Environmental DNA: A molecular smoke detector

Public Fact Sheet

C. Wilson[1], A. Welsh[2], C. Jerde[3], M. Docker[4], B. Locke[5]

[1,5]Ontario Ministry of Natural Resources and Forestry, [2]West Virginia University, [3]University of California – Santa Barbara, [4]University of Manitoba

Environmental DNA has become an important tool for tracking species that may otherwise be hard to find, such as invasive species during early stages of arrival and expansion, and rare species that may be too scarce for regular field sampling to find them.

What is environmental DNA?

Environmental DNA, or eDNA, is genetic material (DNA) that's been shed by living or dead animals into the surrounding environment. Organisms continuously shed living and dead cells into the environment via skin, feces, blood and urine, as well as eggs and sperm at mating times. All of these contain DNA, which can be used as a species detection tool, just as DNA is used for forensics cases.

What is it used for?

Environmental DNA can be detected by sampling the habitats that species use, such as soil or water. It is not necessary to directly find or catch the species themselves, since detections are focused on the DNA that they have left in the surrounding environment. If DNA from the species of interest is detected at a particular location, it's a good indicator that the species itself may be present. By looking for these traces of DNA, eDNA testing acts like a molecular early-warning system that identifies areas that need a closer look.

How is it done?

Collecting environmental DNA samples can be straightforward, but requires careful planning and strict protocols to prevent contamination. In many cases, it can be as simple as taking water samples and concentrating or trapping the DNA so that it can be later purified and tested in the lab. To test for eDNA from a particular species of interest, scientists develop genetic markers that target a DNA sequence that is unique to that species and allow its detection with specialized equipment. eDNA markers are available for a growing list of aquatic invasive and endangered species. Most eDNA testing is done for a particular species of interest, such as Asian carp in the Great Lakes, but new research

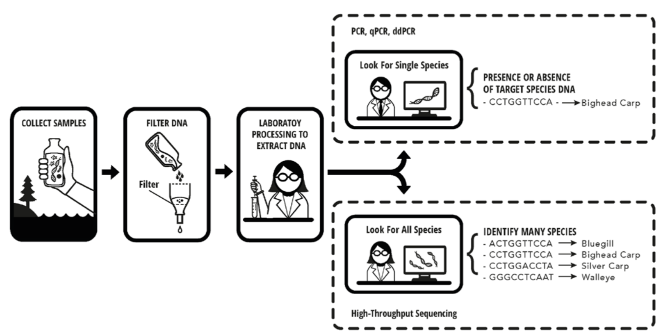

Figure 1: Process for collecting and analyzing eDNA.

is looking at different ways to use eDNA to identify all species present within sampled habitats ("eDNA metabarcoding").

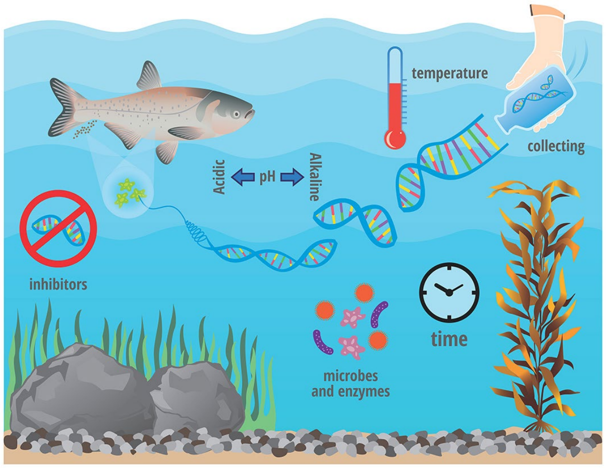

Figure 2: Many factors can influence eDNA degradation in the environment.

Detection of eDNA is affected by the numbers, size, life history, and biomass (amount by weight) of the species of interest in or near a given location, as well as how close (or far away) the species is from where water samples are collected. This is particularly important in flowing systems like rivers, since a positive detection may be caused by the species being upstream and the DNA moving with the water, rather than where the sample was collected. Scientists therefore take habitat information (waterbody size and type, depth, flow if appropriate, and likely/preferred habitat for the species of interest) into consideration to increase the likelihood of detecting species if they are present.

What does a positive detection mean?
A positive detection signals that DNA from the species of interest was present at the sampling location. This doesn't necessarily mean there's an established population of the species, since the eDNA test doesn't distinguish between live and dead sources, or sources that stay put versus ones "just passing through". Scientists can learn more by repeating sampling efforts at areas with positive detections, since the signal from dead or passing sources will disappear fairly quickly. If an area produces a positive eDNA result again, this tells scientists they need to take a closer look by searching for the species using traditional methods (e.g., netting).

What does a negative detection mean?
On the flip side, negative eDNA detections don't necessarily mean that a species is not present. Negative results or detection failures can happen as a result of not taking enough samples, environmental chemicals ('inhibitors') that interfere with DNA detection, too little DNA being present, DNA breaking down in the environment, or problems with laboratory procedures. These risks can be reduced by appropriate field sampling design and quality control testing during eDNA analysis.

Last words
As a way to collect information that is otherwise hard to get, eDNA is a useful tool that adds to the value of traditional sampling methods. Management agencies and university scientists are actively pursuing research on eDNA methods, sampling design, and analyses, and finding new uses for eDNA data. As eDNA science and its uses continue to grow, this sensitive tool for detecting species will likely find more applications for managing these species and the ecosystems they live in.