DWR Environmental DNA Strategy

PURPOSE

The Department of Water Resources (DWR) Environmental DNA (eDNA) Strategy is a roadmap for operationalizing eDNA technologies to support sustainable management of water resources in California. This strategy seeks alignment with the framework for a national eDNA Strategy so DWR eDNA contributions and practices are integrated at a broader scale, as appropriate.

BACKGROUND

DWR manages California's water resources, systems, and infrastructure with a fundamental core value of using best available science to inform management practices and decisions, often through promotion of cutting-edge technologies and community engagement. Hand-in-hand with its water management responsibilities, DWR is required to study and monitor potential operational impacts to terrestrial and aquatic species. In addition, DWR is a leading innovator in nature-based approaches to water management and environmental stewardship practices in California, which requires adoption of best practices for biological and environmental monitoring. One tool that has gained traction as a complement to traditional biological monitoring is eDNA monitoring. eDNA is genetic material that living organisms leave behind as they pass through the environment, and it can be collected from water, soil, and air. Methods to detect eDNA are non-invasive, cost-effective, highly sensitive, safe, efficient, and well suited to community science. Although the study of eDNA is a relatively nascent field, foundational research has shown that eDNA detection tools are ready for widespread adoption in natural resource management. DWR recognizes the value and potential benefits of emerging eDNA technologies and seeks to incorporate these tools, where appropriate, into biological monitoring that is essential for management of California's water resources.

APPLICATIONS

Agency scientists and managers often call upon eDNA approaches when there is a need to monitor a large ecosystem or when other methods do not comprehensively address management issues. Importantly, eDNA tools may provide opportunities for biological monitoring that DWR was previously unable to realize, or they may complement traditional biological surveys that are already conducted, including physical capture of organisms or visual identification. The most appropriate tool, or combination of tools, for the specific project purpose or study question should be applied to provide the most useful information to achieve management objectives.

eDNA enables species monitoring without the need to directly collect or observe individuals. Aquatic samples can be non-invasively collected using nets, bottles, or electronic samplers that do not require a person to be present. DWR is advancing applications of eDNA monitoring to detect protected and invasive species to inform water management operations and understand species responses to restoration.

The applications of eDNA tools typically fall into one of several categories that align with DWR priorities:

- **Rare species monitoring**. Detect rare species such as Delta and Longfin smelt and listed runs of Chinook Salmon irrespective of life stage for state and federal Endangered Species Act compliance.
- **Invasive species monitoring**. Identify invasive aquatic species including nutria and dreissenid mussels before a major invasion, to verify successful local eradication, and for advanced water infrastructure planning and maintenance.
- **Nuisance species monitoring**. Tool development to anticipate and evaluate impacts of nuisance organisms such as algal taxa that produce toxic blooms.
- **Biodiversity and climate change assessment**. Assess and track species assemblages and richness across multiple trophic levels in a single eDNA sample. This type of data can also be used to evaluate the success of habitat restoration actions.
- **Pathogen monitoring**. Establish pathogen presence and prevalence, aid in anticipating disease outbreaks, and mitigate risk associated with species translocation and population supplementation. Examples include monitoring of *Ceratonova shasta* in waters surrounding Feather River Fish Hatchery.

Existing projects and studies incorporating eDNA tools are summarized in Appendix A.

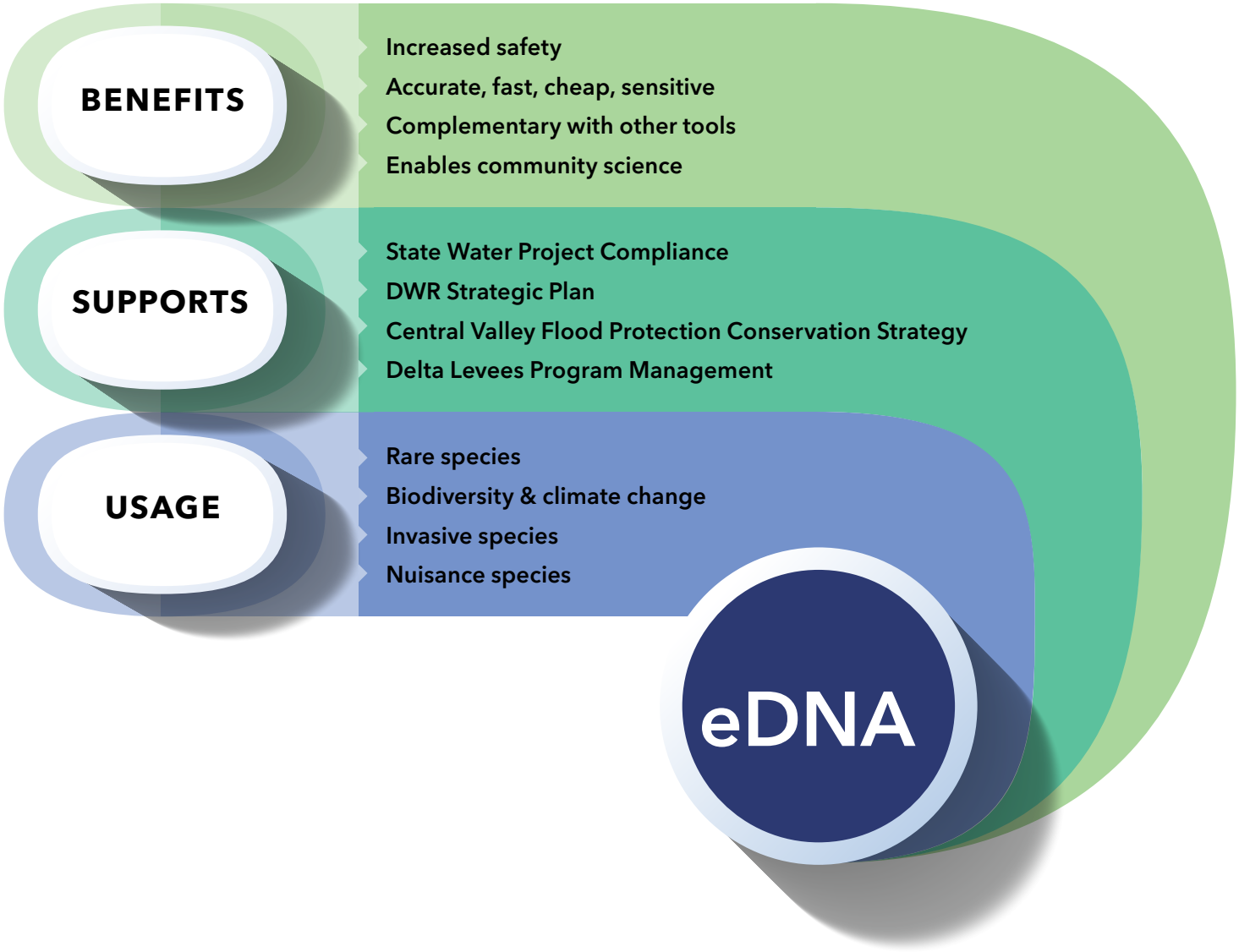
GENETIC MONITORING PROGRAM

In 2022, DWR initiated a Genetic Monitoring (GeM) program housed within the State Water Project's Division of Integrated Science and Engineering with the overarching goal of efficiently meeting conditions in the U.S. Fish and Wildlife Service and National Marine Fisheries Service Biological Opinions and the California Department of Fish and Wildlife Incidental Take Permit for long-term operation of the State Water Project. The GeM laboratory is located in West Sacramento with a clean room that is specifically designated for eDNA work. DWR will leverage the GeM program and laboratory to continue to conduct eDNA work and will also partner with outside entities to realize the full and evolving potential of eDNA tools to support water management for California.

GOALS

This eDNA Strategy establishes five goals that are critical steps that will harmonize internal and external eDNA efforts, solidify DWR eDNA science capabilities, and create meaningful engagement with the community. The goals may be performed in phases or in parallel.

Leveraging eDNA for Management Decisions & Environmental Stewardship



IN PARTNERSHIP WITH

AGENCIES: CDFW, NOAA, USFWS, USGS **INSTITUTES:** Southern CA Coastal Water Research Project, Monterey Bay Aquarium Research Institute **INDUSTRY:** Cramer Fish Sciences (Genidaqs), EQO
ACADEMIC: University of Montana, UC Davis

1 Establish internal collaborative teams, science priorities, and best practices for eDNA

OBJECTIVE 1.1 Establish an internal eDNA Executive Coordination Team, led by the DWR Lead Scientist in partnership with other science leaders of DWR, to establish priorities for the use of eDNA in DWR operations and water management and to provide direction for the action team.

OBJECTIVE 1.2 Establish an internal eDNA Implementation Team, led by GeM program co-managers, to implement internal priorities identified by the eDNA Executive Coordination Team and coordinate and track progress on DWR eDNA activities and research.

OBJECTIVE 1.3 Develop and implement eDNA best practices including metadata and sample collection, sample processing, data QA/QC, data analysis, data deposition, and reporting to ensure eDNA data consistency and integration across DWR (eDNA Implementation Team).

OBJECTIVE 1.4 Align DWR best practices for eDNA with other agencies and scientific institutions such as the White House Office of Science & Technology Policy, the Council on Environmental Quality, and the Southern California Coastal Water Research Project (eDNA Implementation Team).

OBJECTIVE 1.5 Update Appendix A of the eDNA strategy annually to ensure awareness and transparency of eDNA project progress and performance (eDNA Executive Coordination Team).

2 Strategically integrate eDNA information into management decision making

OBJECTIVE 2.1 Identify specific opportunities and uncertainties surrounding adoption and integration of eDNA methods in DWR water management and operations (eDNA Executive Coordination Team).

OBJECTIVE 2.2 Direct studies to support best practices development (see Obj. 1.3), address identified uncertainties (see Obj. 2.1), and compare information gleaned from traditional and eDNA methodologies (eDNA Implementation Team).

OBJECTIVE 2.3 Validate eDNA data, ensuring that it is accurate and reproducible and partner with the Environmental Laboratory Accreditation Program to build an accreditation framework for the GeM laboratory (eDNA Implementation Team).

OBJECTIVE 2.4 Create general eDNA data interpretation guidelines and decision trees to ensure understanding and consistency of use in decision making (eDNA Executive Coordination Team and eDNA Implementation Team).

OBJECTIVE 2.5 Identify existing DWR programs, studies, and mandates that will benefit from eDNA data and incorporate eDNA metrics into water management and operations (eDNA Executive Coordination Team and eDNA Implementation Team).

OBJECTIVE 2.6 Develop an adoption plan for eDNA technology and staff training on eDNA methods and applications (eDNA Executive Coordination Team and eDNA Implementation Team).

3 Invest in and advance management-relevant eDNA research internally and through external science partnerships

OBJECTIVE 3.1 Characterize eDNA including state, transport, retention, and response to environmental variables in dynamic California waterways managed by DWR.

OBJECTIVE 3.2 Conduct studies to improve monitoring of listed species, invasive species, nuisance species, and biodiversity in California waterways managed by DWR.

OBJECTIVE 3.3 Investigate emerging eDNA technologies and benefits for improved DWR water management.

OBJECTIVE 3.4 Form collaborative partnerships with external agencies and institutions such as the Monterey Bay Aquatic Research Institute and Cramer Fish Sciences (Genidaqs) to advance eDNA science and monitoring.

4 Enhance community awareness of DWR science through engagement with eDNA monitoring

OBJECTIVE 4.1 Make DWR eDNA data transparent and accessible by posting on public data repositories (e.g., the California Natural Resources Open Data Portal, or similar), publication of manuscripts in agency periodicals or peer-reviewed journals, and the potential creation of a public-interfacing DWR data portal.

OBJECTIVE 4.2 Initiate eDNA monitoring programs and studies that incorporate a community science approach to gathering data. Ensure consistency with the DWR Racial Equity Action Plan Strategy 2.3: "All programs and projects that solicit community input must develop intentional public engagement strategies."

OBJECTIVE 4.3 Launch eDNA education modules for K–12 students and advance the DWR Racial Equity Action Plan Strategy 2.6: "Provide mentorship and resources for K–12 students in under-represented communities to support water resources career pathways."

5 Ensure adoption of eDNA tools is adequately resourced

OBJECTIVE 5.1 Identify the number of staff needed and secure positions to execute Goals 1–4.

OBJECTIVE 5.2 Recruit and hire top-talent scientists with specialized eDNA and genetics skills for positions requiring eDNA expertise.

OBJECTIVE 5.3 Procure appropriate supplies, equipment, vehicles, and vessels to accomplish Goals 1–4.

OBJECTIVE 5.4 Allocate adequate laboratory and office space for eDNA supplies and equipment, sample processing, sample archival, analysis, and project coordination and reporting.

OBJECTIVE 5.5 Secure cloud computing resources for eDNA analysis.

DWR strategy to operationalize eDNA technologies to support water resource management in California

GOALS

- Establish collaborative teams, science priorities, and best practices for eDNA
- Integrate eDNA into management decision making
- Enhance community awareness of DWR science through eDNA
- Invest in management-relevant eDNA research
- Ensure adequate resources for adoption of eDNA

EXTERNAL PERSPECTIVE

National eDNA Strategy	▪ Align with national guidance for use of eDNA in biological monitoring and water management ▪ Provide input about state and federal partnerships
Community Partnerships	▪ Increase engagement and transparency ▪ Make science more accessible for future career consideration ▪ Do more with less internal staffing
Science Partnerships	▪ Advance eDNA science and monitoring capabilities ▪ Align internal and external best practices

INTERNAL VALUE

Best Available Science for Decision-Making	▪ Identify opportunities and uncertainties ▪ Create interpretation guidelines and decision trees ▪ Ensure accuracy and lab accreditation
Regulatory	▪ Compliance with California and U.S. Endangered Species Acts ▪ Agreements to Support Healthy Rivers and Landscapes ▪ Integrated Watershed Management and Flood Management ▪ Monitor ecosystem impacts of water operations
Monitoring Efficiency and Process Improvements	▪ Cost effectiveness ▪ Non-invasive sampling ▪ Highly sensitive ▪ Safe

REFERENCES

Baerwald, M. R., Funk, E. C., Goodbla, A. M., Campbell, M. A., Thompson, T., Meek, M. H., and A. D. Schreier. 2023. Rapid CRISPR-Cas13a genetic identification enables new opportunities for listed Chinook salmon management. Molecular Ecology Resources. https://doi.org/10.1111/1755-0998.13045

Fediajevaite, J., Priestley, V., Arnold, R., and V. Savolainen. 2021. Meta-analysis shows that environmental DNA outperforms traditional surveys, but warrants better reporting standards. Ecology and Evolution 11:4803-4815. https://doi.org/10.1002/ece3.7382

Feist, S. M., and R. F. Lance. 2021a. Advanced molecular-based surveillance of quagga and zebra mussels: a review of environmental DNA/RNA (eDNA/eRNA) studies and considerations for future directions. NeoBiota 66:117-159. https://doi.org/10.3897/neobiota.66.60751

Feist, S. M., and R. F. Lance. 2021b. Genetic detection of freshwater harmful algal blooms: a review focused on the use of environmental DNA (eDNA) in Microcystis aeruginosa and Prymnesium parvum. Harmful algae 110:102124. https://doi.org/10.1016/j.hal.2021.102124

Holmes, A. E., Baerwald, M. R., Rodzen, J., Schreier, B. M., Mahardja, B. and A. J. Finger. 2024. Evaluating environmental DNA detection of a rare fish in turbid water using field and experimental approaches. PeerJ 12:e16453. https://doi.org/10.7717/peerj.16453

Kelly, R. P., Lodge, D. M., Lee, K. N., Theroux, S., Sepulveda, A. J., Scholin, C. A., Craine, J. M., Allan, E. A., Nichols, K. M., Parsons, K. M., Goodwin, K. D., Gold, Z., Chavez, F. P., Noble, R. T., Abbott, C. L., Baerwald, M. R., Naaum, A. M., Thielen, P. M., Simons, A. L., Jerde, C. L., Duda, J. J., Hunter, M. E., Hagan, J. A., Meyer, R. S., Steele, J. A., Stoeckle, M. Y., Bik, H. M., Meyer, C. P., Stein, E., James, K. E., Thomas, A. C., Demir-Hilton, E., Timmers, M. A., Griffith, J. F., Weise, M. J., and S. B. Weisberg. 2023. Toward a national eDNA strategy for the United States. Environmental DNA. https://doi.org/10.1002/edn3.432

Liu, Q., Zhang, Y., Wu, H., Liu, F., Peng, W., Zhang, Z., Chang, F., Xie, P., and H. Zhang. 2020. A review and perspective of eDNA application to eutrophication and HAB control in freshwater and marine ecosystems. Microorganisms 8:417. https://doi.org/10.3390/microorganisms8030417

Mangan, A. M., Kronenberger, J. A., Plummer, I. H., Wilcox, T. M., and A. J. Piaggio. 2023. Validation of a nutria (Myocastor coypus) environmental DNA assay highlights considerations for sampling methodology. Environmental DNA. https://doi.org/10.1002/edn3.412

Meyer, R. S., Ramos, M. M., Lin, M., Schweizer, T. M., Gold, Z., Ramos, D. R., Shirazi, S., Kandlikar, G., Kwan, W., Curd, E. E., Freise, A., Parker, J. M., Sexton, J. P., Wetzer, R., Pentcheff, N. D., Wall, A. R., Pipes, L., Garcia-Vedrenne, A., Mejia, M. P., Moore, T., Orland, C., Ballare, K. M., Worth, A., Beraut, E., Aronson, E. L., Nielsen, R., Lewin, H. A., Barber, P. H., Wall, J., Kraft, N., Shapiro, B. and R. K. Wayne. 2021. The CALeDNA program: Citizen scientists and researchers inventory California's biodiversity. California Agriculture. https://doi.org/10.3733/ca.2021a0001

Nagarajan, R. P., Sanders, L., Kolm, N., Perez, A., Senegal, T., Mahardja, B., Baerwald, M. R., and A. M. Schreier. 2023. CRISPR-based environmental DNA detection for a rare endangered estuarine species. Environmental DNA. https://doi.org/10.1002/edn3.506

Sanches, T. M., and A. M. Schreier. 2020. Optimizing an eDNA protocol for estuarine environments: balancing sensitivity, cost, and time. PLoS One 15:1-18. https://doi.org/10.1371/journal.pone.0233522

Stein, E. D., Jerde, C. L., Allan, E. A., Sepulveda, A. J., Abbott, C. L., Baerwald, M. R., Darling, J., Goodwin, K. D., Meyer, R. S., Timmers, M., and P. M. Thielen. 2023. Critical considerations for communicating environmental DNA science. Environmental DNA. https://doi.org/10.1002/edn3.472

APPENDIX A

On-going DWR eDNA projects. Acronyms: Southern California Coastal Water Research Project (SCCWRP), Incidental Take Permit (ITP), U.S. Geological Survey (USGS), Monterey Bay Aquarium Research Institute (MBARI), California Department of Fish and Wildlife (CDFW), Longfin Smelt Technical Team (LFSTT), Specific High-sensitivity Enzymatic Reporter unlocking (SHERLOCK)

Title	Objectives	Management goal	Collaborators
Align with national framework for eDNA guidelines	Put forth recommendations for national guidelines for the incorporation of eDNA into natural resource management decision making	Align DWR best practices for eDNA with the national guidelines	Biden administration, SCCWRP
Larval smelt entrainment in Clifton Court Forebay	(1) Evaluate shedding rate of larval Delta Smelt of varying biomasses in the laboratory (2) Evaluate detection probability of larval Delta Smelt of varying biomasses and distances from a live car source in the field (3) Test four eDNA sample collection methods, including an autonomous eDNA sampler	ITP 7.6.2: Larval Smelt Entrainment Monitoring; ITP 7.6.3: Longfin Smelt Science Program	Cramer Fish Sciences, USGS, MBARI
Larval smelt entrainment near water export facilities	Combine eDNA methods with net sampling for comprehensive larval smelt entrainment monitoring in Clifton Court Forebay	ITP 7.6.2: Larval Smelt Entrainment Monitoring; ITP 7.6.3: Longfin Smelt Science Program	CDFW, LFSTT
Invasive species detection	Develop rapid eDNA and eRNA detection assays (SHERLOCK technology) for nutria and dreissenid mussels	Restoration research, predict and mitigate invasive species damage to DWR infrastructure and the San Francisco Estuary	UC Davis
Smelt detection for targeted sorting of aquatic weeds	Use eDNA samples to prioritize sorting of aquatic weeds and estimate take of listed fishes at Barker's Slough Pumping Plant	ITP 1.1.4.3 and 7.7: Barker's Slough Pumping Plant Aquatic Weed Removal	
Phytoplankton community and cyanobacteria analysis and methods comparison	Assess phytoplankton community at EMP sampling stations at and below (1 m depth) the surface. Compare genetic data with community and toxin data collected by contractors	Improve accuracy of phyto-plankton monitoring mandated by Water Rights Decisions D-1641 and D-1485	