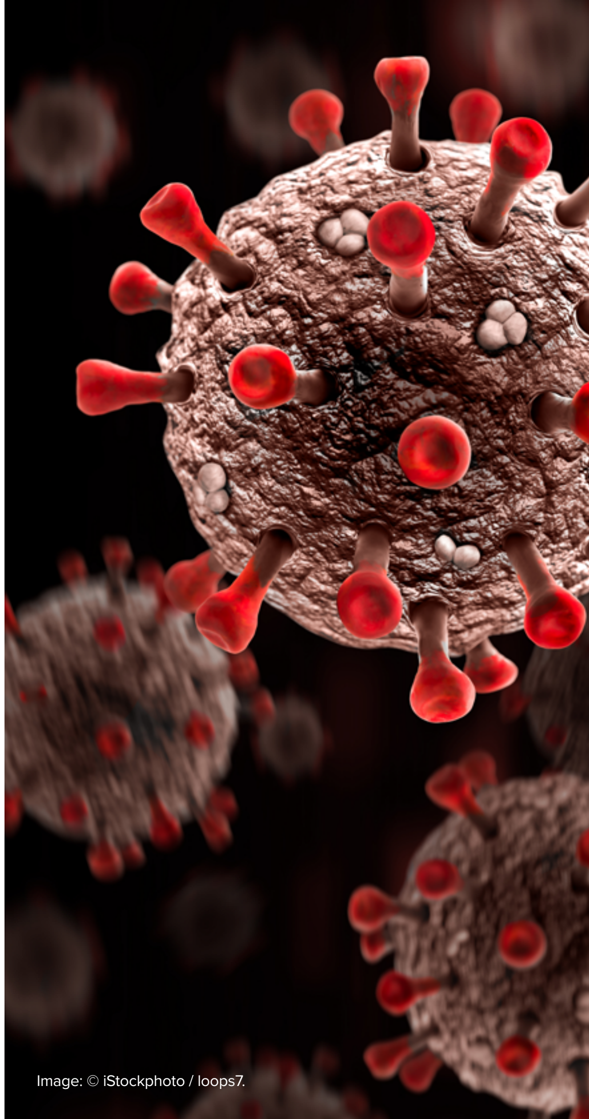

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Using eDNA to detect endangered species

Eels were once numerous in the Somerset Levels but have become critically endangered due to drainage and farming of the area that was once marshland. This means, like other endangered species, it can be very hard to detect their presence or absence via visual monitoring methods. Therefore, to monitor their presence, scientists were able to filter and test water samples for fragments of eel eDNA.

eDNA monitoring revealed that there were no eels in the drainage system of the wetland areas, meaning the river was not feeding eels into the Levels. Some experts concluded that blocked migration pathways and an electric pumping station were responsible for driving down the eel population.

eDNA methods can be very valuable for detecting elusive or endangered species which is important for informing conservation efforts.

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Using eDNA to monitor air pollution in London

56% of the worlds' population already live in urban areas, the UN expects this to increase to >70% by 2050. In London, air pollution and allergens have been linked to respiratory disease and 4,000 deaths a year: including the death of nine-year old Ella Kissi-Debrah to air pollution triggered asthma, and Awaab Ishak who died after exposure to fungal material.

Scientists have used eDNA air capture methods to sample London air and provide an insight into seasonal biodiversity changes, pollen types and levels, fungal spores and antimicrobial resistance genes. This data provides important insights into the condition of London's air which can be used to support policies relating to which tree species to plant, low emission zones, the move to electric vehicles and respiratory related public health interventions.

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Using eDNA to detect and trace falsified medicines

Substandard and falsified medical products can harm patients and contribute to antimicrobial resistance. The World Health Organization estimates that roughly 10.5% of low- and middle-income country medicines are substandard or falsified.

The FORESFA project – FORensic Epidemiology and impact of Substandard and Falsified Antimicrobials on public health is using forensic science, including eDNA techniques, to improve understanding of the origins and make-up of substandard and falsified medical products. eDNA techniques enable scientists to compare genuine and falsified antimicrobials and can be used to identify both the origin and trade routes of these falsified medicines.


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Using air capture eDNA methods to detect crop pests and pathogens

Modern intensive monoculture farming is inadvertently ideal for epidemics. Crop diseases have large impacts, UN FAO estimates global crop production losses of 20 – 40% or $200 billion per annum.

Using air filter devices, eDNA can be collected, analysed and used to detect pests and pathogens which may damage agricultural crops. As fungal spores arrive through the air, air eDNA surveillance can detect them before they have caused disease symptoms. This could act as an early warning signal and allow farmers to spray only when early signs of infection are detected, as opposed to preventatively spraying. eDNA informed spraying could reduce environmental damage and farmers' costs, whilst increasing yields.

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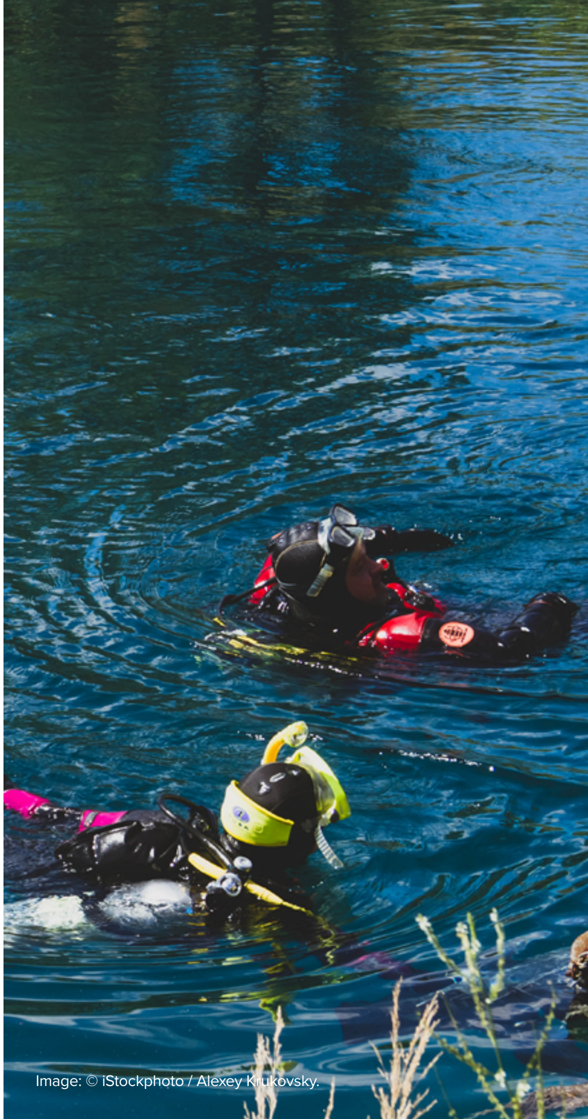
Using eDNA to help find and identify missing people

Increasingly, eDNA methodologies are becoming accurate enough to detect DNA from a specific individual, as opposed to just a target species. This may mean that applications such as using eDNA to trace missing people are not completely outside the realms of future possibility.

Human eDNA can last for around 11 days in freshwater, so when missing people are thought to be in rivers or lakes eDNA could be a potentially important future tool for identifying whether or not the body may be there. Both water and sediment can be screened for human eDNA. Soil can also be tested for traces of human eDNA.

It might also be possible in the future to identify eDNA from missing people by monitoring wastewater, especially if they are thought to be in a certain vicinity. In the same way, eDNA may also potentially be used to identify the remains of people lost at sea or in previous conflict, through marine sediment or soil samples. But linking these fragments of DNA to individuals and their living relatives is still a bit of a way off.



Using eDNA to detect pathogens in sea turtles

eDNA "fingerprints" left behind by sea turtles offer scientists a simple, powerful way of tracking the health and whereabouts of these endangered animals, which is important for their conservation.

Scientists have created techniques that can identify the presence of green turtles and loggerheads turtles via eDNA in a small scoop of sand or a litre of seawater. Minuscule amounts of DNA revealed not only which species of sea turtles had recently passed through, but their place of origin and the subpopulation to which they belonged. On sand, it was even possible extract viable DNA from a crawl track made by a single loggerhead hatchling, which weighs about as much as a dozen paperclips.

Scientists can also ascertain sea turtle pathogens in eDNA samples, including the main virus that causes fibropapillomatosis, an increasingly common cancer that leads to cauliflower-like tumors on sea turtles' skin, eyes, mouth and internal organs. eDNA techniques can pinpoint specific variants of the virus and its concentration in the water column — helpful for monitoring its spread and developing potential treatments.

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Image: © iStockphoto / richcarey.

Using eDNA to link suspects to crime scenes

Plant eDNA in the soil on the sole of a suspect's shoe can be traced back to unique vegetation at a crime scene. This is done by characterising the microbial fungi that grow on plants' surfaces such as leaves, which are often unique to plants in a particular location and habitat. This can provide a crucial links between suspects and crime scenes.

In addition, pioneering research on dust and air samples is increasingly able to detect which individuals were in a room and how recently – though much of this research is still at the proof-of-concept stage.

Standardisation of the methodology and wider development of DNA databases is needed to ensure that results of eDNA applications are consistent, scientifically reliable and valid so that they can be accepted into forensic evidence. A parallel conversation around the ethical use of human eDNA obtained without consent is also required.

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Using eDNA to monitor bio-terror threats

Bioterrorism is the deliberate release of viruses, bacteria, toxins or other harmful agents to cause illness or death in people, animals or plants. Often these agents can spread across wide geographical distances, making it difficult to monitor their distribution and impact.

eDNA sampling technologies could prove useful for quantifying the extent and levels of contamination from biological agents. These techniques could be leveraged following a wide-area contamination incident. Water, soil and air monitoring techniques could be used for this type of surveillance.

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Image: © iStockphoto / SrdjanPav.

Using eDNA from honeybees to monitor ecosystem health

With the help of beekeepers, honey samples have been collected from across the UK since 2018. These samples are analysed using advanced eDNA barcoding techniques to identify the species of plant pollen present. This tells us what bees are feeding on in different parts of the country and at different times of year. This information helps us identify possible threats to the floral resources of pollinating insects.

Bees and their honey are excellent indicators for overall ecosystem health as they are particularly sensitive to environmental stressors such as climate change, the emergence of new diseases, pesticide use and land use change.

This research directly informs Defra's 25 Year Environment Plan indicator framework – relating to 'Exposure and adverse effects of chemicals on wildlife in the environment'.

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Using eDNA for pollen forecasting and predicting respiratory related hospital admissions

Hay fever is the most common allergen and grass pollen is responsible for the majority of cases. However, grass pollen cannot be readily discriminated using standard microscopy measures, which can only distinguish between flower, tree and grass pollens.

Using eDNA methods, it is possible to distinguish between different grass species and also pre-emptively detect which species of grasses will likely make up pollen counts within the next few weeks (detecting very small particles before they become abundant). This data can be combined with existing Met Office pollen reporting data to make forecasts more accurate.

This grass pollen data was linked to epidemiological health data related to hospital admissions with respiratory symptoms. A subset of grass species seem to have a disproportionate influence on population-scale respiratory health responses during peak grass pollen concentration.

Image: © iStockphoto / Tunatura.

Using eDNA to monitor lake fish communities

Monitoring of lake-fish communities is required by law, under the Water Framework Directive, but surveying fish using traditional methods such as netting is invasive or even lethal for fish. eDNA metabarcoding provides a non-invasive alternative to these traditional methods. Since 2015, researchers have been working closely with end-users such as the Environment Agency and Scottish Environmental Protection Agency to develop and roll out new methods for lake-fish monitoring using eDNA metabarcoding.

eDNA metabarcoding has proven to be highly effective in detecting fish species, when compared to other methods. This method also provides repeatable data on species relative abundance and was sensitive enough to be used to detect differences in the fish communities determined by ecological status of water bodies. It has since been rolled out for routine surveys of lake-fish communities across the UK. This is the first example of the application of eDNA metabarcoding for routine biodiversity monitoring.

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