Environmental DNA in the Fight to Combat Invasive Species

By Rhonda J. Moniz

Over 40% of endangered or threatened species are at risk due to invasive organisms. It is estimated that of over the 100 plants and animals that are endangered or threatened, nearly 85 of those are impacted by non-native species. When an invasive species is introduced into an environment, it throws off the balance of that ecosystem. That introduction can also profoundly affect the local economy and human health. Invasive species account for over one trillion USD in damages annually. It is one of the most significant worldwide conservation threats that affects both terrestrial and aquatic environments. Marine invaders are wreaking havoc in oceans around the world. Some well-known examples include the lionfish, zebra mussel, killer algae, and European green crabs. Many of these hitchhikers are introduced via ballast water tanks of ships and on the ships, or by aquarium owners who release them into the wild.

To combat the rise in marine invasive species, scientists combine biology with technology to better detect these aquatic invaders. Environmental DNA, or eDNA, is a powerful tool for early detection. As an organism moves through the environment, it leaves in its wake a trail of data containing genetic information. This material lingers in the environs providing natural source material with a genetic record of the organism that left it behind. Suspended in the water column, this eDNA is then detectable to researchers with the tools to extract it from water samples collected. Early detection allows scientists and resource managers the time to develop a mitigation strategy to decrease and control the population of the invasive species and to head off the organism's efforts to become well established. Once an invasive species is well established in a new ecosystem, controlling those organisms can become problematic and costly.

What is eDNA?

As we learned in biology class, deoxyribonucleic acid, known as DNA, contains the basic building blocks of life. It is present in nearly all living things and carries our genetic information. Genetic information includes the instructions for all life to survive, develop, and reproduce. It bears the biological instructions that make us who and what we are. It contains all the material that makes us unique and is required to build and maintain all organisms. It is our genetic code.

Environmental DNA, or eDNA, is the DNA released into the environment by an organism as it passes through that environment. It is everywhere. It is present in the soil, seawater, lakes, rivers, snow, and even the air.

Collecting eDNA

Researchers collect water samples to study marine invasive species to investigate what organisms are present. Scientists use sampling tools such as Niskin bottles attached to fixed or moving platforms or contained on a CTD rosette. CTD—conductivity, temperature, and depth—are all essential measurements that provide important information about the water column's biological, chemical, and physical properties. The CTD is a series of small probes deployed in a group such as a rosette or integrated into many observation platforms such as autonomous underwater vehicles (AUVs), remotely operated underwater vehicles (ROVs), or fixed buoys. Water samples are collected with data including CTD filtered material that are then labeled with latitude and longitude. The samples are separated and cleaned before being frozen or preserved in an aqueous solution to prevent degradation. After collection, DNA sequencing begins back in the lab. Once the sequencing is complete, it is compared to other organisms in a DNA library for identification. This gives an accurate picture of the biodiversity in each area and indicates if any invasive species are present.

There are many benefits to eDNA collection that complement traditional sampling efforts. It does not require interacting with the actual organisms, making it a non-invasive sampling method. It also has the added advantage of capturing the illusive lives of organisms that have not previously been recorded in video or stills, especially when dealing with life forms that may be frightened away by the bright lights of a remotely operated vehicle or other platforms. eDNA can also detect a wide range of marine life.

Working with eDNA

The primary approach of eDNA analyses from environmental samples is to detect the presence of individual species of interest. Invasive or rare and endangered species are often the focus. A quantitative polymerase chain reaction (qPCR) is a valuable way to determine whether eDNA matching a target species exists. In this analysis, researchers look in the genomes of intracellular organelles, like mitochondria or chloroplasts, for sequences of DNA containing nucleotide successions unique to a target species. Mitochondrial DNA is primarily the focus of eDNA studies involving animal species. Animal cells have many more copies and may be more resistant to degradation. If no eDNA in the sample includes these species-specific sequences, no detectable documents will be created.

Another commonly used method to simultaneously detect many species in the same test from the same environmental sample is metabarcoding. For animal species, metabarcoding involves initial PCR amplification of mitochondrial DNA but differs from qPCR analyses. Target genes specific to a particular group or groups of a specific species are amplified from the eDNA blend using group-specific DNA sequences. These magnified products are then pooled into what is referred to as a library. This library is compared to a reference library using advanced DNA sequencing technology. The reference library comprises many sequences stemming from species of a known identity. If a line from the sample matches a known species in the library, it is recorded as a match.

Using eDNA does have its challenges. It can be like finding a needle in a haystack, mainly due to animal eDNA often being present in small quantities. Samples can also be easily contaminated during collection. Sterilizing the area and running control samples to monitor contamination when gathering and processing samples is essential. And because eDNA analysis is a new methodology, scientists are still unsure how quickly it degrades, how fast animals release it into the environment, or how it is transported.

Early detection of invasive species

Although the technology faces some challenges, it has a higher chance of detecting non-native species than traditional methods. Environmental DNA has the power to revolutionize biodiversity monitoring and early detection of invasive species. It can be used to study the impacts of climate change and assess the overall health of terrestrial and aquatic ecosystems. It is proving to be one of the most powerful new tools in the invasive species detection kit, and with the rapid spread of non-native organisms worldwide, scientists need all the help they can get.