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Unlocking the Future of Environmental Monitoring: Environmental DNA as a Tool for Biological Characterization and Site Management (Part Two of a Two-Part Series)

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In this second installment of our environmental DNA (eDNA) series, we discuss practical applications of this technology. Understanding the biological community present at a site can help focus the scope of remedial investigations and ecological risk characterizations. Integral applies this novel approach to characterize the presence and abundance of certain freshwater fish, birds, bats, amphibians, and marine biota in both contaminated sediment and greenfield applications.

Case Study: Former Landfill Feasibility Study

A former landfill in New Jersey, dormant since the late 1960s, is surrounded by wetlands and presently supports a diverse range of wetland, meadow, and forested habitats like those at an adjacent wildlife refuge and conservation area. Ten years ago, Integral evaluated potential ecological risks of landfill-related chemicals in the soil and sediment of those habitats to the flora and fauna of the site. More recently, Integral has been revisiting the characterization of those habitats in support of a feasibility study, including documenting the biota present using eDNA surveys of the aquatic and terrestrial habitats.

Large stands of Phragmites-dominated marshes and dense scrub/shrub wetlands make navigating the approximately 200-acre site challenging, so traditional biological surveys would be time- and labor-intensive. Therefore, the primary objective of the eDNA survey is to document current biodiversity in the array of habitats present. The eDNA survey includes collection of water and soil samples in key areas, with eDNA data compared to the reference conditions at the neighboring conservation area. This information can also be used to define baseline conditions that can later be compared to results from post-remedy eDNA surveys.

Through eDNA, Integral will quickly gain a comprehensive understanding of the current biological communities present and how the proposed cleanup may impact those communities. The eDNA data collected post cleanup will aid in documenting the recruitment of the flora and fauna, and, in the long term, register the success of restoration and resiliency of those communities.

Beyond Contaminated Sites: Broader Applications of eDNA

Potential uses of eDNA analysis extend to greenfield-related applications of environmental monitoring and compliance.

Threatened and Endangered Species Monitoring

eDNA is particularly valuable for monitoring rare or protected species at sediment sites and in other habitats.

Integral is collaborating with an eDNA laboratory and academic partners to use eDNA collected from northern

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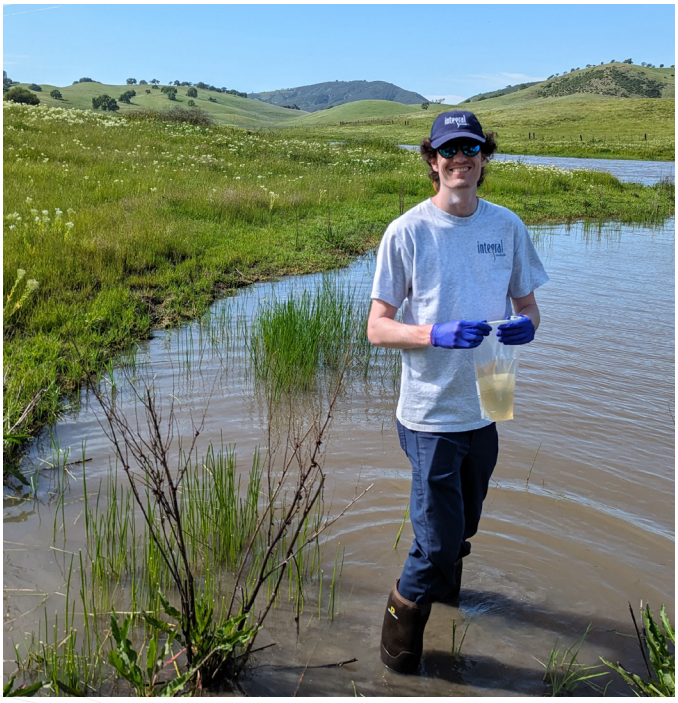
California seasonal ponds to differentiate between native and hybrid populations of the California tiger salamander, a state- and federally listed species. Traditional methods require finding and catching salamanders during specific seasons, followed by invasive tail clipping for testing to distinguish the species and determine the level of hybridity. Conversely, collection of water and sediment samples from the target ponded habitats and eDNA analysis of those samples could offer a noninvasive, cost-effective alternative to identification of hybrid populations.

Similarly, a recently published investigation into the feasibility of using airborne eDNA to detect aquatic organisms[1] demonstrated that fully passive airborne eDNA sampling accurately assessed spawning Coho salmon *(Oncorhynchus kisutch)* presence in Issaquah Creek near Seattle, Washington. Aerosolized genetic material (resulting from evaporation, bubble-bursts and splashing at riffles, and spawning activity) enables this novel approach to detect sensitive aquatic species while allowing scientists to track site use without invasive or laborious surveys.



Collection of a pond water sample for eDNA analysis.

Conservation and Restoration

eDNA is being used to monitor biodiversity in restoration projects, track invasive species, and assess the success of habitat interventions. Its ability to detect species presence without requiring detailed community or habitat surveys makes it ideal for identifying cryptic, rare, or invasive species, and for tracking community changes spatially, seasonally, or over broader time spans. The efficiency of eDNA in detecting focal species and assessing biodiversity also allows landowners to understand species assemblages on their land and manage accordingly; enables park and open space agencies to prioritize areas that support vulnerable species; and permits conservation groups to assess the ecological value of sites targeted for protection efforts. Some companies are also using eDNA to monitor biodiversity as part of their sustainability initiatives and reporting.

Renewable Energy and Extractive Industries

Site assessments for wind farms, solar installations, and mining operations increasingly incorporate eDNA to characterize ecological communities and evaluate potential impacts before, during, and after development. Integral is incorporating eDNA data into an essential fish habitat assessment for offshore wind projects. Some offshore wind farms in the United States have added eDNA to their required fisheries and benthic monitoring programs.

Environmental Permitting

Permits for wastewater discharge often require biological monitoring to ensure compliance with water quality standards. Although the biotic indices typically specified in permit conditions necessitate traditional biological surveys, supplemental eDNA analysis can provide an additional line of evidence to evaluate community health and clarify potential impacts to benthic invertebrates and other organisms.

Water Management

The use of eDNA is revolutionizing water management at local, regional, and state levels. For example, in 2024, the California Department of Water Resources (DWR) released its eDNA Strategy,[2] outlining its approach to integrating eDNA technology to detect rare, invasive, and nuisance species; assess and track biodiversity; and monitor pathogens. Using eDNA, DWR can more effectively monitor large and remote ecosystems, improve science-based management decisions and environmental stewardship, and enhance collaboration both within the agency and with external partners. DWR's eDNA efforts are in support of key operational goals, including compliance with environmental regulations,

Field processing of a water sample for transport to an analytical laboratory.

informing habitat restoration, anticipating harmful biological events such as toxic algal blooms or disease outbreaks, and creating opportunities for meaningful community engagement.

Conclusion

eDNA has the potential to revolutionize how we understand and manage ecosystems. From contaminated urban waterways to remote conservation areas, eDNA offers a powerful, efficient, and noninvasive means of assessing biodiversity. Including eDNA as a line of evidence in the early phases of project planning can allow project proponents the opportunity to design around sensitive resources to maximize development, remediation, and habitat restoration opportunities on a site while minimizing impacts to species or habitats of concern.

Although challenges remain, the momentum is clear: eDNA is not just a research tool—it is a practical tool for the complex environmental challenges of today and tomorrow. As adoption grows, eDNA will play a critical role in advancing sustainable development, protecting endangered species, and promoting ecosystem health.

[1] Ip, Y.C.A., G. Guri, E.A. Allan, and R.P. Kelly. 2025. Passive air sampling detects environmental DNA transfer from water into air. Sci. Rep. 15:42245. https://doi.org/10.1038/s41598-025-26293-6.

[2] California Department of Water Resources. 2024. Department of Water Resources Environmental DNA (eDNA) Strategy. Sacramento, CA. 38 pp. Available at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/What-We-Do/Science/Files/eDNA_Strategy.pdf