SALT ECOLOGY

Scoping review to update the National Estuary Monitoring Protocol

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GLOSSARY

AFDW	Ash Free Dry Weight
AMBI	AZTI Marine Biotic Index
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018)
aRPD	Apparent Redox Potential Discontinuity
As	Arsenic
BHM	Benthic Health Model
Cd	Cadmium
Cr	Chromium
CSIG	Coastal Special Interest Group
Cu	Copper
EQR	Ecological Quality Rating
ETI	Estuary Trophic Index
GIS	Geographic Information System
GPS	Global Positioning System
Hg	Mercury
LAWA	Land, Air, Water Aotearoa
LCDB	Land Cover Database
LiDAR	Light Detection and Ranging (remote-sensing method)
LINZ	Land Information New Zealand
MfE	Ministry for the Environment
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
NEMP	National Estuary Monitoring Protocol
Ni	Nickel
NIWA	National Institute of Water and Atmospheric Research
NPF	National Planning Framework
NPSFM	National Policy Statement for Freshwater Management
OMBT	Opportunistic Macroalgal Blooming Tool
ORP	Oxidation-Reduction Potential
OTOT	Oranga Taiao, Oranga Tangāta Research Programme
Pb	Lead
QA	Quality Assurance
RSET	Rod Surface Elevation Tables
SACFOR	Epibiota categories of: Super-abundant, Abundant, Common, Frequent, Occasional, Rare
SOE	State of Environment (monitoring)
SOI	Southern Oscillation Index
TBI	Traits Based Index
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TS	Total Sulfur
Zn	Zinc

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Northland Regional Council	NRC	Richie Griffiths
Auckland Council*	AC	Janine Kamke, Tarn Drylie, Megan Carbines
Waikato Regional Council	WRC	Stephen Hunt, Mike Townsend, Eleanor Gee, Chris Eager, Kit Squires
Bay of Plenty Regional Council	BOPRC	Josie Crawshaw, Stephen Park
Taranaki Regional Council	TRC	Thomas McElroy, Jesu Valdes
Horizons Regional Council	HRC	Elizabeth Daly, Maree Patterson
Gisborne District Council*	GDC	Isabella Clere, Paul Murphy
Hawkes Bay Regional Council	HBRC	Becky Shanahan, Anna Madarasz-Smith
Greater Wellington Regional Council	GWRC	Megan Oliver, Megan Melidonis
Marlborough District Council*	MDC	Oliver Wade
Nelson City Council*	NCC	Harry Allard, Paul Fisher
Tasman District Council*	TDC	Trevor James
West Coast Regional Council	WCRC	Jonny Horrox
Environment Canterbury Regional Council	ECan	Melanie Burns
Otago Regional Council	ORC	Sam Thomas
Southland Regional Council	ES	Nuwan DeSilva, Ash Rabel

*Unitary authority

National Institute of Water and Atmospheric Research	NIWA	Drew Lohrer, Andrew Swales
Cawthron		Anna Berthelsen, Dana Clark

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SUMMARY

In 2002, a National Estuary Monitoring Protocol (NEMP) was developed proposing standard methods that regional councils and unitary authorities could use to assess the state of their estuaries, and to enable temporal changes to be consistently evaluated. Although originally intended as a 'living-document' that would be regularly updated, the NEMP has not been formally evaluated or revised since its 2002 release. Consequently, ad hoc extensions and improvements have been made to the methods over time, and uptake and application has varied between councils and science providers. In light of the pending need to define monitoring methods to support estuarine attributes proposed for environmental limits and targets in the National Planning Framework (NPF), the Ministry for the Environment (MfE) considered it timely to review whether the NEMP remains fit-for-purpose, whether specific method updates are required, and/or whether improvements are needed to fill gaps or meet changed needs.

To this end, MfE contracted Salt Ecology to engage with regional council and unitary authority scientists to collect high level information on the current application of the NEMP, to document gaps, extensions and improvements made to methods, and make recommendations on whether the NEMP required updating or replacing. Engagement was undertaken via an on-line questionnaire and follow-up interview. Two national research providers familiar with the NEMP (NIWA and Cawthron), were also interviewed. Recommendations were compiled from end-user and national research provider responses, literature review and our own expertise in the application of the NEMP.

KEY FINDINGS

- Fourteen of the 16 regional or unitary councils in New Zealand have NEMP-based or equivalent estuary SOE monitoring programmes.
- In terms of the 'broad-scale' monitoring protocol, one council uses the traditional (unmodified) NEMP methods, nine use variations of the broad-scale NEMP, and four use different methods. The most common variations address identified gaps (e.g., assessment of macroalgae or seagrass), method improvements (e.g., improved substrate classification), or extensions (e.g., terrestrial margin mapping).
- In terms of the 'fine-scale' monitoring protocol, 12 councils use variations of NEMP methods and two use different methods. Most variations relate to differences in data collection (scope and frequency), analysis (methods and indicators), and site selection. Councils highlighted that the current NEMP fine-scale approach is expensive and, in many cases, not fit-for-purpose.

There was general agreement that a revision of the NEMP would be useful and that, in particular, there needed to be agreed methods to support estuarine attributes proposed for environmental limits and targets in the NPF.

RECOMMENDATIONS

Based on the work undertaken, we recommend that the NEMP be revised and that it include the following:

1. A NEMP methods report that incorporates the broad-scale and fine-scale updates recommended in this report. A NEMP update should include methods for other estuary types and consider approaches that improve the linkages between broad- and fine-scale monitoring.
2. Specific methods for the proposed NPF attributes.
3. Guidance documents to accompany a revised NEMP, including:
    - Broad-scale and fine-scale indicator thresholds to contextualise estuary health (incorporating a revision of the Estuary Trophic Index (ETI) criteria and assessment of infauna indices).
    - Options and methods for event-based monitoring.
    - Case studies and/or methods for targeted investigations, including lessons learned, pros and cons.

It is emphasised that the revision should aim to develop approaches that allow councils flexibility to choose methods or monitoring frequency (e.g., tiered or nested monitoring approaches), where appropriate, to accommodate variable budgets. Guidance should include decision trees to support monitoring design and management.

Additional recommendations from the questionnaire responses and council interviews were that:

- MfE review the current funding model for SOE monitoring (see Section 6.3) as increasing obligations imposed by central government have resulted in added costs and significant strain on council resources.
- The NEMP revision should be led by a technical expert with a good understanding of council processes, capabilities and needs, supported by an expert technical advisory group including council scientists.
- MfE should consider engaging an independent reviewer to ensure updates are impartial, fit-for-purpose and reflect best practice.

1. SCOPE

In 2002 a National Estuary Monitoring Protocol (NEMP) was developed, proposing standard methods for regional councils and unitary authorities to assess the state or condition of estuaries, and to enable temporal changes in condition to be consistently evaluated (Robertson et al. 2002). Although originally intended as a 'living-document' that would be regularly updated, the NEMP has not been formally evaluated or revised since its 2002 release. Consequently, while it has been used extensively by many regional councils and unitary authorities to monitor their estuaries, ad hoc extensions and improvements have been made to the methods over time, resulting in variable uptake and application between councils and science providers.

As part of National Planning Framework (NPF) and current resource management reforms, various estuary attributes and environmental limits and targets have been proposed (Table 1). This situation creates a need for fit-for-purpose monitoring methods that can be consistently applied by different organisations. Consequently, the Ministry for the Environment (MfE) considered it timely to review whether the NEMP remains fit-for-purpose in an NPF context, whether specific method updates are required, and/or whether improvements are needed to fill gaps or to meet the needs that have emerged since the original protocols were developed.

Table 1. Estuarine attributes proposed for environmental limits and targets in the NPF.

Attribute	Unit
Estuaries (intertidal areas only)	
Nuisance Macroalgae	OMBT-EQR
Sediment Mud Content	% (dry wt)
Sediment Accretion Rate	mm/yr
Estuaries and coastal waters	
Seagrass Extent	ha
Saltmarsh Extent	ha

To this end, MfE contracted Salt Ecology to engage with regional councils and unitary authorities, as well as key science providers, to collect high level information on the current use of the NEMP; document gaps, extensions and improvements made to methods over the last two decades; and recommend whether the NPF and wider council monitoring needs can be met by updating the NEMP, or whether consideration should be given to developing a new standard protocol(s).

The specific key deliverables for the current scoping project were to:

- Define the estuary SOE monitoring methods/ protocols being most frequently used in NZ.
- Outline any significant differences between the NEMP and other methods/protocols.
- Summarise any key method improvements, indicators or new protocols developed subsequent to the NEMP.
- Highlight key gaps in the current NEMP.
- Review the potential to include proposed estuary NPF attribute methods in any NEMP update.
- Outline any reasons for the NEMP not being used, and determine council willingness (in principle) to adopt and consistently apply a national approach.
- Recommend whether MfE updates the existing NEMP or considers developing a new standard protocol(s).

2. BACKGROUND

Estuary monitoring is undertaken by most councils in New Zealand as part of their State of the Environment (SOE) programmes. The most widely-used monitoring framework is that outlined in the NEMP (Table 2; Robertson et al. 2002). The NEMP was intended to provide resource managers nationally with a scientifically defensible, cost-effective and standardised approach for monitoring the ecological status of estuaries in their region. The results establish a benchmark of estuarine health in order to better understand human influences, and against which future comparisons can be made. The NEMP was developed during 2000-2002 with 11 participating regional and local authorities, and involved trialling monitoring techniques in nine estuaries spread across New Zealand. The final approach that was developed (Table 2; Fig. 1) involves three key components:

i. A decision matrix to select priority estuaries for monitoring.

ii. Methods describing broad-scale mapping of intertidal estuarine habitats.

iii. Methods describing fine-scale monitoring of estuary biota and sediment quality.

Since its publication in 2002, the NEMP (or equivalent versions), have been adopted by the majority of regional councils in New Zealand (e.g., Robertson & Stevens 2007a; Stevens & Robertson 2008; Townsend et al. 2010; Park 2011; Griffiths 2012; Stevens & Robertson 2013; Berthelsen et al. 2015; Robertson et al. 2017; Stevens 2017; SLR. 2018; Forrest & Stevens 2019b; Stevens & Forrest 2019; Forrest et al. 2020; Stevens & Forrest 2020; Jones 2021; Berthelsen et al. 2022; Bolton-Ritchie et al. In prep).

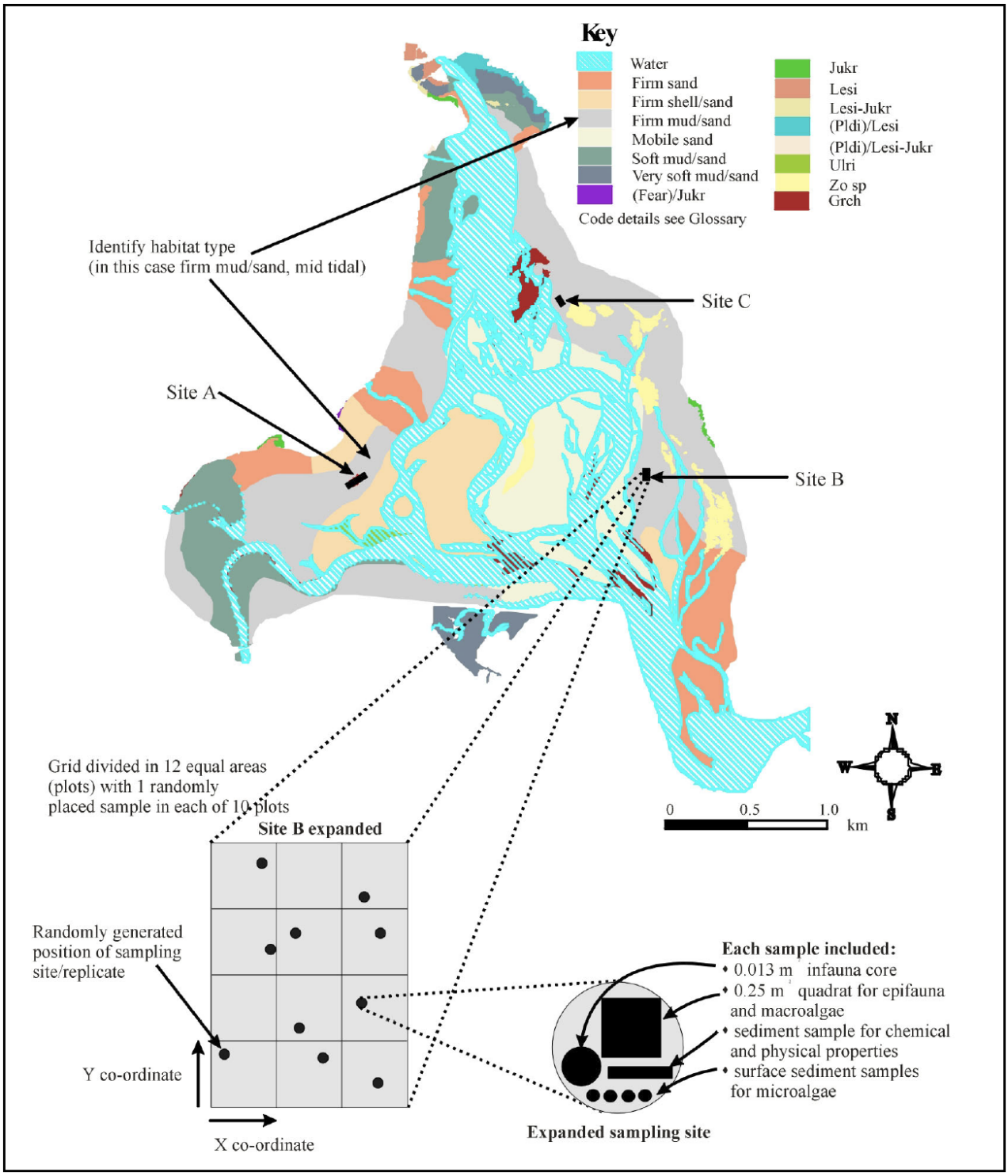

Fig. 1. Schematic of the NEMP methods applied to an estuary, with the fine-scale sampling site expanded for clarity. Diagram from Robertson et al. (2002).

As noted above, the NEMP was intended to be a 'living document' that would be updated periodically as more estuaries were monitored, methodologies were refined/improved and/or new technologies became available. However, due to a lack of ongoing funding there have been no updates to the NEMP since its original release in 2002. Consequently, ad hoc changes in the NEMP methods by different councils and providers (i.e., method improvements/exclusions, lab analyses, application to different estuary types, adoption of new technologies and/or indices) have led to deviations in NEMP usage. Further, many councils have also used the NEMP to address specific management priorities (e.g., targeting vulnerable or degraded areas), that were outside of its original purpose.

More recently, other estuary monitoring tools that overlap with the NEMP have been developed (e.g., Estuary Trophic Index, ETI; Robertson et al. 2016b, a), or specific additional methods have been proposed (e.g., draft CSIG seagrass monitoring protocol - Shanahan et al. (2023). Among other things, the combined effect of the various method deviations and changes has had a number of flow-on effects, one of which has been difficulties in collating national estuary datasets, particularly with regard to fine-scale data (e.g., Berthelsen et al. 2017; Bolton-Ritchie & Lawton 2017; Zaiko et al. 2018; Forrest & Stevens 2019a). For example, analytical methods that are not directly comparable (e.g., total organic carbon and ash-free dry weight for organic content) can limit data analysis and lead to the exclusion or separation of data when compiling national datasets (Berthelsen et al. 2017).

Broad-scale mapping (top) and fine-scale sampling (bottom).

Table 2. Overview of the NEMP approach (Robertson et al. 2002).

Decision matrix Initial assessment ranking tool (decision matrix) developed to support councils to prioritise estuaries for broad-scale and/or fine-scale monitoring across their region. The decision matrix provides a rapid, broad overview of the condition/status of an estuary based on four main categories; i) existing physical and biological characteristics, ii) natural character and values, iii) characteristics that indicate a potential for an adverse impact, and iv) characteristics that indicate and existing impact. The decision matrix was intended as a tool to provide guidance rather than a 'magic' number that would represent estuary health.
Broad-scale habitat mapping Broad-scale mapping characterises dominant habitat based on surface substrate (e.g., mud, sand, gravel, cobble) or vegetation type (e.g., seagrass, salt marsh, mangrove). The approach involves experienced scientists' ground-truthing the estuary identifying dominant habitat types and their boundaries, and recording that information onto laminated aerial photographs. Hand-drawn maps are then digitised in Geographic Information System (GIS), and habitat maps and areal summaries of habitat types are produced. After a ground-truthed baseline habitat map has been produced, changes in the extent and distribution of habitat types can be compared in future surveys (repeated 5 yearly unless a shorter-term question needs to be addressed e.g., invasion of exotic species).
Fine-scale monitoring Following broad-scale mapping, discrete sites (e.g., 60m x 30m) within intertidal soft sediment habitat (usually the most dominant habitat type in the mid-low tidal range) are selected for more forensic fine-scale monitoring of benthic indicators that are known indicators of estuary condition. These are infauna (sediment-dwelling animals), epifauna (surface-dwelling animals), microalgae and macroalgae, sediment grain size (% mud, sand, gravel), nutrients (TN and TP), organic matter (Ash free dry weight; AFDW), and common trace metals (Cu, Cr, Cd, Ni, Pb, Zn). Sampling is carried out annually for the first 3-5 years to establish a baseline and then the data is used to optimise the design and sample less frequently (e.g., every 2-5 years).

3. APPROACH

3.1 OVERVIEW

To meet the project goals, the initial phase involved engagement with scientists from all regional councils and unitary authorities in New Zealand, as well as key scientists from the National Institute of Water and Atmospheric Research (NIWA) and Cawthron Institute (Table 3). Each council participant was asked to complete an on-line questionnaire which was followed up by a 1-hour interview. Engagement with NIWA and Cawthron was by interview only. The participant list, mode of engagement (i.e., questionnaire and interview), and specific questionnaire questions were approved by MfE before commencement. Based on the council and research provider responses, and supported by literature review information and our own expertise in the application of the NEMP, a suite of summary points and recommendations were compiled.

3.2 QUESTIONNAIRE

An online questionnaire, built in Survey Monkey, was sent to councils at the end of April 2023 with a covering email explaining the context of the project (Appendix 1). Questions focused on the type and scope of estuary monitoring undertaken by councils, and sought detail on the monitoring methods and parameters used, and any gaps in, or deviations from, the NEMP. Participants were also asked to indicate reasons for any deviations from the NEMP or why it was not being used. Additional questions were asked on current reporting and monitoring priorities, and participants were given the opportunity to suggest general improvements to NEMP-based monitoring. There was a 100% response rate to the survey, with questionnaire responses compiled and summarised in Section 4. While some of the data collected has been captured previously (e.g., Berthelsen et al. 2017; Bolton-Ritchie & Lawton 2017), this report represents the most up-to-date iteration, tailored to the scope of the current project. All raw data from the questionnaire has been provided to MfE electronically.

3.3 INTERVIEWS

Following the completion of the questionnaire by councils, council scientists and the two research providers were interviewed. The interviews were split into three main parts: (i) specific detail relating to the questionnaire responses (councils only), (ii) additional questions that were not captured in the questionnaire, and (iii) an open forum for discussion. Responses from the interviews were compiled and are summarised in this document.

Table 3. Regional council, unitary authority and research agency participants.

Organisation	Questionnaire completed	Interview	
		Date	Scientists
Council			
Northland	✓	22-May-2023	Richie Griffiths
Auckland	✓	24-May-2023	Janine Kamke, Tarn Drylie, Megan Carbines
Waikato	✓	22-May-2023	Stephen Hunt, Mike Townsend, Eleanor Gee, Chris Eager, Kit Squires
Bay of Plenty	✓	23-May-2023	Josie Crawshaw, Stephen Park
Taranaki	✓	19-May-2023	Thomas McElroy, Jesu Valdes
Horizons	✓	18-May-2023	Elizabeth Daly, Maree Patterson
Gisborne	✓	24-May-2023	Isabella Clere, Paul Murphy
Hawkes Bay	✓	23-May-2023	Becky Shanahan, Anna Madarasz-Smith
Wellington	✓	16-May-2023	Megan Oliver, Megan Melidonis
Marlborough	✓	19-May-2023	Oliver Wade
Nelson	✓	17-May-2023	Harry Allard, Paul Fisher
Tasman	✓	21-Apr-2023	Trevor James
West Coast	✓	09-May-2023	Jonny Horrox
Canterbury	✓	18-May-2023	Melanie Burns
Otago	✓	08-May-2023	Sam Thomas
Southland	✓	09-May-2023	Nuwan DeSilva, Ash Rabel
Research organisation			
NIWA	na	25-May-2023	Drew Lohrer, Andrew Swales (Judi Hewitt sent apologies)
Cawthron	na	26-May-2023	Anna Berthelsen, Dana Clark

4. KEY FINDINGS

4.1 WHAT DO COUNCILS DO?

Fourteen of the 16 regional councils or unitary authorities in New Zealand undertake estuary SOE monitoring, and have NEMP-based or equivalent programmes (Table 4). The exceptions are West Coast Regional Council and Gisborne District Council. Of the 14 councils that monitor estuaries, the NEMP application is as follows:

Broad-scale:

- 1 uses the broad-scale NEMP unmodified,
- 9 use variations of the broad-scale NEMP, and
- 4 use different methods to the broad-scale NEMP.

Fine-scale:

- 12 use variations of the fine-scale NEMP, and
- 2 use different methods to the fine-scale NEMP.

Table 4. Current SOE monitoring programmes and methods that councils implement.

	SoE	Original NEMP		Variation to NEMP		Other
		FS	BS	FS	BS	
Northland	✓			✓		✓[1]
Auckland	✓					✓[2]
Waikato	✓					✓[2]
Bay of Plenty	✓			✓		✓[3]
Taranaki	✓			✓	✓	
Horizons	✓			✓	✓	
Gisborne	×	-	-	-	-	-
Hawkes Bay	✓			✓	✓	
Wellington	✓			✓	✓	
Marlborough	✓			✓	✓	
Nelson	✓			✓	✓	
Tasman	✓			✓	✓	
West Coast	×	-	-	-	-	-
Canterbury	✓		✓	✓		
Otago	✓			✓	✓	
Southland	✓			✓	✓	

[1] Broad-scale remote sensing.
[2] Custom long-term broad- and fine-scale monitoring.
[3] Broad-scale remote sensing (seagrass & mangroves only).

The most common variations to NEMP broad-scale methods include improvements to address identified gaps (e.g., assessment of macroalgae or seagrass percent cover), method improvements (e.g., improved substrate classification), or extensions (e.g., terrestrial margin mapping).

The most common variations to NEMP fine-scale methods include a reduction in sampling effort due to budget constraints (e.g., composite rather than replicated sediment chemistry samples) and/or use of new methods (e.g., AFDW replaced with TOC) or inclusion of additional sediment quality analytes (e.g., As, Hg, TS) within the standard NEMP indicator suite.

The three councils who deviate most from the NEMP are Auckland, Waikato and Bay of Plenty. These councils all have long-term marine monitoring programmes that were established prior to the NEMP, which were developed, refined and implemented in collaboration with research scientists. While different to the NEMP, the principles are the same and methods used are also similar.

The most widely adopted new methodology since the development of the NEMP (used by 12 of the 14 councils) is the use of 'sediment plates' to measure sediment deposition at a site scale (Hunt 2019; Forrest et al. 2022). It is noted, however, that specific measurement methods differ between councils.

Other bespoke methods have been applied to different estuary types, targeted investigations and/or subtidal areas. These are discussed in more detail later and include:

- Water quality monitoring in river-dominated estuaries and harbours (e.g., Whareama, Ōhau, Tauranga Harbour, Mahurangi Harbour).
- Subtidal macrofauna and sediment quality monitoring (e.g., Te Awarua-o-Porirua).
- Subtidal habitat mapping (e.g., Whangateau Harbour, Queen Charlotte Sound, Te Awarua-o-Porirua).
- Synoptic macrofauna sampling at low replication and high spatial coverage to characterise habitat types (e.g., Waipati Estuary, Whangarei Harbour).
- Remote-sensing to monitor extent of habitat types (e.g., Ruakaka Estuary, Tauranga Harbour).
- Detailed seagrass condition surveys (e.g., leaf size, biomass, colouration; Whangarae Estuary).
- Sediment cores and LiDAR or hydrodynamic surveys to investigate sedimentation rates (e.g., Te Awarua-o-Porirua), and sediment source tracking (e.g., Waimea, Pleasant River).

Further detail on NEMP variations is provided below.

4.2 BROAD-SCALE NEMP VARIATIONS

4.2.1 Broad-scale habitat mapping methods and indicators

There was general agreement that broad-scale habitat mapping is very useful for characterising the baseline condition of an estuary and for management purposes. However, the broad-scale methodology is the NEMP component where the largest deviations from the original protocol are evident. These deviations have arisen primarily as a consequence of method improvements or gaps being addressed in an ad hoc manner outside of the NEMP framework at a regional level. They include technology and method improvements summarised in Tables 5 and 6, respectively, or the addition of new methods or indicators as summarised in Table 7.

In the technology space, for example, there have been significant improvements to aid broad-scale habitat mapping, including increased availability of relatively low-cost high-resolution imagery (i.e., aerial, satellite, drone) and advancements in computing (i.e., improvements in digitising hardware, QA tools for ArcMap, remote-sensing).

Table 5. Summary of NEMP broad-scale methodology and improvements and/or variations that have been implemented since 2002.

NEMP	Current NEMP	NEMP improvements and/or variations implemented
Estuary selection	Decision matrix	Refined decision matrix approaches have been developed and applied (e.g., Robertson & Stevens 2007c, b, 2008; Stevens & Robertson 2017; Stevens 2018; Roberts et al. 2022; Roberts et al. 2023) As the decision matrix is reliant on desktop information or knowledge of an estuary, a field-based rapid assessment approach that captures high level information on estuary condition and susceptibility has been trialled (e.g., Roberts et al. 2022; Roberts et al. 2023).
Imagery	Rectified aerial imagery to a minimum resolution of 0.5m/pixel. Mapped at >1:5000.	Imagery sources have become more accessible including aerial (0.5 to 0.075m/pixel), drone (varied resolution) and satellite imagery (<0.3m/pixel). Mapped to a minimum of 1:5000, most commonly 1:3000.
Time of monitoring	September to May when most plants are visible and have not died back.	In general, macroalgae is monitored over the summer period (i.e. December to March).
Frequency	5-yearly, short-term management questions may require more frequent monitoring (e.g., yearly)	Monitoring frequency is variable, dependent on susceptibility and likelihood of change in the short term. Some councils apply a nested approach to monitoring; i.e., monitor seagrass and macroalgae annually to track changes, where there are problems, with full broad-scale monitoring undertaken every 5 to 10 years depending on susceptibility to change.
Extent of survey	MHWS to MLWS	Several different approaches are used to define estuary extent. This element needs to be standardised.
Digitising	Digitise hand drawn features into GIS using a mouse.	High resolution drawing tablets are now available that display imagery in GIS and significantly reduce boundary errors when digitising. GPS-linked photos, GPS tracks and discrete data points from electronic data capture software (e.g., Survey 123, Fulcrum) are useful for defining boundaries of features not clearly visible on the imagery (e.g., changes in substrate).
QA and data analyses	Not included	Custom tools developed in python for ArcMap that automatically check shapefiles for overlapping polygons, gaps, slivers and coding errors at the end of the digitising process. Map symbology and summary tables are also automated using the same principles. QA tools have been applied to historic shapefiles to rectify errors.
Data storage	Shapefiles	Different councils used different data storage methods.

Early in the initial implementation of the NEMP, providers and councils identified a number of limitations. In particular, the field-based mapping approach was found to lack method detail in key areas (e.g., seagrass and macroalgae cover), included subjective assessments (i.e., depth of sinking into substrate as a proxy for mud content), and was missing important habitat components (i.e., substrate beneath salt marsh, seagrass and macroalgae). These types of limitations impacted the efficacy and repeatability of spatial assessments, and the ability to determine key drivers of change directly relevant for management purposes.

As a result, broad-scale mapping techniques have developed over time and in general there are now three main approaches adopted by councils today (listed in order of uptake from highest to lowest):

- A variation of the NEMP that applies: i) updated classifications for substrate (based on geological terminology and mud content), ii) mapping of substrate beneath vegetation, iii) new methods for assessing nuisance macroalgae cover, biomass and entrainment (i.e., OMBT), iv) seagrass (percent cover), and v) 200m terrestrial margin land cover (Table 7).

Table 6. Summary of the features mapped in the NEMP broad-scale method, and improvements and/or variations that have been implemented since 2002.

NEMP	Current NEMP	NEMP improvements and/or variations implemented
Substrate	Basic descriptors that rely on sinking to differentiate different levels of mud/sand. Substrate not recorded beneath vegetation.	Substrate is recorded as a continuous layer across the intertidal area. Revised and more comprehensive substrate classification system based on standard geological terms and mud content, independent of 'sinking'. Methodology is validated with collection of sediment grain size samples (e.g., Stevens et al. 2023). The revised framework allows cross comparison with previous NEMP surveys, and mapping of mud-elevated (>25%) and mud-dominated (>50%) substrates. In addition to the use of aggregated NEMP classes, NIWA classify substrate based on ecological features and ecosystem services (e.g., Needham et al. 2013). If considered for inclusion in the NEMP this method requires further development. Habitat classification should be classified independently to substrate as it addresses a different purpose (i.e., changes in mud extent or mud content measure a specific driver of change, whereas ecological features measure an integrated response to multiple drivers).
Salt marsh	Mapped extent with no substrate recorded. Classified by structural class and dominant cover.	Substrate beneath salt marsh recorded to create a continuous estuary substrate layer. Minor updates to the classification system; i.e., removal of terrestrial classes from salt marsh to the terrestrial 200m terrestrial margin; see Table 7 (e.g., Stevens et al. 2023). Remote-sensing methods, either automated or manual, to delineate habitat extent.
Seagrass	Mapped extent when it is the dominant feature (i.e., >50% cover) and no substrate beneath vegetation recorded.	Mapped seagrass patches are designated a percent cover (1-100%; e.g., FGDC 2012). Substrate beneath seagrass recorded to create a continuous estuary substrate layer. Remote-sensing methods, either automated or manual, to delineate extent of generally high cover (i.e., >50%) seagrass beds. Shanahan et al. (2023) "Guidance on CSIG seagrass monitoring" outlines other techniques used by councils to monitor seagrass.
Macroalgae	Mapped extent when it is the dominant feature (i.e., >50% cover) and no substrate beneath vegetation recorded.	Opportunistic Macroalgal Blooming Tool (OMBT; WFD-UKTAG 2014) recommended in the ETI (Robertson et al. 2016a). Adapted to New Zealand estuaries by applying the improvements described in Plew et al. (2020) and Stevens et al. (2022). OMBT records macroalgae extent, percent cover, biomass and level of entrainment. Substrate recorded beneath macroalgae to create a continuous estuary substrate layer. Remote-sensing methods, either automated or manual, to delineate extent of generally high cover (i.e., >50%) macroalgal beds.
Mangrove	Mapped extent with no substrate recorded. Classified as scrub within the salt marsh classification	Waikato (NIWA) map mangroves as two sub-categories (i.e., adult plants and pneumatophores; Needham et al. 2013). Auckland (NIWA) map mangroves based on density (i.e., high, low and scattered; Townsend et al. 2010). Record substrate beneath mangroves to understand mud-extent. Remote-sensing methods (automated or manual) can delineate extent (e.g., Park 2015).

- An approach that applies the general principles of the NEMP but uses an ecosystem services approach which maps ecological features of unvegetated substrates (e.g., crab burrows), vegetation where it is the dominant feature, and separates mangroves into sub-categories.
- Remote-sensing techniques and/or desktop classification of habitat types (i.e., salt marsh, mangroves, seagrass) via manual digitising or automated processes (e.g., vegetation index algorithms).

The NEMP also provides a decision matrix to prioritise estuaries for broad-scale mapping. Several councils have subsequently used more refined decision matrices to prioritise estuaries (e.g., Robertson & Stevens 2007c, b, 2008; Stevens & Robertson 2017; Stevens 2018; Roberts et al. 2022; Roberts et al. 2023).

These updates reflect an improved understanding of pressures and values in New Zealand estuaries following the collection of estuary monitoring data, as well as development of preliminary assessment criteria presented as part of the Estuary Trophic Index (ETI) project (Robertson et al. 2016a). Recent iterations have been used as a multi-purpose tool to prioritise sites for long-term monitoring, highlight areas of management priority, provide a broad overview of estuary condition and susceptibility, and identify commonalities between estuaries within a region or sub-region.

Specific recommendations for the broad-scale methods are presented in Appendix 2 (A2.1).

4.3 FINE-SCALE NEMP VARIATIONS

4.3.1 Fine-scale monitoring methods and indicators

In principle, councils generally follow the NEMP for fine-scale monitoring, although there are many minor deviations (see summary below and Tables 8 and 9). Deviations are driven by method differences (both field and analytical methods), data preparation and analysis and/or budget constraints. As noted in Table 8, Hewitt (2021) recommended a sampling design with a minimum of 6-monthly sampling at fine-scale sentinel sites, with high intensity replication within each site. However, due to budget constraints, most councils can only undertake monitoring every 1-5 years, have reduced the number of infauna cores collected, and collect composite sediment chemistry samples rather than discrete samples due to the low (generally) within site variance.

Other changes relate to different data needs. For example, samples are variably reported as being analysed using whole sample, <2mm, <0.5mm or <0.063mm fractions, and method differences are apparent (e.g., TOC measured directly vs calculated from AFDW, sediment mud content measured by wet sieving vs laser analysis). The number of sediment grain size classes analysed can also be variable, requiring aggregation of data for comparisons.

Sample timing is variable between councils, in a large part due to practical considerations (staff or lab availability), and also to minimise field expenses by concurrently collecting fine-scale and broad-scale data, with timing often being determined to detect seasonal blooms of nuisance macroalgae (e.g., December to March). Alternatively, a small number of councils collect samples in spring to avoid high macrofauna abundances owing to juvenile recruitment. However, most councils collect data at a consistent time of year when undertaking repeat surveys.

Table 7. Additional broadscale methods/ indicators that have been adopted since the release of the NEMP.

Indicator/ Method	Description
Estuary Trophic Index (ETI)	Robertson et al. (2016a) developed the ETI with the intent of creating a multi-metric index to assess eutrophication impacts in estuaries. While the principles and thresholds in the ETI are helpful, further development work is required to make it a functional tool. Like the NEMP, it was intended to be reviewed after its initial application, and without review there remain limitations and/or ambiguities.
High enrichment conditions (HEC)	Areas of HEC (or Gross Eutrophic Zones – GEZ) represent extreme sediment enrichment owing to high eutrophication. Variable terms and definitions have been used to classify extreme sediment enrichment. A HEC definition and spatial mapping methodology is presented in Forrest et al. (2023).
200m terrestrial margin	The 200m terrestrial margin metric captures the level of land use modification on the estuary margin. The margin is mapped based on aerial extent and classified using the LCDB5 classes, dominant species are also recorded as metadata where known (e.g., Stevens et al. 2023).

For infauna, one council (Bay of Plenty) uses a different mesh size (1mm) to the NEMP and all other councils (0.5mm), and one council (Northland) uses a different core diameter (150mm vs 130mm specified in the NEMP). There is also variability or uncertainty about whether epibiota are included or excluded from macroinvertebrate indices.

Table 8. Summary of NEMP fine-scale methodology and improvements and/or variations that have been implemented since 2002.

NEMP	Current NEMP	NEMP improvements and/or variations implemented
Site selection	Use broadscale habitat maps to locate areas of unvegetated mid-low water, mud/sand habitat positioned away from river mouths (>20ppt salinity). Number of sites should be proportional to estuary size.	Synoptic sampling of macrofauna across different habitat types (e.g., composite sediment chemistry and 2-3 macrofauna cores) to better characterise general ecology and identify sites that might be most suited for fine scale monitoring (e.g., Griffiths 2012; Forrest et al. 2023). Many councils have established sites based on regional priorities (i.e., areas vulnerable to degradation, important habitats) because mid-low water intertidal sites, generally located in well-flushed areas away from deposition zones, do not always detect early signs of estuary degradation or responses to land management. Site location often determined by suitable habitat location more than tidal height, e.g., mid-low tide sites are often unsuitable due to location in unstable habitat (e.g., edge of channel, mobile sands).
Time of monitoring	January to March, low tide ~1.5h to low water	Most councils monitor over summer (December to March) to capture worst-case macroalgal conditions and reduce duplicated sampling costs. At this time, macrofauna samples can be prone to high abundances from juvenile recruitment, although these are generally excluded in the data-processing phase. Hewitt (2021) noted sampling in winter was comparative to sampling twice per year because samples were less affected by recruitment variability. Waikato undertake monitoring in October for this reason.
Site size	60 x 30m; subdivided to 12 quadrants	Councils have adapted the size of the site depending on its location, available habitat, and monitoring purpose.
Frequency	Annual monitoring for first 3-5 years. Optimise sampling after baseline to reduce frequency (e.g., to 2-5 years).	Hewitt (2021) recommended a minimum of 6-monthly sampling at fine scale sentinel sites and suggested it is better to drop sites and take a nested approach to monitoring than to reduce frequency and replication, i.e., monitor sentinel sites 6-monthly and monitor second tier sites on rotation, using sentinel sites to put any changes in the community into the context of long-term trends. Outside of Auckland, most councils cannot meet the requirements outlined in Hewitt (2021) and monitor sentinel sites 1 to 5-yearly depending on budget and resourcing. Many councils do not optimise sampling following the baseline survey.
Core profile	60 (d) x 100mm (l) Perspex core split to describe sediment profile	Not consistently implemented by councils. The aRPD is generally assessed by splitting a macrofauna core or collecting a sample with a trowel adjacent to the core.
QA and data analyses	High level QA and data analyses detailed. No macrofauna indices recommended.	Data analysis packages available (e.g., R, Primer/Permanova) and approaches to analyse data are now available. An online Envirolink Taxonomic Tool is being developed to foster consistency in macrofauna taxonomy among providers. Several macrofauna indices are also now available (e.g., TBI, BHM, AMBI), although input data such as AMBI eco-groups are not necessarily nationally standardised (or available) or relevant to New Zealand.
Data storage	Spreadsheets	Different councils used different data storage methods.

While many of the deviations can be accounted for, e.g., standardising infauna to a common unit (e.g., number/m^2), the combined effect of small differences in analysis methods, replicates, frequency and timing of monitoring means that compilation of national datasets is challenging. Recent attempts to compile fine-scale data for national reporting purposes (e.g., Berthelsen et al. 2017; Bolton-Ritchie & Lawton 2017; Zaiko et al. 2018) led to exclusion of data, or required post-processing of data, to meet minimum requirements for analysis.

A fine-scale method review should identify where standardisation can be achieved via data analysis, but highlight the critical parts of the methodology where standardisation in data collection is necessary. Any revision to the NEMP should review what councils have already tested in-house with regard to method development (e.g., Auckland have compared the usefulness of extractable and total metals, while Southland have explored the influence of macroalgae cover on infauna abundances/diversity). Sampling

Table 9. Summary of the benthic indicators collected in NEMP fine-scale monitoring and method improvements and/or variations that have been implemented since 2002.

NEMP	Current NEMP	NEMP improvements and/or variations implemented
Infauna	10 cores across site within each the sub-quadrants, core size 130mm diameter to 150mm depth. Sieved in 0.5mm mesh. Preserved in 95% ethanol.	Most councils collect ≤10 infauna cores. Hewitt (2021) recommends 12 cores per site. A more thorough review of sampling sufficiency is required. Preservative is often 50-70% isopropyl alcohol not 95% ethanol. No agreed level of taxonomy, although the recent Envirolink Taxonomic Tool is expected to improve consistency between providers. Macrofaunal indices and methods of analysis differ among providers.
Epifauna	10 replicate 0.25m^2 quadrats within each site	Other approaches, e.g., SACFOR (MNCR 1990; Blyth-Skyrme et al. 2008) are available that better characterise intertidal epibiota with patchy or clumped distributions.
Sediment quality	10 replicate samples collected adjacent to the infauna core. Top 20mm of sediment scraping from the sediment surface. Particle grainsize (% mud, sand, gravel), nutrients (TN and TP), Ash free dry weight (AFDW) as a measure of total organic content (TOC), common trace metals (Cu, Cr, Cd, Ni, Pb, Zn).	Hunt & Jones (2019) reviewed analysis methods for grain size and recommended wet-sieving over laser diffraction. Direct analysis of Total Organic Carbon (%TOC) is now readily available and is preferable to conversion from %AFDW. Hg and As are commonly added to the metal suite. Some councils have adopted small corers to more accurately collect the surface 20mm. Trowel sampling can lead to variable depths if not careful.
Sediment aRPD	Measured in a separate core profile (60 (d) x 100mm (l) Perspex core)	The aRPD depth is measured in cores or via trowel. The aRPD approach is subjective and may require further development and/or training. To date ORP measured in pore water via portable instruments has proven unreliable.
Macroalgae	Cover assessed in 0.25m^2 quadrats by dividing into 36 equal squares, intersections that overlap vegetation are counted	Other approaches, e.g., SACFOR are available that better characterise patchy or clumped distribution.
Microalgae	Surface 5mm composite for analysis of chl-a and phaeopigment	Not routinely implemented by councils, except for Auckland.
Seagrass	Not included in NEMP. NEMP recommended FS sampling in unvegetated sites.	Quadrat or SACFOR are used by councils to assess seagrass cover. Further method guidance for site scale seagrass assessment is under development by CSIG (Shanahan et al. 2023).

sufficiency has also been assessed for many individual sites or estuaries, although it is emphasised that such assessments are driven by the specific purpose of monitoring. For example, the level of sampling to confidently determine if metal concentrations are below ANZG guideline values is very different to that required for assessing potential trends in metal concentrations when present at trace levels.

In addition to differences in data collection and analysis, councils highlighted that the current NEMP fine-scale approach is expensive, and in many cases, not fit-for-purpose (e.g., monitoring mid-estuary sites provides councils with limited help in understanding vulnerable or degraded areas, or detecting early changes in estuary condition). Except for metals and mud content, the interviews also highlighted that very few councils use fine-scale monitoring data to trigger a management response, and that infauna and epifauna are often only used in a narrative or supporting context. Due to high costs and low perceived benefit some councils are questioning whether macrofauna should be included in the NEMP. As such, it is timely for a critical review of the fine-scale methodology.

Specific recommendations for the fine-scale method are presented in Appendix 2 (A2.2).

4.4 EMERGING TECHNOLOGIES

There are four key methods that are currently under development that should be considered for inclusion in future NEMP iterations.

1. Remote sensing technologies are improving with the availability of imagery (e.g., satellite or drone) and machine learning techniques. Basic remote sensing techniques are already being trialled by some councils (e.g. salt marsh, mangrove and seagrass mapping) while other habitat types remain under development (e.g. macroalgae, water quality, habitat classification). Satellite imagery coupled with automated image analysis methods has the potential to provide a powerful tool for broad-scale mapping of vegetated habitats, improving spatial coverage and monitoring frequency in addition to affordability, particularly at a national scale.
2. Research is currently underway to assess the utility of eDNA as an estuary monitoring tool for bacteria, infauna, epifauna and higher-level organisms (e.g., fish). While promising, the development of a reliable eDNA indicator for estuaries is likely 5-10 years away (pers. comm D. Clark 26-05-2023).
3. Sensors that log continuous data for water, sediment and air (e.g., temperature) quality could provide contextual information for both broad- and fine-scale monitoring. However, their utility in routine SOE monitoring has not been assessed.
4. The availability of LiDAR or point cloud GIS data is becoming increasingly accessible, and can be used to guide site selection, define bathymetry, assess sea level rise predictions, and support the development of tidal exchange models.

4.5 METHODS FOR PROPOSED NPF ATTRUBUTES

Five attributes (Table 1) have been proposed under the NPF for environmental limits and targets. Clause 53 of the Natural and Built Environment Bill states that the NPF must:

(i) require the monitoring and reporting of environmental limits and targets, and

(ii) enable data obtained from that monitoring to be aggregated at a national level.

Implicit in the latter is a requirement for national consistency in methods. However, councils emphasised that their key objective was to achieve regional consistency over time (to track change) rather than seeking to obtain national consistency. This was reflected in a general consensus that NEMP methods should not be too prescriptive and instead allow for flexibility in method selection among councils.

Councils that were aware of the attributes proposed in the NPF process (Table 1) insisted that MfE needs to provide guidance on methods for these attributes and that an update of the NEMP is an appropriate place for this. However, if councils are required to adopt different methods than they currently use to facilitate data aggregation at a national level, councils indicated that such changes would need to be supported by central government (e.g., funding). If flexible methods are to be adopted for the NPF attributes, the impact on data aggregation at a national level must be considered.

A flexible approach could be applied to extent-based indicators such as seagrass or saltmarsh where extent can be measured either by a variation of the NEMP, or through remote-sensing techniques (e.g., Table 6). Suggested methods for each of the Table 1 attributes are presented in the following sections.

4.5.1 Nuisance macroalgae

Apply the OMBT (WFD-UKTAG 2014) as adapted for New Zealand estuaries with improvements described in Plew et al. (2020) and Stevens et al. (2022). Broad-scale mapping methods are described in detail in Stevens et al. (2022). Monitoring frequency should be determined by the susceptibility of an estuary to macroalgal problems (e.g. OMBT-EQR >0.8 represents low risk). It is noted that ongoing method validation and refinement is required, particularly within mangrove dominated systems with low overall cover.

4.5.2 Sediment mud content

All councils that currently monitor estuaries collect sediment grain size samples from the surface 20mm, which is consistent with the proposed attribute method. However, there are some discrepancies between the size fractions that councils analyse (i.e., whole sample, <2mm, <0.5mm) that could affect the calculation of %mud (<63µm). Further, lab analyses also vary (e.g., wet-sieving vs laser diffraction) among councils, with Hunt & Jones (2019) recommending wet-sieving as the preferred method.

4.5.3 Sediment accretion rate

The preferred method of councils to measure sedimentation rate was the sediment plate method, where concrete pavers are buried in a standard configuration (e.g., Roberts & Ward 2018; Hunt 2019; Forrest et al. 2022) and sediment accrual or erosion is measured at least annually. Mean annual sedimentation rates measured using this approach become more reliable as the length of the data record increases, with a minimum of 5-years monitoring data recommended before assessing potential trends. It is recommended that a grain size sample also be collected at the sediment plate site to contextualise the results (i.e., is sediment accrual the natural movement of sands vs deposition of fine sediments), although this component is not essential for reporting on the NPF sediment accretion rate attribute. Some councils use other methods to assess sedimentation rate including sediment cores, LiDAR or hydrographic surveys, or Rod Surface Elevation Tables (RSET) in salt marsh areas. While other methods can be used, we recommend the sediment plate method for the NPF attribute because it is simple, cost-effective, and reproducible.

4.5.4 Seagrass Extent

A flexible approach could be adopted for seagrass extent. Currently seagrass is mapped using two main approaches: (i) a variation of the NEMP where aerial imagery is ground-truthed and all seagrass patches identified during ground-truthing are mapped and designated a percent cover (e.g., Stevens et al. 2023), or (ii) remote-sensing methods, either automated or manual, where extent is mapped and cover estimated (e.g., Park 2016; Shanahan et al. 2023). Potential issues with remote sensing data (e.g., mis-classification of features) need to be accounted for.

Both approaches need to consider the accuracy of mapping seagrass boundaries, particularly in areas of sparse cover (i.e., <30% cover), and at intertidal/subtidal boundaries, to ensure true changes in seagrass extent can be tracked rather than changes due to method limitations or variances. If a flexible approach is adopted for seagrass, methods need to consider how the data will be aggregated at a national level.

4.5.5 Salt marsh extent

A flexible approach could be adopted for salt marsh extent. Currently it is mapped using two approaches: (i) a variation of the NEMP where salt marsh extent is mapped by ground-truthing aerial imagery (e.g., Stevens et al. 2023), or (ii) remote-sensing methods, either automated or manual, where extent is mapped (e.g., Macdonald et al. 2020). Potential issues with remote sensing data (e.g., mis-classification of features) need to be accounted for.

Both approaches need to consider the level of accuracy around extent boundaries to ensure true changes in salt marsh extent can be tracked over time. If a flexible approach is adopted for salt marsh, methods need to consider how the data will be aggregated at a national level.

4.6 ADDITIONAL GAPS IN THE NEMP

In implementing the NEMP, many councils have identified limitations or gaps that should be addressed and/or updated in any revision. The key topics outlined in this section were raised either in the questionnaire responses and/or interviews with councils. Recommendations regarding the inclusion of these topics in a NEMP revision are provided.

4.6.1 Disconnect between broad- and fine-scale monitoring

At present there is a disconnect between broad- and fine-scale monitoring. With fine-scale sites generally situated on well-flushed tidal flats, they can paint a different picture of estuary health when compared to broad-scale monitoring data (e.g., Pleasant River Estuary; Forrest et al. 2021; Roberts et al. 2021). There is also very little fine-scale information on other habitat

types within an estuary that might be more high value (e.g., seagrass beds) or degraded (e.g., macroalgae) and provide context to broad-scale monitoring data.

A NEMP review should consider ways to better connect the two monitoring approaches. For example, broad-scale mapping accompanied by synoptic sampling of sediment chemistry and macrofauna across different habitat types can help in understanding ecological values and condition across a wider range of habitat types, and be used to help select fine-scale monitoring sites and/or provide contextual information to fine-scale and broad-scale monitoring data (e.g., Griffiths 2012; Forrest et al. 2023).

4.6.2 Estuary typology

For New Zealand estuaries, councils use two main classification systems based on the physical characteristics of an estuary:

- A detailed hierarchical classification system based on geomorphic classes of New Zealand's coastal hydrosystems (Hume et al. 2016). If it were to be adopted, the decision classification matrix requires review as it currently allows for classification of multiple typologies based on the same criteria.
- The estuary classification described in ETI Tool 1 (Robertson et al. 2016b). This is a simplified typology based primarily on estuary susceptibility (flushing and dilution). If it were to be adopted in the NEMP, further detail is needed on the classification rules and descriptions of estuary type.

We recommend use of a simplified estuary typology in the NEMP, such as that described in the ETI, noting that it would need to be comprehensively defined if it was to be included.

4.6.3 Application of the NEMP to other estuary types

The NEMP methodologies were originally developed for estuaries defined in the ETI as shallow, intertidally dominated estuaries (SIDEs; see Robertson et al. 2016b). Councils have expressed a critical need for other estuary types to be considered in a NEMP revision.

River dominated estuaries are not currently captured in the NEMP, but their intertidal areas are nonetheless commonly monitored using NEMP methods. Because these estuaries have a large subtidal component, are strongly influenced by freshwater, and are subjected to increased flood disturbance relative to other estuary types, they require both bespoke intertidal and subtidal methods to properly characterise them. Regions with a high number of river-dominated estuaries (e.g., Taranaki, Gisborne, Horizons, Wellington, Otago) consider this to be a priority. As such we recommend methods should be developed specific to these estuary types for inclusion in a NEMP revision, which could draw on methods applied previously in river dominated estuaries (e.g., Roberts et al. 2021c, a, b).

Subtidal monitoring, particularly in deeper systems (e.g., fiords, sounds, harbours, bays), is not currently captured in the NEMP. Some councils have developed bespoke subtidal monitoring programmes to address this gap (e.g., Lawton & Conroy 2019; Anderson et al. 2020; WRC. 2020; Cummings et al. 2022; Ingley & Groom 2022). While subtidal monitoring has not been highlighted as a critical need, because most councils do not have the resources to undertake subtidal work, councils would like some high-level guidance on how to monitor these systems in a way that is linked to the purpose of subtidal monitoring (i.e., in terms of supporting management decisions). We recommend high-level guidance is included in a revised NEMP with case studies that present relevant methods (e.g., water quality monitoring, habitat mapping).

4.6.4 Water quality

Few councils currently monitor estuary water quality. Of those that do, except for human health (e.g., recreational bathing), they emphasised that it is used primarily as a supporting indicator or explanatory variable rather than for setting policy direction. Nevertheless, most councils indicated that despite it not being suited for inclusion in the NEMP and being outside the scope of what most councils can implement, general guidance on the utility, indicators and purpose of water quality monitoring would be very helpful.

4.6.5 Recommended indicators and thresholds

Several councils highlighted the usefulness of non-compulsory indicator banding thresholds to contextualise estuary health. While there was a general consensus that these should accompany the NEMP, most councils indicated that these would ideally sit within a separate guidance document because it would likely require more development and review of data than a revision of the methods. It was also emphasised that thresholds may be different depending on geographic location (e.g., presence and absence of mangroves) and estuary type.

The ETI presents preliminary banding thresholds for some broad- and fine-scale indicators (Robertson et al. 2016a), however these bandings require review. Salt Ecology (e.g., Forrest et al. 2023; Stevens et al. 2023)

also presents preliminary banding thresholds for broad- and fine-scale indicators that are based on the ETI, ANZG (2018), FDGC (2012), Townsend and Lohrer (2015) and Stevens & Robertson (2014). As many of these were developed based on literature it would be an opportune time to analyse the available data to refine the preliminary thresholds for New Zealand estuaries. Levels of uncertainty in threshold bandings should be included.

4.6.6 QA procedures, data analysis and reporting

There is limited information on QA procedures, data analysis and reporting in the original NEMP. Councils (or their providers) manage and process their data differently, which can cause discrepancies between councils even if the methods are the same. To move toward standardisation, guidance on QA procedures and data analysis is essential. This should include important QA steps for both broad- and fine-scale data collection, post-processing of data, and data analysis options including appropriate indices and/or methods.

While councils were supportive of guidance on QA steps and data analysis, they were less supportive of guidance related to reporting because it requires a regional context. However, some smaller councils requested high-level guidance on reporting options for different audiences (e.g., planning, science, councils, public etc).

4.6.7 Climate change

Several councils highlighted the need for more guidance on how to capture climate change impacts in estuary monitoring programmes, and how to differentiate these from manageable anthropogenic impacts (e.g., diffuse or point sources, habitat loss). Councils commonly assess sea level rise risk with respect to coastal hazards or salt marsh retreat, but there is limited information on other climate change drivers. Below are some suggestions on where MfE can support councils in this space:

(1) Provide guidance on methods and indicators that could be used to assess potential climate change impacts. A revised NEMP could also include a risk matrix that would support councils to make decisions about monitoring climate change indicators within their routine SOE monitoring programmes.

(2) Provide guidance on how councils account for natural climate variability in their SOE datasets (e.g., data analysis methods that account for southern oscillation index in infauna trend analysis or temperature drivers (marine heatwaves) of macroalgal or seagrass change).

(3) Facilitate the availability of publicly funded national datasets on climate change drivers, e.g., temperature, wind, rainfall, storm surge, southern oscillation index.

4.6.8 Event-based monitoring

With the number of large flood-events likely to increase, and the pressure of more recent events readily evident (e.g., Cyclone Gabrielle Feb-2023, Nelson floods Aug-2022, Southland floods Feb-2020), councils have highlighted a need for advice on event-based monitoring. The interviews conducted as part of this project highlighted four key needs for event-based monitoring:

(1) Methods and indicators that should be used to characterise the impact of the above types of events. Given the NEMP is primarily focused on SOE monitoring, it is recommended that methods for event-based monitoring sit within a separate guidance document.

(2) Quick access to remote information capture, e.g., satellite imagery and LiDAR. This information, particularly imagery, is needed immediately, and at intervals within the first year of an event, for planning and monitoring (e.g., up-to-date high-resolution imagery is essential for habitat mapping post-event). Given the physical and financial resourcing issues faced by councils during an event response, and because of the national value gained from post-event monitoring, information capture and supply is best suited to a central funded government agency (e.g., LINZ).

(3) The need for budget to undertake event-based monitoring. In general, council monitoring programmes are budgeted through the long-term plan process and do not allow for unplanned monitoring. Several councils suggested that a centralised fund to subsidise event-based monitoring is needed. For example, Nelson City Council has sourced funding through Envirolink to capture event-based data, and Hawke's Bay have collected samples post Cyclone Gabrielle but do not have the budget to analyse them. Given the benefits nationally to understanding the impact of extreme weather events it would be desirable to have budget allocated to this at the central government level, and to ensure the findings are shared with all councils.

(4) The need for on-the-ground resourcing to undertake event-based monitoring. Council staff often have secondary roles within the emergency response team and are not available to undertake

event-based monitoring in a timely manner. Several councils suggested it would be beneficial to have access to a centrally funded preferred provider(s) 'team' that could undertake event-based monitoring. Having this captured at a central government level negates the need for vetting and contracting at a regional level when there are more immediate emergency response pressures, and ensures that data collection during events is standardised and consistent.

Post-flood sediment monitoring in the Nelson Haven Estuary showing significant fine-sediment deposition and smothering of seagrass beds.

4.6.9 Targeted investigations

Several councils highlighted the need for more guidance on targeted investigations. There were mixed opinions on whether this should be included in a revised NEMP or whether it would be better suited to a separate guidance document. Given the NEMP is primarily focused on SOE monitoring, we would recommend a decision tree be included in the NEMP, with any method detail on options for targeted investigations sitting in a separate guidance document. For example, if SOE monitoring showed there was an increasing mud-extent, the decision tree could outline some high-level options for further investigative monitoring and/or discrete projects. Many of the larger councils have undertaken targeted investigations and have a good understanding of the pros and cons of different approaches. It would be particularly useful to capture these different options in one guidance document so that smaller councils can benefit from these learnings. Some examples of targeted investigation needs include:

- Effects of point source discharges (e.g., stormwater)
- Linking catchment loads to outcomes in the estuary.
- Sediment cores and/or LiDAR surveys to investigate sedimentation rates.
- Sediment source tracking to determine relative loadings from different land uses.
- Restoration options (e.g., salt marsh)
- Historic information on seagrass and salt marsh.
- Bird and fish monitoring.
- Seagrass condition surveys.
- Water quality monitoring.
- Ecosystem services assessments.

5. COUNCIL WILLINGNESS TO ADOPT NEMP

The original intent of the NEMP was to develop standardised methods that allowed for the collection of scientifically credible data that was comparable across New Zealand estuaries. While standardisation is useful for national reporting, regional councils and unitary authorities are responsible for managing estuaries within their own regions. As such, many councils have moved away from standardised approaches to address localised management questions (see Tables 5 to 8). Most councils (13 out of 16 councils) agreed that "nationally consistent methods are vital for ensuring estuaries are managed appropriately" while also agreeing (13 out of 16 councils) that "regional differences require site-specific approaches which should be decided locally" (Appendix 1; Table A1.2). These statements are contradictory. However, in the interviews, as we delved into this further, we identified that while in principle councils were supportive of standardisation, there was a shared sentiment that it had to be relevant to their region (i.e., councils would prioritise other methods over the NEMP if they better addressed regionally specific questions).

The questionnaire asked councils whether they would adopt the NEMP if it were updated; 11 agreed, four remained neutral and one disagreed. Councils that agreed largely apply the current NEMP with the described variations (Table 5 to 9), and were involved in the original NEMP development. Councils that responded neutral were those that have bespoke long term monitoring programmes (e.g., Nicholls et al. 2002;

Ford & Anderson 2005; Halliday et al. 2006; Kim 2007) and at the time of the initial NEMP development chose to continue using their own protocols rather than participate in establishing the NEMP. These neutral respondents had reservations about agreeing to adopt a revised NEMP if it did not allow for flexibility to maintain current long-term programmes and did not suit the needs of their region. Auckland Council recorded that they would not adopt a revised NEMP regardless of the types of revisions, because they have committed to a 30+ year monitoring programme that is now being used to inform localised management decisions. However, during the interview, as we delved deeper into their response, they expressed their reluctance to change their fine-scale monitoring programme but said they would consider adopting NEMP broad-scale mapping improvements where relevant to them.

Interviews with council staff revealed a large disparity in both budget and staff resourcing across the country. Councils with smaller ratepayer bases had less in-house capability and less budget for external contractors. For example, Environment Southland manages 3,400km of coastline with an allocation of one full time equivalent scientist, while Waikato Regional Council manages 1,140km of coastline with four full time equivalent scientists. West Coast Regional Council currently have no coastal scientist and manage 600km of coastline.

To account for the disparity between councils we recommend that any revisions to the NEMP adopt a flexible approach to monitoring, similar to the Coastal Special Interest Group (CSIG) guidance on seagrass monitoring where there are tiered monitoring levels, described as gold, silver and bronze (Shanahan et al. 2023). A tiered approach (Figs. 2 & 3) caters for different levels of resourcing between councils with the base level monitoring still able to address minimum council requirements. In situations where both temporal replication and spatial representativeness are required, a nested approach may be appropriate (Drylie 2021; Fig. 4). To enhance the likelihood of councils adopting a revised NEMP, tiered and/or nested monitoring approaches that allow for flexibility should be considered by MfE. Irrespective of the approach it is crucial that the NEMP presents the pros and cons associated with each level of monitoring and articulates how the information collected is directly linked to management.

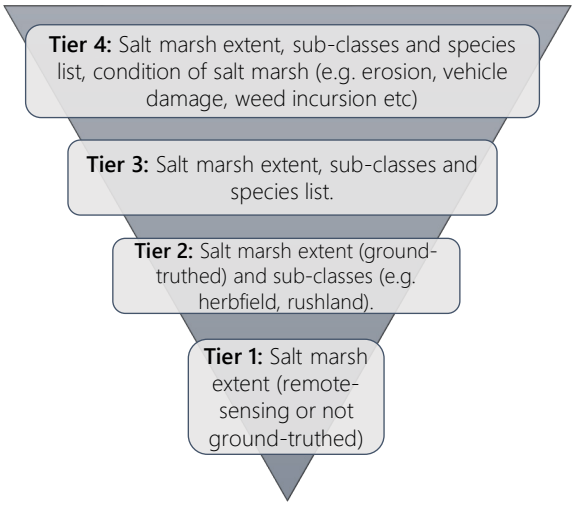

Fig. 2. Conceptual example of a simple tiered monitoring approach for salt marsh.

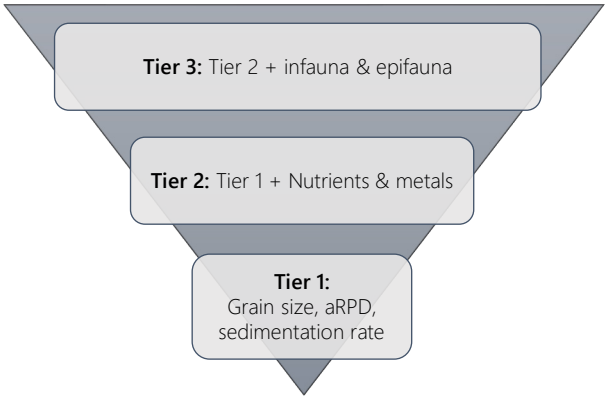

Fig. 3. Conceptual example of a simple tiered monitoring approach for fine-scale monitoring.

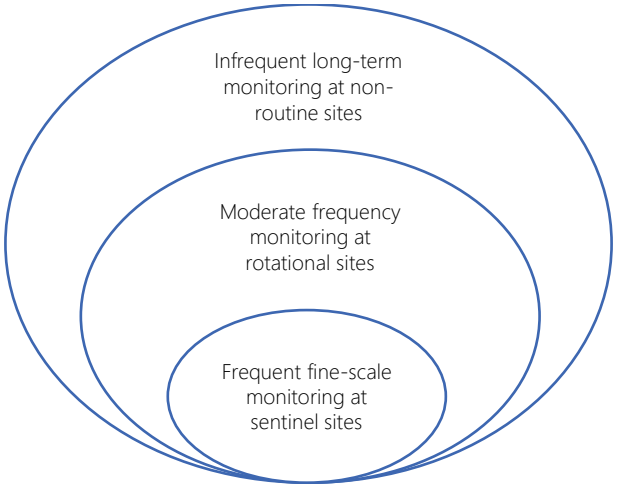

Fig. 4. Conceptual example of a nested monitoring approach for fine-scale monitoring. The sentinel sites are used to contextualise trends at the rotational and non-routine sites.

6. THE ROLE OF MFE

Several themes with regard to the national direction and MfE's influence on estuary monitoring were highlighted in the questionnaire and subsequent council interviews. These are summarised below.

6.1 NATIONAL DIRECTION

Councils have varied viewpoints on national direction (e.g. NPSFM, NPF attributes). In general, councils were supportive of national direction because it raises the profile of issues within a particular domain (e.g., estuaries) which allows councils to leverage funding for monitoring and management through their long-term plan process and/or other pathways. However, there were reservations about the potential severity of regulation, and most councils preferred non-regulatory pathways and/or some guarantee that they would not be immediately held accountable for imposed targets (i.e., action plan approach). Further, several councils were concerned about whether national direction would be relevant to all regions and how they would resource implementation of the NPF and monitoring of mandatory attributes (see 6.3 Funding model).

6.2 NATIONAL REPORTING & STANDARDISATION OF METHODS

As discussed in Section 4, councils see the value in standardised methods and the collection of nationally consistent data. However, the value of standardisation is perceived as substantially higher for central government than it is for councils. If councils are able to effectively manage estuaries through their SOE monitoring programmes, there is little incentive for them to transition towards national consistency where it requires additional cost or effort.

At present central government passively harvest data from regional councils for national reporting purposes. During the interviews with council staff there was discontent with current national reporting approaches, for example, the reporting of estuary metrics on LAWA. While these have been developed in partnership between LAWA and the CSIG, many councils highlighted that sites had been selected to address regional management issues and were not selected to meet the requirements of a national monitoring network that has not been formally defined or agreed on. As sites are displayed without regional context, they may not be the best overall representation of regional or national estuary health and could lead to unfavourable or unfair regional comparisons, or inappropriate use or interpretation of data.

6.3 FUNDING MODEL

There was a general consensus among councils that the existing funding model for environmental monitoring is not effective, noting that this sentiment was not exclusive to the coastal domain. With central government policies (e.g., NPSFM or NPF) becoming more prescriptive and requiring councils to do more within their management domains (e.g., freshwater, biodiversity, coast, etc.), it has resulted in increased costs for ratepayers and a strain on council resources. While councils need to monitor the environment in order to manage it, SOE monitoring should be a national priority, particularly when the data is used for national reporting and/or the development of national models. Several councils highlighted the need for a review of the current funding model if more obligations are to be implemented by central government. Some examples were discussed in the interviews and are outlined below. It is recommended that MfE consider a review of the current funding model with the implementation of the NPF, to support councils to achieve better outcomes in their region and nationally.

6.3.1 MfE support councils with data availability

Councils would benefit from access to nationally funded data and models that they can use to support both monitoring and management, for example:

- Fund appropriate capture and data storage (e.g., LINZ Data Service) for aerial and/or satellite imagery and LiDAR data. Currently, image capture is infrequent and comes at a significant cost to councils. More frequent image capture would also benefit other environmental domains and improve council access to remote sensing data. Central government could hold a bulk contract for annual capture of high-resolution (<30cm) satellite imagery (i.e., early summer, low tide) and high-resolution (<10cm) capture of aerial imagery and LiDAR every 5-years, for example.
- Support councils to undertake event-based monitoring either through direct funding, imagery capture post-event (see 4.6.7) and/or funding for a 'team' that can travel around the country and carry out event-based monitoring.
- Provide more frequent updates to the national land cover mapping database so that it can be used to relate land use changes to a response in the estuary (e.g., LCDB5 is based on 2018 land use) at a more relevant temporal scale.
- Facilitate open access to national models (e.g., sea surface temperature, wind, rainfall, storm surge, SOI,

turbidity, salinity, river and land use modelling), or commonly used code or metrics (e.g., biotic indices). Models are often produced through national funding and/or use council datasets yet councils cannot access the information without associated costs, and standardised open-source code facilitates efficiency, transparency and consistency in calculations.

6.3.2 MfE support councils with guidance

While the CSIG represents a good avenue for councils to share information, there is no resourcing to formally compile standard protocols, monitoring standards, guidance documents and learnings. A recent example, preparation of the CSIG guidance on seagrass monitoring, has emphasised (based on council feedback) that councils are not well placed to compile this information due to limited in-house resourcing to prepare the document and limited funding for expert input and review. MfE is well placed to fund and produce guidance documents at a national level in partnership with councils, for example:

- Revise the NEMP based on the recommendations in the current report and commit to funding regular revisions (e.g., 3-yearly) to accommodate updates and incorporate emerging technologies.
- Support the development of national and/or regional thresholds that will allow councils to assess estuary condition, and improve understanding of stressor-response relationships for indicators presented in the NEMP (i.e., review existing data).
- Support development of tools (e.g., remote sensing and automated image analysis or QA scripting tools to support analyses) that have the potential to make key aspects of broad-scale monitoring cheaper and standardised across regions.
- Prepare guidance documents that would support councils to manage estuaries (e.g., targeted investigations, event-based monitoring).
- Fund an expert panel that councils can access for advice on action plan development. This would support councils with limited in-house capability in the coastal domain and facilitate the sharing of knowledge across regions (i.e., applying lessons learned from other regions).
- Better align underpinning research from national providers with tools and knowledge needed by councils to monitor and manage estuaries.

6.3.3 Partnership model for SOE monitoring

The below has been paraphrased, and added to, from the interview with Waikato Regional Council and email correspondence with M. Townsend on 23-05-2023.

MfE could consider a partnership model between councils and central government to monitor a national network of 'sentinel' estuaries. If 'sentinel' estuaries were co-funded by central government this would allow councils to monitor at the recommended sampling frequency, capture high quality data in a standardised way and use the 'sentinel' estuaries to contextualise other regional monitoring data (e.g., Fig. 4). Data captured from these sites would form a national estuarine dataset that could be used for national reporting purposes, national models, the development of thresholds and/or contribute to understanding stressor response relationships in estuaries.

A national network of 'sentinel' estuaries would require geographic spread, and would need to include different estuary types. A co-funded partnership would be conditional on the collection of data and analysis of samples being consistent with nationally standardised methods (e.g., revised NEMP). For example, for fine-scale monitoring, central government could hold a bulk contract for infauna processing and sediment quality samples, while councils undertake field work. Similarly, for broad-scale habitat mapping, central government could hold a bulk contract for imagery capture and/or specialist broad-scale mapping.

Councils would not be eligible for the partnership model if they continued to exclusively use 'alternative' methods to the NEMP (e.g., different sized cores or sieve sizes) that make data non-comparable. However, if councils wanted to also persist with their traditional methods (i.e., maintain regionally consistent time series), the collection of additional samples could facilitate a method comparison. Over time this might generate data that allows the discontinuation of 'old' methods following a better understanding of how a method change will affect a long-term dataset. This would incentivise councils to move towards standardised NEMP methods, support them to transition and allow them to shed the cost of non-standard methods.

7. HOW SHOULD A REVISED NEMP PROCEED?

Councils were unanimous that a revision of the NEMP would need to include councils as the end-users throughout the whole process. However, councils also emphasised that they could not contribute in a substantiative way to literature review or analysis of existing datasets to support NEMP revision, and/or writing of protocols/methods, due to limited resourcing. If a revision of the NEMP is to proceed, based on our interviews with councils, it is recommended that:

- The NEMP review be prepared by a lead writer and technical expert that has a good understanding of council processes, capabilities and needs. The lead writer/expert would be supported by a group of technical experts and representative council staff. While council interviews agreed that national research providers should be part of the process, most had strong reservations about research providers leading a NEMP revision based on past experiences (e.g., recommendations that are not fit-for-purpose) and vested interests (e.g., taxonomy).
- At the start of the project, MfE fund a facilitated workshop to develop the framework for the NEMP revision with council staff and key providers. The foundational information used in the workshop should be information gathered in the current project and previous pieces of work (e.g., LAWA, OTOT). Previous experience attending CSIG meetings and workshops has highlighted that a facilitator is essential for the workshop to be effective and ensure that all councils have an equal say. Travel grants may also be required to incentivise council involvement in the workshop.
- To ensure councils remain connected throughout the process, and the output is fit-for-purpose, it is recommended that a sub-group of council representatives are engaged in an advisory role and review of the final output. The final output can also be presented to the CSIG in the final stages to close the loop on council engagement.
- It was highlighted in the interviews that council staff, research organisations and other providers in New Zealand all have potential biases and/or vested interest in particular methods. To minimise the influence of this on a NEMP revision, we recommend engaging an independent reviewer(s) at the start of the project (i.e., to review output from the initial workshop) and for a review the final report.

8. CONCLUSION AND RECOMMENDATIONS

Based on the council and national research provider responses, limited literature review, and our own expertise in the application of the NEMP, it is concluded that an update of the NEMP is both timely and necessary. It is recommended that this be done in the following manner:

1. Prepare a NEMP methods report that incorporates the broad- and fine-scale method updates as recommended in Appendix 2. Many of the method updates are relatively straightforward and can be implemented with ease. Others will require interrogation of existing data to allow for an optimised approach. A NEMP update should also include methods for other estuary types and consider approaches that improve the linkages between broad- and fine-scale monitoring.
2. Include specific methods for proposed NPF attributes in the revised NEMP. In practice, methods could be developed separately and subsequently integrated into a NEMP framework.
3. Prepare guidance documents to accompany a revised NEMP on:
    - Broad-scale and fine-scale indicator thresholds to contextualise estuary health (incorporating a revision of the Estuary Trophic Index (ETI) criteria and assessment of infauna indices).
    - Options and methods for event-based monitoring.
    - Case studies and/or methods for targeted investigations, including lessons learned, pros and cons.

It is emphasised that the revision should aim to develop approaches that allow councils flexibility to choose methods or monitoring frequency (e.g., tiered or nested monitoring approaches), where appropriate, to accommodate variable budgets. Guidance should also include decision trees to support monitoring design and management decisions (e.g., targeted investigations).

Any review should include new approaches that could better connect broad- and fine-scale monitoring (e.g. synoptic sampling approaches), consider an estuary typology framework and methods for different estuary types (e.g., river-dominated systems), include guidance on monitoring or incorporating climate change (e.g., indicators and/or risk assessment), and provide

recommendations on QA procedures and data analysis options.

The following are additional general recommendations from the questionnaire responses and council interviews:

- With the implementation of the NPF, MfE review the current funding model (see Section 6.3) for SOE monitoring. Increasing obligations imposed on councils by central government has resulted in added costs for ratepayers and a strain on council resources. There is national value in collecting SOE data, and several ways in which MfE can support councils in this space.
- The NEMP revision should be led by a technical expert that has a good understanding of council processes, capabilities and needs. They should be supported by an expert technical advisory group including council scientists. All council staff should be included at the beginning of the process via a facilitated workshop. MfE should consider engaging an independent reviewer to ensure the review process is impartial, updates are fit-for-purpose and reflect best practice.

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APPENDIX 1. COUNCIL QUESTIONNAIRE

An electronic output of questionnaire results and interviews with councils and national research providers has been provided to MfE. A subset of the questionnaire results are presented in the following tables below.

A1.1. General questions regarding the NEMP.

Question	YES	NO	NA
General questions about the NEMP			
Does your council have an estuary monitoring programme?	14	2	0
Do you use the National Estuary Monitoring Protocol (NEMP)?	12	2	2
Does the NEMP require review?	16	0	0
Estuary monitoring programme			
How long has your Council been undertaking estuary SOE monitoring?			
0 years	2	-	-
1-5 years	3	-	-
6-10 years	2	-	-
11-15 years	5	-	-
16-20 years	1	-	-
>20 years	3	-	-
Has the monitoring used consistent methods over time?	11	3	2
Has the monitoring used consistent providers over time?			
Is your ability to implement estuary monitoring restricted by budget & resourcing?	12	4	0
Do you need guidance on monitoring frequency?	14	1	1
Do you need guidance on site selection?	13	3	0
What is the future of your estuary monitoring programme over the next 10 years?			
No significant changes expected	6	-	-
Increase current sampling frequency or number of estuaries monitored	9	-	-
Decrease current sampling frequency or number of estuaries monitored	1	-	-
What is the future of targeted investigations over the next 10 years?			
No significant changes expected	4	-	-
Increase current level of targeted investigations	12	-	-
Decrease current level of targeted investigations	0	-	-
What should a NEMP revision include and would it be adopted?			
Should an update of the NEMP include guidance on reporting and data analysis?	10	4	2
Should nationally consistent assessment criteria be developed to assess estuary health?	11	3	2
Should nationally consistent assessment criteria be included in a revised NEMP?	8	6	2

NA=Not Answered

A1.2. General questions regarding the NEMP.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The existing NEMP is a 'fit for purpose' method for the evaluation of shallow intertidally-dominated estuary state and no changes are needed?	0	1	6	8	1
The NEMP focus on providing practical and cost-effective SOE monitoring methods should be maintained in any future revisions?	3	11	1	1	0
Parts of the NEMP are 'fit for purpose' for SOE monitoring but there are gaps that need to be addressed or improvements that need to be incorporated.	3	11	2	0	0
A revised NEMP should incorporate monitoring of subtidal estuary habitat.	3	9	1	2	1
A revised NEMP should incorporate monitoring of shallow short-residence time tidal river estuaries.	2	11	3	0	0
A revised NEMP should incorporate monitoring of deeper subtidally-dominated estuaries, including sounds and fiords.	2	7	5	1	1
A revised NEMP should incorporate monitoring of nearshore coastal areas and shallow bays.	1	5	5	3	2
Nationally consistent methods are vital for ensuring estuaries are managed appropriately.	6	7	0	2	1
Sediment macrofauna data are critical for councils to make estuary management decisions.	5	2	4	5	0
Regional differences require site-specific approaches which should be decided locally.	4	9	1	2	0
If key gaps were addressed, an updated NEMP would be a useful tool for councils.	7	7	2	0	0
If the NEMP was updated, it would likely be adopted and used by my council.	3	8	4	1	0
My council would be unlikely to voluntarily change its current SOE monitoring approach even if a national protocol was available.	0	1	7	5	3

A1.3. Questions relating to broad-scale intertidal habitat mapping.

Question		YES	NO	NA
Do you do broad scale habitat mapping following the NEMP?		10	4	2
Do you deviate from the NEMP broad scale methods?		14	0	-
Is broad scale habitat mapping done in-house or contracted out?	In-house	1	-	-
	Contracted out	3	-	-
	A combination of in-house and contracted out	10	-	-
	Not applicable	2	-	-
How do you assess seagrass?				
	Mapping extent of visible seagrass beds	14	-	2
	Subdivision of mapped beds into percent cover bands	10	-	6
How do you assess salt marsh?				
	Mapping extent of visible saltmarsh	14	-	2
	Subdivision of mapped extent into dominant classes, e.g. herbfield, rushland etc.	10	-	6
	Subdivision of classes into dominant species assemblages	7	-	9
	Assessment of ecological condition e.g. biodiversity, habitat complexity, patch size	3	-	13
How do you assess macroalgae?				
	Mapping extent of visible macroalgal beds	10	-	6
	Subdivision of mapped beds into percent cover bands	9	-	7
	Measurements of macroalgal biomass	8	-	8
	Description of species composition	9	-	7
	Application of the OMBT (Opportunistic Macroalgal Blooming Tool)	9	-	7
How do you assess terrestrial land cover around the estuary margin?				
	Land Cover Database (LCDB)	9	-	7
	Dominant land cover (in-house)	4	-	12
	Dominant species	4	-	12
	Ecological condition	3	-	13
How do you assess benthic microalgae?				
	Not assessed	9	-	7
	Mapping extent of visible microalgal beds	0	-	16
	Subdivision of mapped beds into percent cover bands	0	-	16
	Measurements of sediment chlorophyll-a	6	-	10
How do you assess mangroves?				
	No mangroves are present in our region	9	-	7
	Mapping extent of visible mangrove beds	5	-	11
	Subdivision of mapped beds into percent cover bands	0	-	16
	Measurements of biomass	0	-	16
How do you assess mud content/fine sediment extent?				
	Not assessed	0	-	16
	Mapping spatial extent of "muddy" habitat	10	-	6
	Subjective classification of substrate into percent mud classes, e.g. 0-10%, 10-25% mud	9	-	6
	Laboratory analysis of percent mud content	12	-	4
How do you measure changes in estuary sediment deposition?				
	Not assessed	2	-	14
	Buried sediment plates	12	-	4
	Hydrographic surveys	1	-	15
	LiDAR	2	-	14
	Stable isotope analyses (of sediment cores)	2	-	14
How do you measure or assess trophic (nutrient enrichment) state?				
	Not assessed	1	-	15
	Subjectively estimated	3	-	13
	Application of the Estuary Trophic Index	9	-	7
	Nutrient modelling	2	-	14
	Water quality	1	-	15

NA=Not Answered/Not Applicable

A1.4 Questions relating to fine-scale monitoring.

Question	YES	NO	na
Do you do fine scale monitoring using the NEMP?	12	2	2
In-house	3	-	-
Contracted out	4	-	-
A combination of in-house and contracted out	7	-	-
Do you deviate from the NEMP fine scale methods?	14	0	2
Where are your fine scale sites located?	YES	NO	na
Representative areas of the dominant intertidal habitat type	11	3	2
Deposition zones where eutrophic impacts are likely to be first expressed	3	11	2
In a range of intertidal habitats	5	9	2
Subtidal areas	1	13	2
What fine scale parameters do you analyse?	YES	NO	na
Carbon as Ash Free Dry Weight (AFDW)	3	11	2
Carbon as Total Organic Carbon (TOC)	13	1	2
Sediment aRPD (apparent Redox Potential Discontinuity) depth	10	4	2
Sediment ORP (Oxidation-Reduction Potential)	1	13	2
Particle grain size (PGS) by wet sieving	13	1	2
Particle grain size (PGS) by laser diffraction	2	12	2
TN (Total Nitrogen)	13	1	2
TP (Total Phosphorus)	13	1	2
TS (Total Sulfur)	2	12	2
Basic metals suite (Cu, Cd, Cr, Ni, Pb, Zn)	14	0	2
Extended metals (e.g. As, Hg)	12	2	2
Polycyclic aromatic hydrocarbons (PAHs)	4	9	2
Semi-volatile organic compounds (SVOCs)	4	10	2
Emerging contaminants	2	11	2
Sediment Chlorophyll-a	7	7	2
What type of samples are collected? (D = discrete, C = composite)	C	D	na
Metals	11	3	2
Nutrients (TN, TP)	10	3	3
Carbon (AFDW/TOC)	11	3	2
Particle Grain Size (PGS)	11	3	2
PAHs, SVOCs	5	0	11
Emerging contaminants	2	0	13
Chl-a	3	3	10
aRPD/ORP	1	8	7
For chemical analyses, what depth of sediment is collected?	YES	NO	na
Surface 20mm	14	0	2
Core depth (150mm)	0	14	2
For chemical analyses, what fraction of the sediment sample is analysed?	YES	NO	na
Whole sample	11	3	2
<2mm (mud and sand fractions)	2	12	2
<0.5mm	1	13	2
<63µm	1	13	2
What is the average number of sediment chemistry samples collected per site?	≤3	4-9	≥10
Metals	8	4	2
Nutrients	8	3	2
AFDW/TOC	7	3	2
PGS	7	2	1
PAHs	1	2	1
SVOCs	1	1	1
Emerging contaminants	0	1	1
Chl-a	1	3	1
aRPD/ORP	2	1	4

NA=Not Answered/Not Applicable

A1.3. Continued. Questions relating to fine-scale monitoring.

Question				
What macroinvertebrate sampling parameters do you use?		130mm	150mm	Other
	Core diameter	13	1	0
	Core depth	0	14	0
What macroinvertebrate sampling parameters do you use?		0.5mm	1.0mm	Other
	Mesh size	13	1	0
What is the average number of macrofauna samples collected per site?		≤9	10	>10
		2	8	4
How do you assess epibiota?				na
	Not assessed	2		2
	Quadrat counts	7		2
	Site SACFOR rating	6		2
	Derived from macroinvertebrate cores	2		2
Are epibiota excluded from macrofauna analyses? (Unkn = unknown)		YES	NO	Unkn
		9	2	3

NA=Not Answered/Not Applicable

APPENDIX 2. SPECIFIC RECOMMENDATIONS FOR BROAD- AND FINE-SCALE MONITORING

A2.1 Broad-scale method recommendations

The discrepancy between councils, and participant feedback, has highlighted a clear need to review and update the broad-scale methodology. Specific method recommendations are listed below. The supporting detail for these recommendations is in the main body of the report, Appendix 1 and embedded in the electronic raw data provided to MfE. Recommendations are as follows:

- Adopt the OMBT methodology for assessing nuisance macroalgae, assess its applicability in estuaries containing mangroves with low levels of macroalgal cover, and validate New Zealand based modifications for biomass classes using available data.
- Develop and adopt a simple seagrass percent cover classification, and develop methods for consistent application at a patch-scale.
- Revise the NEMP substrate classification as follows:
    - Adopt a substrate classification system based on standard geological terms, and which removes subjective 'sinking' as a proxy for mud content, e.g., Stevens et al. (2023). Ensure new classifications can be aggregated to match existing NEMP classifications for comparison with older datasets.
    - Use validation samples to confirm subjective substrate classifications, evaluate number of samples required to assess substrate type (i.e., undertakesynthesis of existing data (40+ estuaries) on validation accuracy).
    - Update method to record substrate beneath vegetation (e.g., salt marsh, macroalgae, seagrass, mangroves).
- Provide a method for consistently defining estuary extent, i.e., how to determine upper and lower estuary mapping boundaries.
- Assess methods for classifying mangrove sub-categories and whether this is useful for management.
- Provide guidance on QA steps (i.e., define minimum data requirements for checking for overlapping polygons, gaps, slivers, classification code errors; e.g., QA tools run on 2004 Bluff/Awarua broad-scale shapefiles identified >100 errors) and minimum metadata requirements for post-digitising GIS layers (e.g., imagery source, extent of ground-truthing, estimated spatial accuracy of mapping). Consider developing of an automated QA tool as part of the NEMP package, which are freely available and accessible to councils.
- Define imagery resolution requirements, and document common imagery sources and digitising tablet options.
- Review and assess remote-sensing methodologies including manual and automated methods. Consider developing automated processes that are freely available and accessible to councils.
- Improve guidance on the timing and frequency of monitoring (i.e., when do you increase sampling frequency?). A risk matrix or decision tree would be useful (e.g., if macroalgal problems are increasing monitor more frequently).
- Update the decision matrix. Consider rapid estuary assessment methods to improve the information quality used in the decision matrix and to provide councils with a tool to gather synoptic information on a larger number of estuaries.
- Consider the inclusion and/or update of the indicators or methods presented in Table 7.
- Some councils emphasised that mapping the ecological features (e.g., crustacean burrows, tube worms, crabs, shellfish) of substrate was essential (e.g., Needham et al. 2013). Ecological features reflect an integrated response to multiple drivers and are not uniform within substrate types. Therefore, this component should be considered independently of substrate mapping, which can be related to specific drivers of change in a management context (i.e., changes in mud extent or mud content). To address this aspect, a review of the required effort, utility and national applicability of mapping ecological features such as those described in Needham et al. (2013) is needed.

A2.2 Fine-scale method recommendations

Specific recommendations are listed below. As was the case for the broad-scale assessment above, these recommendations draw on detail in Appendix 1 and the raw data file, and are as follows:

- Provide high-level guidance (e.g., decision tree) on when/where fine-scale monitoring is applicable/ useful, and what different types of monitoring and levels of sampling effort would be needed to answer specific questions (e.g., characterising baseline state vs detecting trends).
- Include a clearly stated purpose for each type of NEMP fine-scale indicator (e.g., infauna, sediment quality), along with the pros and cons relating to how data may be used (e.g., useful for spatial analysis but sampling frequency insufficient to assess trends).
- A fine-scale method review should identify where standardisation can be achieved via data analysis, but highlight the critical parts of the methodology that require standardisation in data collection.
- Review the current suite of fine-scale indicators, and recommend standard analysis methods (see Table 9), detection limits and sampling procedures.
- Outline minimum sampling frequency and replication requirements for baseline fine-scale SOE monitoring, noting that most councils considered the recent recommendations in Hewitt (2021) to be unaffordable and not fit-for-purpose.
- Define specific minimum QA procedures for infauna processing, including metadata requirements (e.g., Hewitt et al. 2014), and define a process for how provider differences could be resolved.
- Provide guidance on macrofauna data analysis including QA steps, how to manage juveniles and epifauna, suitability of different indices, community analysis and assessment of sampling sufficiency.
- Include in NEMP guidance a list of infauna identified in New Zealand estuaries, and define a target level of identification required for each taxa.
- Review suitability of the epifauna and vegetation cover methodology.
- Update site selection guidance to include habitat types other than mid-low water unvegetated intertidal flats and, in particular, include guidance for different estuary types (e.g., SIDEs vs SSRTREs).
- Include methods, or a case study, to describe the pros and cons of synoptic fine-scale sampling approaches that characterise a broader range of estuary habitats but at less detail than a NEMP fine-scale approach, i.e., approaches with high spatial coverage but limited within-site replication (see Griffiths 2012; Forrest et al. 2023).
- Provide guidance on sample collection in macroalgae and seagrass habitats and associated limitations in the application of biotic indices (e.g., where sensitive species may be able to survive in macroalgal mats, but not the sediment).
- Remove microalgae as a specified NEMP indicator.
- Describe methods for installing sediment plates at fine-scale sites as an additional explanatory variable and to provide a measured annual overview of site condition even when fine-scale samples are not collected annually.
- Support the collection and application of desktop data (i.e., LiDAR) to assess tidal elevations (e.g., to determine upper estuary extents and fine-scale site elevations).
- Facilitate access to (or information on how to access) regionally or nationally collated data on potential explanatory drivers of change: e.g., sea surface temperature, wind, rainfall, storm surge, southern oscillation index (SOI), turbidity, salinity etc.
- Provide councils with support and advice on how to best store and manage data (currently contained in a mix of spreadsheets and databases).
- Facilitate and support training across councils to improve consistency in sample collection and data analysis.

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