Water samples teeming with information: Emerging techniques for environmental monitoring

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Environmental policy must respond to ever-changing conditions on the ground and in the water, but doing so requires a constant flow of information about the living world.

In a paper published in *Science* last week, scientists from Stanford's Center for Ocean Solutions, the University of Washington and the University of Copenhagen propose employing emerging environmental DNA (eDNA) sampling techniques that could make assessing the biodiversity of marine ecosystems – from single-cell critters to great white sharks – as easy as taking a water sample.

Controlling invasive species and saving endangered ones are among the many applications of a new set of monitoring tools that use DNA recovered from the environment.

Although traditional sampling methods – including dive surveys and deploying sampling gear in the water – have been widely used in environmental monitoring, they are expensive, invasive and often focus only on a single species. Genetic monitoring via a form of DNA, known as eDNA, that is shed into the environment by animals could overcome some of these issues.

eDNA is like a fingerprint left at a crime scene. This material may come from metabolic waste, damaged tissue or sloughed off skin cells. Once it

is collected, scientists can sequence the DNA to create a fast, high-resolution, non-invasive survey of whole biological communities.

"The eDNA work is potentially a game-changer for environmental monitoring," said Larry Crowder, a professor of biology at Stanford's Hopkins Marine Station, senior fellow at the Stanford Woods Institute for the Environment, science director at the Center for Ocean Solutions and a co-author of the study. "A number of laws require monitoring, but actually keeping tabs on large, mobile, cryptic animals is challenging and expensive."

Using DNA to inform policy

The cost of DNA sequencing is decreasing rapidly, a trend that has fueled eDNA studies in recent years.

"We wanted to know how to put these amazing new genetic tools to use," said lead author Ryan Kelly, an assistant professor at the University of Washington and a visiting fellow at the Center for Ocean Solutions. "Harnessing eDNA is a perfect example of how cutting-edge science can plug into many of the environmental laws we have on the books."

Nearly every environmental law imposes environmental monitoring obligations on government or the private sector, said Meg Caldwell, a senior lecturer at the Stanford Woods Institute and Stanford Law School, and executive director of the Center for Ocean Solutions, as well as a contributing author of the study. "Pushing the science of genomics to help society perform monitoring more cheaply and effectively is one of our core goals," she said.

The authors provide several examples of scientific-legal interactions, among them the use of eDNA to inform the enforcement of laws such as the Endangered Species Act and Clean Water Act with detailed, low-cost

data.

So far, eDNA has been used to determine the presence or absence of certain target species. This technique is useful for detecting invasive species or changes in the distribution of endangered species. However, scientists are still evaluating how eDNA concentrations relate to specific numbers of organisms in the wild.

A challenging aspect of the approach is determining exactly where the eDNA was generated, especially in dynamic marine systems. eDNA is thought to persist in water for only a few days.

With these limitations, eDNA alone is not yet enough for policy applications, but it is already being used to supplement existing monitoring. This combination approach has recently been used in California to detect human- and animal-based pathogens in waters off state beaches.

"There is much work left to do to develop and validate this approach, but the potential is amazing," Crowder said. "We will continue to work with other scientists at the Center for Ocean Solutions and worldwide to advance and test this approach."

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