Environmental DNA for estuary monitoring in Aotearoa New Zealand

Summary guidance for councils, practitioners, iwi and hapū

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Estuaries are among Aotearoa New Zealand's most productive and culturally significant ecosystems. However, many are under increasing pressure. Detecting ecological change early, understanding its causes and implementing effective management responses are therefore critical challenges for estuary management.

This summary document presents the key findings and recommendations from the Transforming Coastal Monitoring research programme, which evaluated the potential for environmental DNA (eDNA) metabarcoding to strengthen estuary monitoring in Aotearoa New Zealand. Drawing on more than 1,000 sediment samples collected from 59 sites across 21 estuaries, the programme provides one of the most comprehensive assessments of estuarine eDNA monitoring undertaken internationally.

Conventional estuary monitoring programmes in Aotearoa New Zealand are typically based on sediment quality measurements and macrofaunal community assessments. The research programme examined whether eDNA could complement conventional scientific monitoring and mātauranga Māori approaches to estuary health assessment by improving detection of environmental change and supporting the diagnosis of environmental stressors.

Readers seeking detailed methods, results, supporting evidence and implementation guidance should refer to the full guidance document, *Weaving new tools into estuary monitoring: guidance on integrating environmental DNA* (Clark et al. 2026).

Estuary monitoring at Wairau Lagoons, Marlborough

Key messages

➢ **eDNA is highly sensitive to key estuarine stressors**

eDNA communities responded strongly to key estuarine stressors, particularly sedimentation and metal contamination. Bacterial and microalgal communities generally showed stronger and more consistent responses than eukaryotic communities.

➢ **eDNA has strong future potential for stressor diagnosis**

eDNA communities exhibited both shared and stressor-specific responses to environmental stressors, indicating strong potential for the development of future indicators capable of identifying the causes of ecological change.

➢ **eDNA matched or exceeded macrofaunal sensitivity to key stressors**

Across the stressors examined, eDNA communities showed sensitivity comparable to macrofauna for sedimentation and nutrient enrichment, and greater sensitivity to metal contamination.

➢ **eDNA aligns with mātauranga Māori**

In Tauranga Moana, eDNA indicators aligned closely with whānau assessments of estuary health and distinguished between sites of differing condition, even where conventional sediment quality measurements showed little difference.

➢ **eDNA complements rather than replaces existing monitoring**

eDNA, macrofauna, sediment quality measurements and mātauranga Māori each give different but complementary perspectives on estuary health. Together, they provide a more complete understanding than any single approach alone.

➢ **Standardised eDNA sampling can be implemented now**

Environmental DNA monitoring can be incorporated into existing monitoring programmes immediately. A minimum of five analysed sediment samples per site is recommended, with bacterial (16S) communities prioritised for routine monitoring.

➢ **Building the evidence base is the greatest immediate opportunity**

An Aotearoa New Zealand-specific eDNA indicator and integrated stressor-response framework are being developed. Continued collection of nationally comparable eDNA datasets is now needed to support testing, validation and implementation of these tools across the diverse environmental conditions found in Aotearoa New Zealand estuaries.

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What is eDNA and why is it useful?

Environmental DNA (eDNA) metabarcoding uses genetic material collected from environmental samples to characterise biological communities. Unlike conventional monitoring, it can detect bacteria, microalgae, protists and other small organisms that play important roles in ecosystem functioning.

Different molecular markers can be used to examine different components of estuarine biodiversity. In this research:

- bacterial communities were characterised using the 16S marker
- eukaryotic communities using the 18S marker
- microalgal communities using the rbcL marker.

These communities often respond rapidly to environmental change and can provide sensitive indicators of ecosystem condition. By identifying thousands of taxa with differing environmental preferences, eDNA has the potential to detect both ecological responses and the environmental stressors driving them. Sediment samples are quick and straightforward to collect, and can readily be incorporated into routine monitoring with minimal additional field effort.

Importantly, eDNA should not currently be viewed as a replacement for existing monitoring approaches. While its role may evolve, eDNA is most likely to add value as a complementary component of integrated monitoring programmes rather than as a direct substitute for conventional approaches.

Collecting an estuarine sediment eDNA sample

Transforming Coastal Monitoring programme

This summary is based on research undertaken through the Transforming Coastal Monitoring programme, a 3-year Ministry of Business, Innovation and Employment (MBIE)-funded research programme led by Cawthron Institute.

The programme evaluated whether eDNA metabarcoding can strengthen estuary monitoring in Aotearoa New Zealand by addressing three key questions:

- Can eDNA detect ecological change earlier than conventional indicators?
- Can eDNA help identify the environmental stressors driving estuary degradation?
- How can eDNA be integrated with conventional monitoring and mātauranga Māori to support more holistic assessments of estuary health?

The research combined:

- A national-scale estuary experiment
- Regional council monitoring datasets
- A co-developed case study with iwi and hapū partners.

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Environmental DNA for estuary monitoring in Aotearoa New Zealand

What did we find?

The research demonstrated that eDNA communities respond strongly to environmental stressors commonly affecting Aotearoa New Zealand estuaries. In particular, sedimentation and metal contamination were consistently identified as major drivers of community composition across multiple estuaries and environmental settings.

Bacterial and microalgal communities showed particularly strong and consistent responses, even where environmental gradients were relatively subtle. Although sedimentation and metal contamination often occurred together, many indicator taxa were associated uniquely with either stressor, suggesting that eDNA has considerable potential for future development of indicators capable of distinguishing among environmental stressors.

Responses to nutrient enrichment were more variable. While nutrient effects were detected within most estuaries, they tended to be more context-dependent and often exhibited non-linear response patterns. This suggests that nutrient enrichment generates more complex ecological responses than sedimentation or metal contamination and remains an important area for future research.

How does eDNA compare with macrofauna?

The research showed that eDNA provides sensitivity that is at least comparable to conventional macrofaunal monitoring, and for some stressors may be more sensitive. For sedimentation and nutrient enrichment, eDNA and macrofaunal communities performed similarly well. For metal contamination, bacterial and microalgal eDNA communities showed stronger and more consistent responses than macrofaunal communities. In addition, eDNA datasets contained substantially more taxa and a larger number of stressor-specific indicators than macrofaunal datasets, increasing their potential diagnostic value.

However, eDNA and macrofauna provide fundamentally different types of information. Macrofaunal monitoring remains essential for assessing organism abundance, size, condition, harvestability and many aspects of ecosystem functioning. Macrofauna are also supported by decades of ecological research linking community changes to ecosystem health and management outcomes. Consequently, the strongest current application of eDNA is as a complementary monitoring tool rather than a direct replacement for conventional monitoring.

Abel Tasman National Park, Tasman

Environmental DNA for estuary monitoring in Aotearoa New Zealand

Alignment with mātauranga Māori

A co-developed case study undertaken with Te Whānau a Tauwhao in Tauranga Moana (Clark et al. 2026a) explored how eDNA-derived indicators align with mātauranga Māori assessments of estuary health. The results showed strong agreement between the two approaches, with eDNA successfully distinguishing sites assessed by whānau as being in 'Poor' or 'Moderate' condition, despite conventional sediment quality measurements showing relatively little difference among those sites.

Whānau assessments were informed by long-term observation, lived experience, intergenerational knowledge, and changes in the abundance and condition of culturally important species. The close alignment between eDNA and these assessments suggests that eDNA can detect integrated ecological responses that reflect broader ecosystem change, rather than simply tracking individual environmental variables. Importantly, eDNA does not validate or replace mātauranga Māori. Instead, it provides an additional quantitative line of evidence that may align with, and help investigate, patterns already recognised through local knowledge and environmental observation.

Waiaria Rameka, Garston Smith and Reon Tuanau processing eDNA samples at Cawthron Institute

Recommended monitoring approach

Environmental DNA is currently most valuable when used alongside existing monitoring approaches, including sediment quality measurements, macrofaunal assessments and mātauranga Māori. Together, these approaches provide complementary information about estuary health and a more complete understanding of ecosystem condition than any single indicator alone. As eDNA indicators continue to mature, there may be opportunities to optimise monitoring programmes while retaining the information needed for effective management and decision-making.

Based on current evidence, eDNA monitoring can be incorporated into existing monitoring programmes now. A standardised field and laboratory protocol has been developed through the Transforming Coastal Monitoring programme to support consistent implementation and facilitate the development of nationally comparable datasets (Clark et al. 2026b). A practical minimum design is to collect seven sediment samples and one field blank at each site. Five samples should be analysed, with two retained as reserves. Samples should be distributed across the monitoring site rather than concentrated in a small area, as broad spatial coverage provides a better representation of site-level community composition.

Bacterial community profiling using the 16S marker is currently the recommended minimum analytical approach for estuary health assessment. Where resources permit, the rbcL marker should also be considered as it provides complementary information from microalgal communities and may support future multi-marker indicators. Although eDNA sampling can be undertaken at any time of year, maintaining consistent sampling timing across surveys will improve comparability through time.

Where should councils prioritise eDNA sampling?

At this stage, there is value in strategically targeting eDNA sampling rather than immediately implementing it at every monitoring site. The most useful datasets for future indicator development are likely to come from sites that span broad environmental gradients and represent different combinations of stressors. Priority should therefore be given to sites affected by sedimentation, nutrient enrichment and metal contamination.

Particular value would be gained from sampling locations that help separate commonly co-occurring stressors, such as sites with high mud content but low metal contamination, or vice versa. Additional seasonal sampling and increased replication at selected sites would also help refine future sampling recommendations and indicator development.

Ready now	Supported by current evidence, but may evolve	Requires further development
Standardised sediment eDNA sampling and laboratory protocols	Recommended sampling timing and replication	NZ-specific stressor-response indicators and interpretation frameworks
Use of bacterial (16S) community data as complementary evidence	16S as the preferred marker for routine monitoring	Multi-marker indicators
Integration alongside existing monitoring programmes	microgAMBI as a broad indicator of ecosystem condition (use with caution)	Stronger links to ecosystem functioning and ecosystem services
Building baseline datasets	Relative sensitivity compared with macrofauna	
Engagement with iwi, hapū and whānau	Potential use as an early-warning indicator	

Future priorities and implementation pathway

The research demonstrates that the greatest immediate opportunity for estuarine eDNA monitoring lies in building nationally comparable baseline datasets and integrating eDNA alongside existing monitoring approaches. These datasets will support the development and validation of Aotearoa New Zealand-specific indicators, ecological thresholds and interpretation frameworks. The Transforming Coastal Monitoring programme is developing a next-generation eDNA indicator that aims not only to assess ecosystem condition, but also to identify the environmental stressors contributing to observed degradation.

Not all components of eDNA monitoring are at the same stage of development. Some aspects are sufficiently mature for immediate implementation, while others require further testing and validation before they can be routinely applied with confidence (see table at left). Consequently, the primary focus for councils at present should be on collecting nationally comparable eDNA datasets using standardised methods, rather than the routine application of emerging eDNA-based indicators.

Future work should focus on the following areas:

- Refining and validating robust Aotearoa New Zealand-specific indicators
- Developing ecological thresholds
- Developing interpretation frameworks
- Strengthening links between eDNA community responses, ecosystem functioning and management-relevant outcomes.

In parallel, continued collaboration with iwi and hapū will be essential to ensure that eDNA monitoring supports kaitiakitanga, respects Māori data sovereignty and complements mātauranga Māori approaches to environmental assessment.

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