Policy action needed to unlock eDNA potential

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The technological innovation of environmental DNA (eDNA) began about 14 years ago with the detection of DNA from American bullfrogs (*Lithobates catesbeianus*, formerly *Rana catesbeiana*) in water samples from French ponds (Ficetola *et al*. 2008). Hundreds of journal publications later, many research groups have continued to innovate, expanding the genetic information derived from field samples. What started with the detection of a single target species now extends to detecting hundreds of species simultaneously (Deiner *et al*. 2017), and to quantifying genetic diversity and population size (Andres *et al*. 2021). Terrestrial animals and plants are now also targeted from eDNA in water, soil, and air samples (Clare *et al*. 2022).

The rapid pace of research has fueled many studies of management relevance, including detection of incipient invasions to guide control efforts (Jerde *et al*. 2011); detection of imperiled species to facilitate habitat protection; quantification of biodiversity trends over large spatial scales; and, in Europe, monitoring of indicator species or entire biological communities to establish baselines for environmental impacts (Lanzén *et al*. 2021). Deployment of eDNA technology improves measurements of biodiversity, which could enable better management.

Unfortunately, US government policies have lagged behind this scientific innovation, and consequently the eDNA economy has not boomed. Federal agencies have generally regarded eDNA as unreliable for decision making, so far largely failing to establish a potentially virtuous cycle between innovations in eDNA technology and management (Figure 1). The scientific and policy communities now have a crucial opportunity to establish a positive technology–policy feedback using eDNA for biodiversity surveillance, monitoring, and protection as well as for ecosystem management.

My collaborators and I are familiar with the challenges at the eDNA technology–management nexus. We took our first water samples for eDNA in 2009 and produced one of the first publications (Jerde *et al*. 2011) demonstrating eDNA's potential usefulness to natural resource management at a large geographic scale – the invasion of silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*H nobilis*) in Chicago area waterways that connect the watersheds of the Mississippi River and the Laurentian Great Lakes. We discovered invasive carp eDNA far closer to Lake Michigan than expected. After much controversy, many briefings, and actions involving multiple

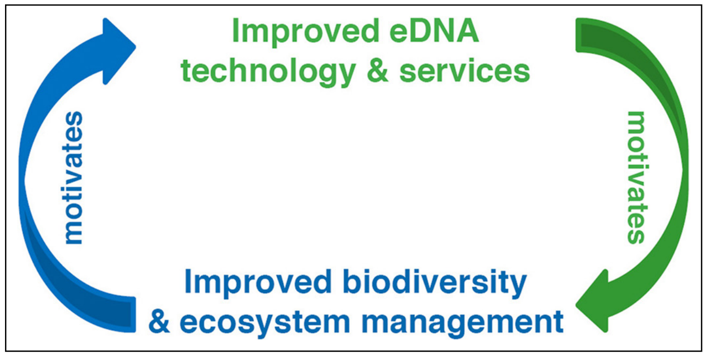

Figure 1. A virtuous cycle of innovation in eDNA-based technology and services would motivate innovation in natural resource management practices, and in turn create new markets for eDNA products to improve environmental protection.

state and federal agencies, the genetic findings that I presented in a 2010 Chicago federal court were admitted as evidence, enabling future uses of eDNA by agencies in litigation. Over a decade later, doubts about the usefulness of eDNA results are long gone, while the need for standard protocols and decision support for management uptake remains (Sepulveda *et al*. 2020).

Multiple federal agencies have built their own eDNA research laboratories (Morisette *et al*. 2021), providing opportunities for federal scientists and decision makers to gain confidence in the potential applications of eDNA. In addition, established companies in field equipment and environmental consulting, along with many start-ups, now sell specialized eDNA field and lab products and offer limited eDNA services. However, for eDNA use to transition – quickly and at scale – from the research laboratory to the management arena, government agencies should take the next step to base regulatory decisions on eDNA. Thus far, federal agencies have largely avoided doing so, despite the precedent of the admissibility of eDNA in federal court. Greater government reliance on eDNA would incentivize market demand for environmental consulting firms, universities, and other potential service providers. Government agencies could establish processes to certify eDNA labs as reliable sources of data. Without such steps, the potential for improved environmental protection and economic growth continues to be unrealized.

There are signs of progress. The National Oceanic and Atmospheric Administration (NOAA) recently proposed to operationalize eDNA to detect harmful marine species, identify mislabeled seafood, monitor aquaculture impacts, manage marine fisheries and food webs, and search for biodiversity of commercial value – all to support the US Department of Commerce's efforts to grow the "Blue Economy" (https://bit.ly/3T5y4uh) (Morisette *et al*. 2021).

Also part of the Blue Economy initiative, offshore wind development has been dramatically accelerated by the Biden administration. This acceleration necessitates learning how to design, site, and operate vast offshore wind farms while minimizing adverse environmental impacts. The US Department of Interior's Bureau of Ocean Energy Management (BOEM) has funded research in preparation for using eDNA to monitor the distribution and abundance of offshore species, as already performed at European offshore energy installations (Lanzén *et al*. 2021). Ørsted recently announced a US$13 million fisheries study, including eDNA surveys, in association with their proposed 1000-megawatt Ocean Wind 1 project off the New Jersey coast. The need for fast and inexpensive methods to collect baseline biodiversity data continues to grow as the Inflation Reduction Act of 2022 extends BOEM's responsibilities to explore feasibility of offshore wind in US territories including Puerto Rico, Guam, and American Samoa.

The US Environmental Protection Agency (EPA) is exploring the use of eDNA or eRNA for assessing risks associated with ballast-water discharge under the Clean Water Act (CWA). EPA could also consider accepting eDNA for pre- and post-project biodiversity monitoring for CWA compliance for inland water discharges, aquaculture facilities, and other installations under EPA purview. Likewise, the White House Council on Environmental Quality and partner federal agencies could encourage the use of eDNA in environmental impact assessments mandated by the US National Environmental Policy Act.

In efforts to prevent the importation of harmful species into the US, the US Fish and Wildlife Service (USFWS) started using eDNA in 2021, as one component of inspection for importations of aquarium moss balls, many of which were contaminated with a prohibited species: zebra mussels (*Dreissena polymorpha*). However, eDNA has so far been neither used as the sole basis for regulatory interdiction nor expanded to other target species for several reasons, including the lack of approved protocols, resistance from states, and industry opposition.

To align with inspection, forensic, and other enforcement standards, broader rules or standards for eDNA must accommodate the best available technology as eDNA innovations continue. The Bipartisan Infrastructure Law of 2022 provides opportunities for federal agencies to build better biodiversity surveillance and monitoring capacities, including eDNA, to make more efficient management possible, especially early detection of invasive species.

NOAA, BOEM, EPA, and the USFWS aspire to use eDNA because no traditional tool for monitoring biodiversity satisfies the need for large-scale, repeatable, fast, and affordable measurements. Aspirations to realize the Blue Economy, and protect the US from invasive species, illustrate the urgent need to incorporate eDNA into agency decision making.

At the global scale, unmet policy imperatives could also be better satisfied using eDNA. More than half of the 20 Aichi Biodiversity Targets under the UN Convention on Biological Diversity (CBD) require metrics of biodiversity. To realize the potential of eDNA in this context, however, implementation of another part of the CBD, the Nagoya Protocol, must be clarified. In the permitting processes of many countries, it is unclear whether or which stages of eDNA samples and data (eg water sample filtrate, eDNA extracts, digital sequence information) are governed by the Nagoya Protocol. This murkiness has inhibited the application of eDNA in international contexts.

The adoption of eDNA for regulatory decisions by US federal agencies and international bodies would enable faster commercialization of eDNA products and services, more affordable quantification of biodiversity, and accelerated energy transitions in response to climate change.

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