Synoptic Subtidal Monitoring of Kai Iwi and Mowhanau Estuaries

June 2019

horizons
REGIONAL COUNCIL

Prepared for:

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June 2019
Report No. 2019/EXT/1650
ISBN 978-1-98-853788-7

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Report 018

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Salt Ecology Report 018


Lower reaches of the Mowhanau Estuary, Feb 2019

RECOMMENDED CITATION

Stevens LM 2019. Synoptic Subtidal Monitoring of Kai Iwi and Mowhanau Estuaries. Salt Ecology Report 018, prepared for Horizons Regional Council. 22p.

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For the People
Mō ngā tāngata

ACKNOWLEDGEMENTS

Many thanks to Janine Kamke (HRC) for her support of the project and provision of water quality summary data, Elizabeth Daly (HRC) for review comments, Mike Gemmel (HRC), Sally O'Neill (Salt Ecology) and Gary Stephenson (Coastal Marine Ecology Consultants) for assistance in the field, and to Barrie Forrest (Salt Ecology) for peer review.

Surveying a cross-section profile in Kai Iwi Estuary, February 2019

Cover design: www.layaroseart.com

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EXECUTIVE SUMMARY

Background

Kai iwi and Mowhanau estuaries are relatively small (~1.7 and 1.1ha respectively) shallow short-residence tidal river estuaries (SSRTREs) whose mouths are mostly open to the sea, but occasionally close. The estuaries are perched at the high water zone and the mouths are commonly constricted by a build-up of beach sand that limits the ingress of seawater. When seawater is retained in the estuaries, it becomes brackish (low salinity) and can stratify with denser seawater being trapped beneath freshwater surface flows.

Broad scale mapping and synoptic assessment in 2016 indicated the estuaries had high nutrient and sediment loads, but that flushing by high flow events, combined with the absence of high value habitat in susceptible areas, indicated that the high nutrient inputs were not resulting in significant algal blooms and associated impacts in the estuaries. The 2016 assessment recommended targeted subtidal monitoring of eutrophication and sedimentation indicators to collect additional data to assess long-term trends in trophic state.

In late 2018 Salt Ecology were commissioned by Horizons Regional Council (HRC) to undertake a targeted subtidal survey to broadly map estuary depth, benthic substrate, seagrass and nuisance macroalgae extent; and to collect water quality measures (i.e. chlorophyll-a, salinity, temperature, dissolved oxygen). The aim was to delineate the spatial extent of any salinity or temperature stratification, and assess trophic state.

Results

Tables 3 and 4 in the main report assess fine scale and broad scale ecological indicators against condition rating criteria for estuary health. Field measurements of subtidal water quality showed no temperature or salinity stratification, with both estuaries freshwater dominated, brackish (salinity <3ppt), and well mixed. Dissolved oxygen concentrations at the deepest sites were relatively high (6.8-7.0mg/l), with no subtidal areas having low oxygen levels in either water or sediment. No seagrass was evident in either estuary.

Condition ratings assigned a 'very good' status in both estuaries were trace elements, macroalgae and the extent of high enrichment conditions (HEC; an index that combines measures of oxygen status, organic carbon, mud and nutrients). Trace elements indicated no concerns relating to human influenced contaminants and the absence of macroalgae and HECs indicated low organic and nutrient enrichment.

The condition ratings assigned a 'poor' status were, in the Kai Iwi: sedimentation rate, mud extent and estuary margin intactness, and at site K5 in the deepest part of the estuary, sediment oxygenation (apparent Redox Potential Discontinuity depth, aRPD) and mud content. In the Mowhanau, only sedimentation rate, estuary margin intactness and salt marsh extent were rated 'poor' with all other indicators except phytoplankton rated 'very good'. Total phosphorus (rating not yet developed) was high relative to the Kai Iwi. Phytoplankton (indicating potential nutrient enrichment within the estuaries, or inputs from upstream sources) was rated 'moderate' in the Mowhanau and 'very good' in the Kai Iwi.

Salt marsh was absent in the Mowhanau ('poor') and present in localised areas (5-10%) in the Kai Iwi ('moderate'). Both estuaries supported freshwater vegetation along the banks of tidally influenced upper estuary reaches.

Synthesis of key findings

Neither Kai Iwi or Mowhanau estuaries are currently expressing significant symptoms of eutrophication, a finding consistent with long-term HRC water quality data. Phytoplankton indicators were low in the Kai Iwi and moderate in the Mowhanau, dissolved oxygen levels were high, sediment oxygenation was generally good and there were no areas of high enrichment conditions (HECs) present. The upper sections of each estuary indicated elevated catchment inputs of muds although these do not appear to be accumulating to a significant extent in the estuaries. A recently developed Estuary Trophic Index (ETI), which describes the position of an estuary on a eutrophication gradient, rated both estuaries in the 'good' category.

Recommendations:

In terms of SOE estuary monitoring, it is recommended that:

1. Both estuaries continue to be evaluated on a 5-10 yearly basis with the need for reassessment determined by the long-term water quality results being collected by HRC, any major changes observed (i.e. algal blooms, low oxygen) when water quality sampling is being undertaken, or following any major change in catchment land use that would be expected to lead to significant increases in contaminant mass loads.

2. Undertake a desktop assessment of potential catchment sources of nutrients to the Mowhanau Estuary to determine if the relatively high level of phosphorus may relate to specific land use activities.
3. Include chlorophyll-a measures as part of the long-term water quality suite currently being monitored in Mowhanau Estuary by HRC.

1. INTRODUCTION

In 2016 Horizons Regional Council (HRC) commissioned a synoptic Ecological Vulnerability Assessment (EVA) of the estuaries on both coasts of the Horizons region to assess sediment and nutrient enrichment (eutrophication) risks (see Robertson and Stevens 2016). Although limited in scope, the study included visits to all of the larger and many of the smaller estuaries to rapidly characterise the prevailing sediment and nutrient status of each one, map key broad scale habitat features, and define ongoing monitoring priorities in a defensible manner.

The EVA assessed both the Kai Iwi and Mowhanau estuaries on the west coast of the Manawatu/Whanganui region (Fig. 1). Both estuaries are relatively small poorly flushed shallow short-residence tidal river estuaries (SSRTRE) with mouths that are generally open but undergo short periods of closure or restriction (days to weeks). The estuaries, although subjected to prolonged periods of poor flushing, do not support significant areas of high ecological value habitat that could be affected.

Based on criteria in the EVA (Robertson & Stevens 2016) and a recently developed New Zealand Estuary Trophic Index (ETI) (Zeldis et al. 2017), Kai Iwi and Mowhanau estuaries are rated as having high susceptibility to sediment and nutrient impacts. Because sediment and nutrients concentrate in the subtidal reaches of SSRTREs under periods of restricted flushing, eutrophication issues are most commonly expressed in the subtidal parts of the estuary.

Broad scale mapping and synoptic sampling in 2016 subjectively assessed nutrient influence by the presence of phytoplankton blooms visible in the water column, and sediment by the extent of fine sediment in the subtidal reaches of the estuary. The EVA consequently recommended targeted subtidal monitoring of eutrophication and sedimentation indicators annually in Kai Iwi Estuary, and 10 yearly in Mowhanau Estuary to collect data to assess long-term trends in trophic state. HRC have an ongoing monthly water quality sampling programme that collects additional data on each estuary.

In late 2018, Salt Ecology was commissioned by HRC to undertake a targeted subtidal survey of Kai Iwi and Mowhanau estuaries to broadly map estuary depth, benthic substrate and seagrass extent; and to collect water quality measures to complement HRC's comprehensive long-term monthly water quality monitoring programme. The aim was to assess trophic state, delineate the spatial extent of any salinity or temperature stratification, and collect sediment samples to assess substrate quality. The following report describes the methods and results of field sampling undertaken in February 2019, and makes recommendations for future monitoring and management.

2. BACKGROUND TO KAI IWI AND MOWHANAU ESTUARIES

Kai iwi and Mowhanau estuaries are both located ~12km north of Whanganui, Kai Iwi immediately to the northwest of Mowhanau Village, and Mowhanau to the south. Both are relatively short (length ~750m and ~250m respectively), small (~1.7 and 1.1ha) and poorly-flushed SSRTREs. The estuaries are perched at the high water zone and the mouths are commonly constricted by a build-up of beach sand that limits the ingress of seawater. When seawater is retained in the estuaries it becomes brackish (low salinity) and can stratify, with denser seawater being trapped beneath freshwater surface flows.

Both estuaries are confined within channelised meandering river banks with a strong freshwater influence but relatively low freshwater inflows ($1.5m^3.s^{-1}$ and $0.25m^3.s^{-1}$ respectively).

Margin vegetation comprises a narrow strip of freshwater species flanked by terrestrial grassland and weeds. Salt tolerant rushes and sedges (e.g. Sea rush, *Juncus krausii*; three square, *Schoenoplectus pungens*) are present (Kai Iwi only), but salt marsh is sparse with freshwater vegetation dominating the river banks of the upper estuary.

Estimated catchment nitrogen (N) areal loadings reported in Robertson & Stevens (2016) are high (7580 and $8048mg/N/m^2/d$ respectively) compared to the tentative guideline for low susceptibility SSRTREs ($2000mg/N/m^2/d$). Phytoplankton blooms, indicated by the presence of green tinged waters, were reported in Kai Iwi in January 2016, and in the upper estuary reaches of the Mowhanau (Robertson & Stevens 2016). Flushing by high flow events, combined with the absence of high value ecological habitat in susceptible areas, suggest that the high nutrient inputs are not resulting in significant algal blooms and associated impacts in the estuaries.

Like nutrients, sediment inputs are relatively high with predicted sediment loads ~9 to ~17 times the predicted natural loads in the two estuaries, respectively. This is evident in the upper estuary subtidal zones being relatively muddy, although both estuaries have extensive areas of sand near the coast.

The respective Kai Iwi and Mowhanau catchments are dominated by grazing: sheep and beef (51% and 66%) and dairy farming (1% and 27%), but with extensive native (19%) and exotic forest (29%) cover also present in the Kai Iwi catchment.

The beaches and surrounds to the lower reaches of both estuaries have high public use.

Figure 1. Kai Iwi and Mowhanau estuaries showing the location of sampling transects established in February 2019, and sediment sampling sites.

At each transect a cross-section was surveyed, water quality assessed, seagrass where present mapped, and bottom sediment condition measured. Sediment samples were collected for chemical analysis of grain size, nutrients, organic content and metals from the deepest part of the cross-section at sites K2, K4, K5 and M1.

3. MONITORING PROTOCOLS USED

A standard approach for assessing the ecological health of estuaries has been produced with methods outlined in a National Estuary Monitoring Protocol (NEMP) originally developed in 2001 by Cawthron Institute (Robertson et al. 2002a; Robertson et al. 2002b; Robertson et al. 2002c).

The NEMP is intended to provide resource managers with a scientifically defensible, cost-effective, easy to use, nationally applied standard protocol with which they can assess and monitor the ecological status of estuaries in their region. The results provide a valuable basis for establishing a benchmark of estuarine health in order to better understand human influences, and against which future comparisons can be made.

The NEMP programme has three main elements. The first part is a coarse screening tool that is intended to enable councils to undertake a preliminary assessment of the condition of estuaries in their region in order to establish monitoring priorities (Robertson et al. 2002a). Once initial priorities are established, the NEMP monitoring approach itself consists of two protocols described in Robertson et al. (2002c), which are as follows:

- Broad-scale mapping of habitat characteristics
  The aim of broad scale habitat mapping is to describe and map an estuary according to the dominant substrate and vegetation features present. Once a baseline map has been constructed, changes in the position, extent or type of dominant features can then be monitored by repeating the mapping exercise. This procedure combines the use of aerial photography, detailed ground truthing, and digital mapping using Geographical Information System (GIS) technology. This approach requires modification when assessing subtidal areas, with additional ground truthing required to validate subtidal features.
- Fine-scale assessment of habitat condition
  Once an estuary has been classified according to its main distinguishing features, and the dominant broad scale habitats have been described and mapped, representative habitats can be selected and targeted for fine scale monitoring. The NEMP, with its focus primarily on shallow intertidally dominated estuaries, advocates monitoring intertidal soft sediment (sand/mud) habitat in the mid to low tidal range of priority estuaries. The NEMP provides no specific guidance for sampling subtidal features.
  The environmental characteristics assessed in NEMP fine scale surveys incorporate a suite of commonly used benthic indicators, including biological (e.g. macroinvertebrate infauna) and physico-chemical (e.g. sediment mud content, metals, nutrients) characteristics.

A recently developed extension to the NEMP in New Zealand has been an Estuary Trophic Index (ETI) (Robertson et al. 2016a, b; Zeldis et al 2017). The ETI describes methods and provides screening guidance for assessing where estuaries of different types (including subtidally dominant estuaries) are positioned on a eutrophication gradient. It utilises several NEMP metrics, and describes additional metrics, which are applied both to the estuary as a whole (i.e. in a broad scale context), as well as at a site-specific level (i.e. in a fine scale context).

4. METHODS

4.1 ESTUARY EXTENT

To set the boundaries for the synoptic survey, estuary extents were based on the definition used in the ETI (Robertson et al. 2016a) which defines an estuary as the area between the upper extent of saline intrusion (i.e. where ocean derived salts during average annual low flow are <0.5ppt) and seaward to a straight line between the outer headlands where the angle between the head of the estuary and the two outer headlands is <150°.

4.2 SYNOPTIC SUBTIDAL SAMPLING

4.2.1. General approach

Synoptic estuary sampling was conducted on 1 February 2019. For tidal river estuaries like the Kai Iwi and Mowhanau, where the most susceptible areas are subtidal, site-specific approaches beyond that described in the NEMP and ETI are needed.

The selected approach was based on sampling of a series of cross-sectional transects throughout the subtidal sections of the estuary, combined with assessment of broad and fine scale metrics (described below), which has previously been demonstrated to be an effective way to map broad scale ecological features and characterise estuary trophic status (e.g. Stevens and Robertson 2012, Stevens et al. 2016). The approach includes measuring a range of water and sediment quality indicators. Water quality measures are instantaneous and reflect ambient conditions and tide. They are supplemented here with HRC data collected as part of a comprehensive long-term monthly water quality monitoring programme in the river catchments. Sediment indicators, such as sediment oxygenation, enrichment and mud content, provide integrated measures of prevailing environmental conditions. As such they are generally less prone to small scale temporal variation and are therefore used in conjunction with water quality measures. This meso-scale assessment approach can be repeated over time and scaled up or down to address specific issues as necessary.

Broad scale measures incorporate wider spatial indicators that commonly integrate a variety of factors, for example macroalgal or seagrass growth reflect the combined influence of nutrient availability, sediment deposition, water quality, and hydrology.

Because the estuaries had previously been mapped, and the key broad scale and subtidal features were already generally known, locations for undertaking cross-section surveys could largely be pre-determined. Eleven sites were distributed relatively evenly throughout representative parts of the lower, middle and upper estuaries, six in Kai iwi and five in Mowhanau. Site locations are shown in Fig. 1. Sampling was conducted around low tide to enable the best delineation of stratified bottom waters retained in the estuary. The tidal range on the day of sampling (1.2m) was in the middle of the range predicted by LINZ (1.9-0.6m), hence represents a state intermediate between spring and neap tides.

At each transect, subtidal habitat was assessed by wading to measure the following variables:

4.2.2 Physical characteristics

Each channel cross-section was surveyed at a 1-2m horizontal resolution to record the channel width, depth and bottom profile. On each transect, sediment quality was assessed by collecting sediment samples from across each profile using a remote grab sampler. At the surface they were assessed for substrate type, aRPD and seagrass or macroalgal cover. At the deepest point in the channel, water quality measures were taken as described below.

4.2.3 Water column indicators

Water quality measures of pH, conductivity, DO, temperature and chlorophyll-a were made using a YSI Pro10 meter and a Delrin Cyclops-7F fluorometer with chlorophyll optics and Databank datalogger. Water quality measurements were collected ~20cm below the water surface, and ~20cm above the sediment surface, with care taken not to disturb bottom sediments before sampling. Thermocline and halocline depths were recorded as the average depth of abrupt changes in temperature and salinity, respectively, recorded on the up- and down-cast meter deployments. Secchi disk clarity was measured to the nearest centimetre. Data were recorded on waterproof paper in the field and logged electronically (see Section 4.3).

Although subject to high spatial and temporal variation, water column measures provide a useful tool for the synoptic appraisal of ecological condition. Salinity measures provide a simple way for determining the upstream extent of the estuary and indicate where stable areas of saline water may be trapped, with phytoplankton potentially able to grow and bloom in the retained water. Waters that are high in phytoplankton typically reflect situations where nutrient supply is high and flushing is low. The nutrients facilitate rapid algal growth but when algal blooms crash and die, they deplete dissolved oxygen levels which can adversely impact both sediment-dwelling and water column communities, and are a primary cause of most fish kills.

The ETI provides criteria for assessing phytoplankton (an optional primary indicator of nutrient enrichment), and for 1-day instantaneous dissolved oxygen minima in the water column measured from representative areas (including likely worst-case conditions). Criteria for nutrient concentrations remain under development.

4.2.4 Sediment measures

Substrate classification

Appendix 1 summarises the key NEMP classes used to define estuarine habitats in the current report. Classification is based on the dominant surface substrate features present; e.g. rock, boulder, cobble, gravel, sand, mud. Sand and mud substrates were divided into sub-categories based on sediment 'muddiness', assessed either through laboratory analysis of sediment mud content, or according to subjective field-based assessment of textural and firmness characteristics.

Sediment sampling and analysis

At the deepest point on transects K2, K5, K6 and M3 (see Fig. 1), a composite sediment sample from 3 separate grabs (~250g in total) was collected from the sediment surface (to 20mm depth). Sediment samples were placed directly into laboratory supplied sample containers, stored on ice, and sent to RJ Hill Laboratories for analysis of: particle grain size (% mud <63µm, sand <2mm to ≥63µm, gravel ≥2mm); organic matter (total organic carbon, TOC); nutrients (total nitrogen, TN; total phosphorus, TP) and metals and metalloids (arsenic, copper, chromium, cadmium, lead, mercury, nickel, zinc). Details of laboratory methods and detection limits are provided in Appendix 2.

Sediment grain size

Sediment grain size indicates the relative proportion of fine-grained sediments that have accumulated within estuary sediments. In general terms, increased muddiness correlates to reduced sediment oxygenation due to limited diffusion among the tightly packed mud matrix. Increasing mud also causes a change in sediment animal communities, with sensitive species like pipi preferring low (<10%) mud environments, and communities becoming dominated by mud-tolerant organisms when mud levels exceed 25%.

Sediment oxygenation

The visual assessment of aRPD depth provides an easily measured, time integrated, and relatively stable measure of sediment oxygenation conditions. Sediment aRPD was assessed by splitting sediment cores or grabs vertically with a hand trowel to determine whether there were any significant areas where sediment oxygenation was depleted. Sediments were considered to have poor oxygenation if the aRPD was consistently <5mm deep and showed clear signs of organic enrichment indicated by a distinctive colour change in the sediments from brown/grey to black. Such sediments can also emanate a strong 'rotten egg' smell of hydrogen sulphide.

Examples of well oxygenated sandy sediment with aRPD >150mm (left) and poorly oxygenated muddy sediment with aRPD <5mm (right).

Sediment nutrients and organic carbon

TN and TP concentrations reflect estuary trophic status and the potential for algal blooms and other symptoms of enrichment to occur and persist. The ETI uses measures of TN from the most impacted 10% of an estuary to rate likely enrichment, while the ratio of TN and TP can be used to indicate which nutrient may be limiting to algal growth (almost always nitrogen in estuaries). Organic carbon provides a measure of the organic material present in sediments. When this exceeds ~2%, sediment oxygen declines. Under anoxic conditions bacteria can break down organic material producing sulphides which, as well a having a strong odour, are toxic to most sediment dwelling animals.

Sediment metals and metalloids

Metals and metalloids provide a relatively cheap indicator for screening for the presence of common toxic contaminants associated with human activities. They are used to determine whether more intensive investigations of sediment contamination are necessary.

4.2.5 Broad scale spatial measures

Macroalgae

The NEMP provides no guidance on the assessment of macroalgae beyond recording its presence when it is a dominant surface feature. When present, the mean percent cover of discrete macroalgal patches was visually assessed to the nearest 10% using the 6-category percent cover rating scale presented in Fig. 2 as a guide.

The ETI has adopted the use of the United Kingdom Water Framework Directive (WFD-UKTAG 2014) Opportunistic Macroalgal Blooming Tool (OMBT) for macroalgal assessment. The OMBT is a 5-part multimetric index that produces an overall Ecological Quality Rating (EQR) ranging from 0 (major disturbance) to 1 (minimally disturbed) and which rates macroalgal condition within overall quality status threshold bands (bad, poor, good, moderate, high). The integrated OMBT index provides a comprehensive measure of the combined influence of macroalgal growth and distribution in the estuary and is applied where macroalgal cover exceeds 5%.

Seagrass

The NEMP provides no guidance on the assessment of seagrass beyond recording its presence when it is a dominant surface feature. When present, the mean percent cover of discrete seagrass patches was visually assessed to the nearest 10% using the 6-category percent cover rating scale presented in Fig. 2 as a guide. Percent change from recorded baseline values are used to assess temporal changes.

High Enrichment Conditions (HEC)

This is an integrated measure of the combined presence of indicators likely to result in adverse ecological outcomes. Referred to alternatively as gross eutrophic zones (GEZs) in the ETI (Zeldis et al. 2017), sites expressing HECs have sediments with elevated organic content (>1% TOC) and/or dense macroalgal cover (>50%), combined with an elevated mud content (≥25% mud) and low sediment oxygenation (<10mm) or water column oxygenation (<4mg/l). Once high organic and nutrient enrichment conditions establish, they are generally difficult to reverse and are likely to cause significant adverse ecological impacts on sediment-dwelling animals.

Sedimentation rate

Because sediment naturally settles and accumulates in estuaries, estuarine communities have an inherent capacity to assimilate inputs from terrestrial catchments. However, when natural terrestrial inputs are accelerated through human-induced land change, sedimentation rates can exceed the assimilation capacity of the estuary, leading to increased muddiness and smothering of habitats. Where long-term measurements of sedimentation rate changes are not available, the ETI uses a desktop approach of the ratio between predicted natural inputs and predicted current inputs to rate the likely susceptibility of an estuary to sediment problems.

4.3 DATA RECORDING, QA/QC AND ANALYSIS

Broad scale habitat features were recorded on a combination of laminated aerial photographs and waterproof paper. They were subsequently digitised into ArcMap 10.5 shapefiles using a Wacom Cintiq21UX drawing tablet, and combined with field notes and georeferenced photographs to produce habitat maps showing dominant estuary substrates, and where present, key features of stratified bottom water, macroalgae and seagrass.

All sediment samples were tracked using standard Chain of Custody forms, and results were transferred electronically to avoid transcription errors. All field measurements were recorded electronically in templates that were custom-built using Fulcrumapp software (www.fulcrumapp.com). Pre-specified constraints on data entry (e.g. with respect to data type, minimum or maximum values) ensured that the risk of erroneous data recording was minimised. Each sampling record created in Fulcrum generated a GPS position for that record and was exported to Excel for reporting purposes.

4.4 ASSESSMENT OF ESTUARY CONDITION

In addition to our expert interpretation of the data, results are assessed within the context of established or developing estuarine health metrics ('condition ratings'), drawing on approaches from New Zealand and overseas. These metrics assign different indicators to one of four 'health status' bands, colour-coded as shown in Table 1. The summarised thresholds used in the current report were derived primarily from the ETI (Robertson et al. 2016b) and subsequent revisions (Zeldis et al 2017).

The ETI provides screening guidance for assessing where an estuary is positioned on a eutrophication gradient. It includes site-specific thresholds for %mud, TOC, TN, aRPD, metals, dissolved oxygen, phytoplankton concentrations and the AMBI biotic index for macroinvertebrates. We adopt these thresh-

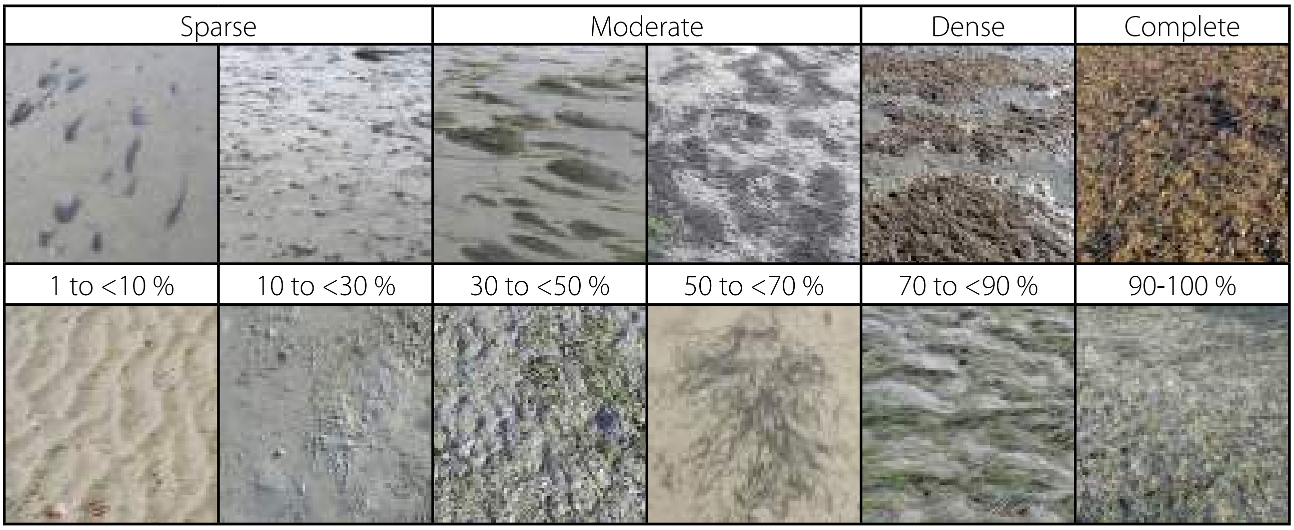


Figure 2. Visual rating scale for percentage cover estimates. Macroalgae (top), seagrass (bottom). Modified from FGDC (2012).

olds for present purposes as relevant, but for aRPD, we have modified the ETI ratings based on the US Coastal and Marine Ecological Classification Standard Catalog of Units (FGDC 2012) which provides a more comprehensive rating than that included in the ETI.

The ETI also contains metrics intended to be applied to the estuary as a whole (i.e. in a broad scale context). Spatial measures include the extent of mud, seagrass, macroalgae, the combined presence of factors contributing to high enrichment conditions (HECs), and sedimentation rate. In addition, previous assessments of estuarine condition have proposed preliminary criteria for the extent of salt marsh, densely vegetated terrestrial margin, and percent change from baseline measures (e.g. Stevens, 2018, Stevens and Forrest 2019). These thresholds are also adopted. As many of the ETI scoring categories and supporting metrics are still provisional or undergoing further development or refinement, they should be regarded only as a general guide to assist with interpretation of estuary health status, particularly if used individually. Overall assessment should be based on a weight of evidence approach using multiple indicators. Online tools have been developed for the ETI to assess estuary susceptibility (Tool 1) and trophic state (Tool 2):

https://shiny.niwa.co.nz/Estuaries-Screening-Tool-1/

https://shiny.niwa.co.nz/Estuaries-Screening-Tool-2/

Table 1. Summary of condition ratings referred to in the present report.

Indicator	Unit	Very Good	Good	Moderate	Poor
Sediment quality					
Mud content[1]	%	< 5	5 to < 10	10 to < 25	≥ 25
aRPD depth[1]	mm	≥ 50	20 to < 50	10 to ≤ 20	≤ 10
Total nitrogen (TN)[1]	mg/kg	< 250	250 to < 1000	1000 to < 2000	≥ 2000
Total organic carbon (TOC)[1]	%	< 0.5	0.5 to < 1	1 to < 2	≥ 2
Sediment trace elements[2]					
As	mg/kg	< 10	10 - < 20	20 - < 70	≥ 70
Cd	mg/kg	< 0.75	0.75 - < 1.5	1.5 - < 10	≥ 10
Cr	mg/kg	< 40	40 - < 80	80 - < 370	≥ 370
Cu	mg/kg	< 32.5	32.5 - < 65	65 - < 270	≥ 270
Pb	mg/kg	< 25	25 - < 50	50 - < 220	≥ 220
Hg	mg/kg	< 0.075	0.075 - < 0.15	0.15 - < 1	≥ 1
Ni	mg/kg	< 10.5	10.5 - < 21	21 - < 52	≥ 52
Zn	mg/kg	< 100	100 - < 200	200 - < 410	≥ 410
Water quality					
Dissolved oxygen (DO)[1]	mg/l	≥ 5.5	≥ 5.0	≥ 4.0	< 4.0
Phytoplankton (chl-a)[1]	ug/l	≤ 5	≥ 5 to < 10	≥ 10 to < 16	≥ 16
Broad scale spatial indicators					
Mud extent[1]	% of estuary	< 1%	1-5%	> 5-15%	> 15%
Macroalgae (OMBT)[1]	Ecological Quality Rating	≥ 0.8 - 1.0	≥ 0.6 - < 0.8	≥ 0.4 - < 0.6	0.0 - < 0.4
Seagrass[3]	% decrease from baseline	< 5%	5%-10%	> 10-20%	> 20%
Salt marsh extent[3]	% of intertidal area	> 20%	> 10-20%	> 5-10%	0-5%
200m terrestrial margin[3]	% densely vegetated	> 80-100%	> 50-80%	> 25-50%	< 25%
High Enrichment Conditions (HEC)[1]	ha or % of estuary	< 0.5ha or < 1%	0.5-5ha or 1-5%	6-20ha or > 5-10%	> 20ha or > 10%
Sedimentation rate[1*]	CSR:NSR ratio	CSR 1 to 1.1 x NSR	CSR 1.1 to 2 x NSR	CSR 2 to 5 x NSR	CSR > 5 x NSR

1. General indicator thresholds derived from a New Zealand Estuarine Tropic Index, with adjustments for aRPD as described in the main text. See text for further explanation of the origin or derivation of the different metrics.

2. Trace element thresholds scaled in relation to ANZECC (2000) as follows: Very good: < 0.5 x ISQG-low; Good: 0.5 x ISQG-low to < ISGQ-low; Moderate: ISQG-low to < ISQG-high; Poor: ≥ ISQG high.

3. Subjective indicator thresholds derived from previous broad scale mapping assessments.

**CSR=Current Sedimentation Rate, NSR=Natural Sedimentation Rate (predicted from catchment modelling)*

Kai Iwi Estuary

Shallow channel where the estuary mouth discharges over the beach

Lower estuary sand flats downstream of the confined middle estuary

Mudstone cliffs on the true right bank of the middle estuary

Channelised and confined upper estuary

Mowhanau Estuary

Lower Mowhanau Estuary showing mouth constricted by beach sand

Middle estuary - deeper water and reinforced rock banks

Confined channel in the middle-upper estuary

Freshwater vegetation on banks in the upper estuary

5. RESULTS

5.1 BROAD SCALE SUBTIDAL MAPPING

A summary of the broad scale subtidal mapping undertaken in each estuary in 2019 is presented in Figs 3 and 4. Results of field measurements of sediment quality collected from each of the 11 cross-sections are presented in Figs 5 and 6. A simplified cross-section of the estuaries from the open coast to the upstream inputs is presented in Fig. 7.

The results shows both estuaries have a very similar composition, soft muds overlying clean sands in the upper estuary, with clean sands dominating in the lower estuary. The presence of muds overlying clean sands indicates catchment inputs are the primary source of the muds, with more extensive deposits present in the Kai Iwi (~20-100mm deep) than in the Mowhanau (1-30mm deep) - see photos in Figs 5 and 6 for examples.

Each estuary had a similar percentage of muddy subtidal sediments (66% and 46% respectively). This extent of mud is expected in estuaries of this type where catchment derived sediments settle in the quiescent waters of the upper estuary where inflow velocities decrease and salinity driven flocculation occurs.

The reason for the higher overall percentage of sand to mud in the Mowhanau is primarily because the boundary of the estuary, as defined in Section 4.1, includes much larger beach-dominated intertidal flats than the more confined Kai Iwi.

Sediment oxygenation (aRPD depth) and bottom water dissolved oxygen (DO) measurements indicated subtidal areas were not experiencing depleted oxygen symptoms at the time of sampling.

Seagrass was not recorded in the current synoptic assessment, nor was it recorded in 2016 (Robertson & Stevens 2016).

Representative water quality measurements from the middle transect of each estuary are presented in Table 2. Both estuaries had generally uniform mixing throughout, with no meaningful differences between surface and bottom water quality measures.

Monitoring showed that both estuaries were slightly brackish (low salinity) but there was no salinity or temperature stratification present in either estuary at the time of sampling.

Phytoplankton concentrations, assessed by the fluorescence of chlorophyll present in the algae (i.e. chl-a measurement), were higher in the Mowhanau (10ug/l) than the Kai Iwi (2ug/l). The water in both estuaries had a similar green-brown tinge at the time of sampling highlighting the difficulty of visually assessing phytoplankton concentrations.

Secchi disk clarity extended to the bottom throughout the relatively shallow Mowhanau, but did not exceed 1.2m in the Kai Iwi.

Sampling showed no parts of either estuary had high enrichment conditions (HEC; the combined presence of low oxygen, elevated TOC, mud and nutrients). The deepest part of the Kai Iwi Estuary (Site K5, 2m deep) showed a slight decrease in dissolved oxygen in bottom water compared to surface water, but concentrations were still high.

Table 2. Summary of field measurements collected at each sampling site. Refer to Fig. 1 for site locations.

Station	Kai Iwi (K5)	Mowhanau (M3)
NZTM East	1762066	1762599
NZTM North	5583551	5583183
Distance from mouth (m)	350	150
Measurement depth (m)	0.2	0.2
Temperature (^{o}C)	22.9	21.7
DO saturation (%)	102	85
DO concentration (mg/l)	8.5	7.0
Salinity (ppt)	0.2	2.1
pH	8.6	8.0
Chl-a (ug/l)	2	10
Stratified	no	no
Halocline depth (m)	na	na
Thermocline depth (m)	na	na
Measurement depth 2 (m)	2	0.55
Temperature (^{o}C)	23.1	21.7
DO saturation (%)	80	85
DO concentration (mg/l)	6.8	7.0
Salinity (ppt)	0.2	2.1
pH	8.6	8.0
Chl-a (ug/l)	2	10
Secchi depth (m)	1.2	Bottom
Maximum depth (m)	1.25	0.75
Channel width (m)	20	10
Sediment type	SM on FS	SM on FS
aRPD depth (mm)	10	5

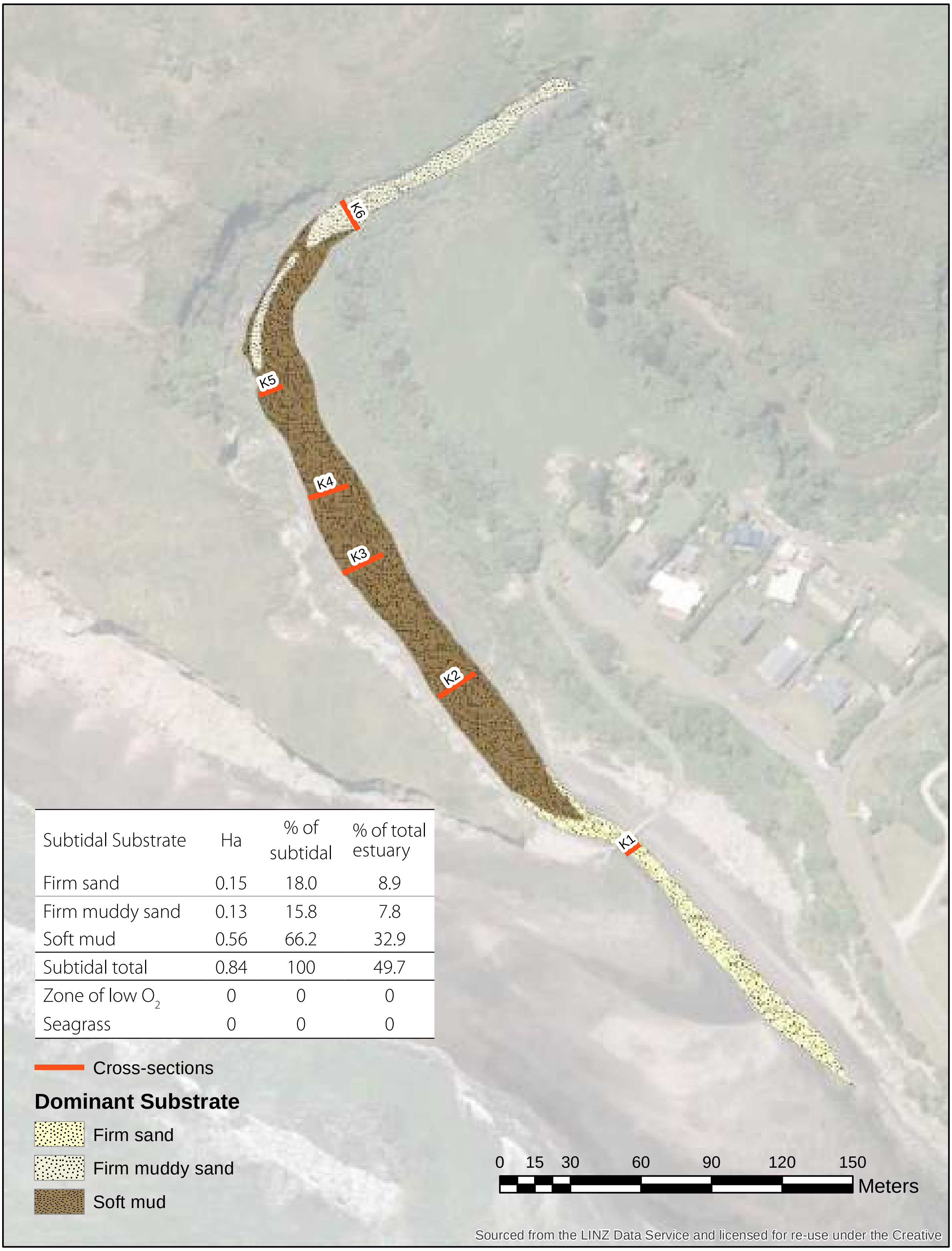
FS=firm sand, SM=soft mud

5.2 SEDIMENT PHYSICAL AND CHEMICAL CHARACTERISTICS

A summary of the 2019 composite sediment sample data collected from three sites in the Kai Iwi and one site in the Mowhanau is provided in Table 3 (see Appendix 2 for raw data from the laboratory).

5.2.1 Sediment grain size

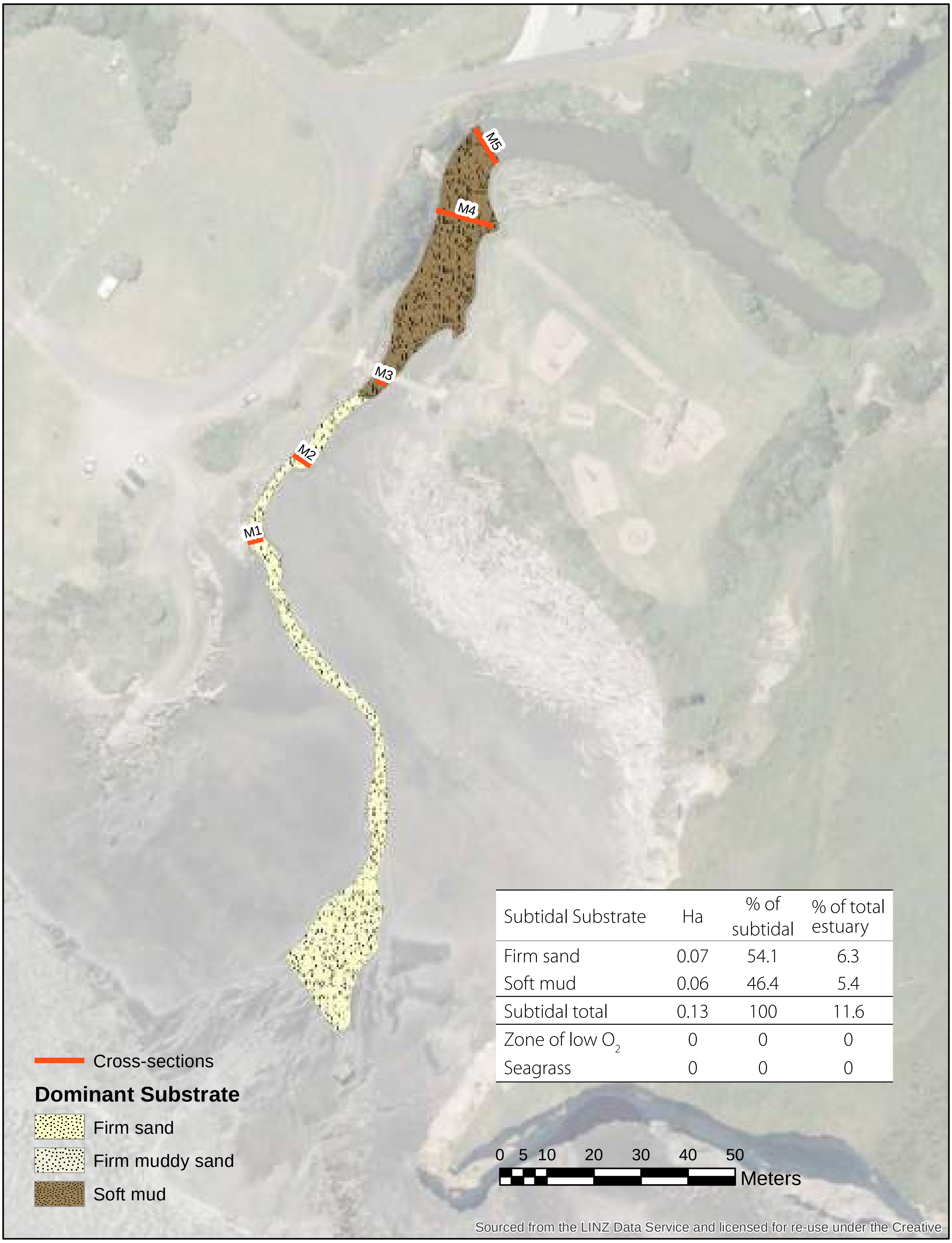
Laboratory analyses revealed that the mud fraction in the Kai Iwi Estuary was low (9%) in the lower estu-



Subtidal Substrate	Ha	% of subtidal	% of total estuary
Firm sand	0.15	18.0	8.9
Firm muddy sand	0.13	15.8	7.8
Soft mud	0.56	66.2	32.9
Subtidal total	0.84	100	49.7
Zone of low O_2	0	0	0
Seagrass	0	0	0

Figure 3. Map of Kai Iwi Estuary showing broad scale subtidal results for substrate, seagrass and bottom water oxygenation.

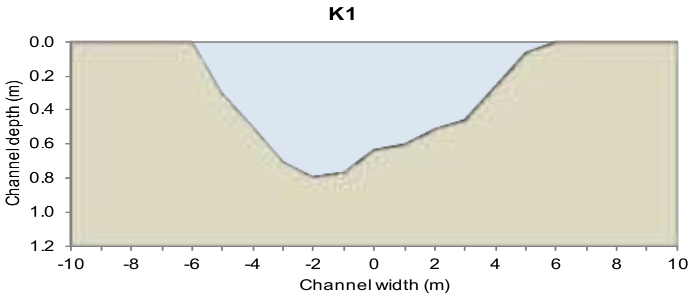
Bottom water oxygenation was measured in situ and used alongside sediment aRPD measurements to assess the presence of subtidal oxygen depletion. Although instantaneous measures are subject to high temporal and spatial variance, they still provide a useful synoptic tool for assessing estuary condition.



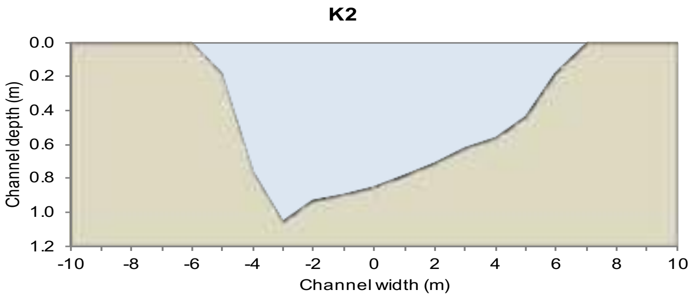
Subtidal Substrate	Ha	% of subtidal	% of total estuary
Firm sand	0.07	54.1	6.3
Soft mud	0.06	46.4	5.4
Subtidal total	0.13	100	11.6
Zone of low O_2	0	0	0
Seagrass	0	0	0

Figure 4. Map of Mowhanau Estuary showing broad scale subtidal results for substrate, seagrass and bottom water oxygenation.

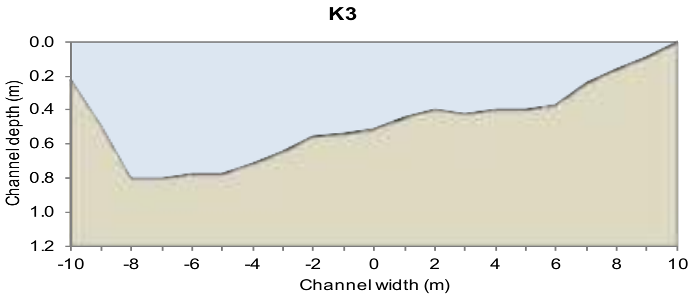
Bottom water oxygenation was measured in situ and used alongside sediment aRPD measurements to assess the presence of subtidal oxygen depletion. Although instantaneous measures are subject to high temporal and spatial variance, they still provide a useful synoptic tool for assessing estuary condition.



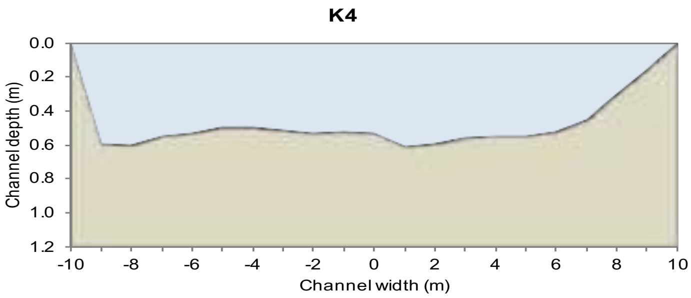
K1 Firm sand, aRPD >50mm



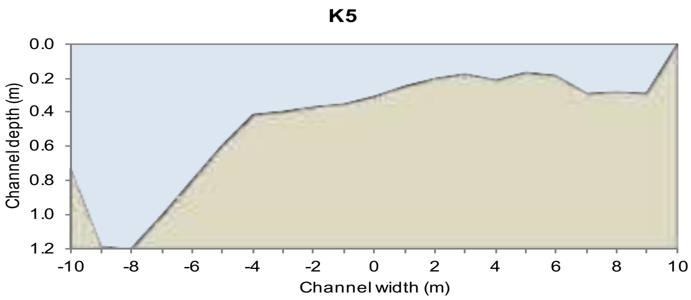
K2 Soft mud on sand aRPD >50mm



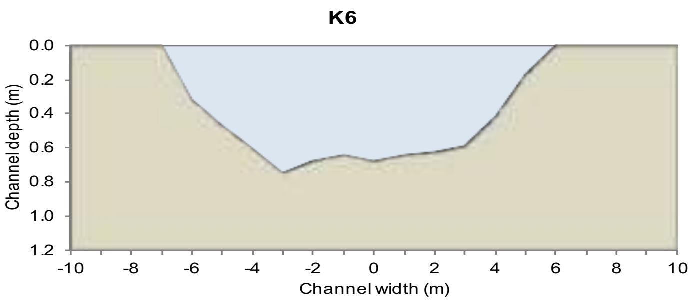
K3 Very soft mud on sand, aRPD 10mm



K4 Soft mud on sand, aRPD 20mm

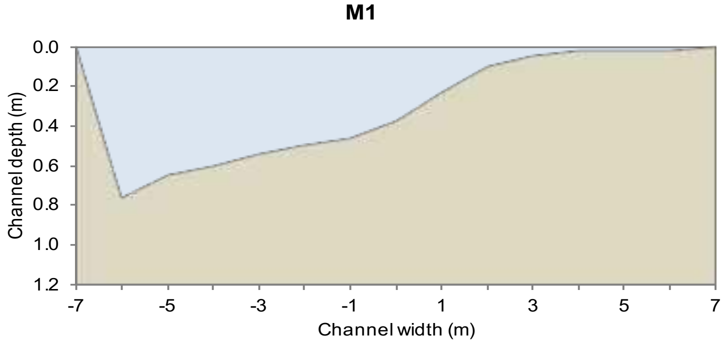


K5 Soft mud on sand, aRPD 10mm

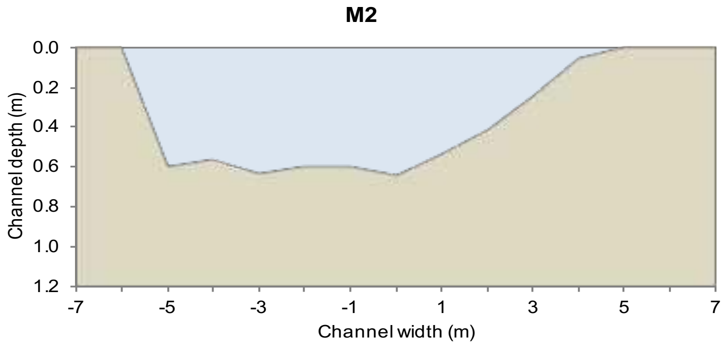


K6 Firm sand, aRPD 50mm

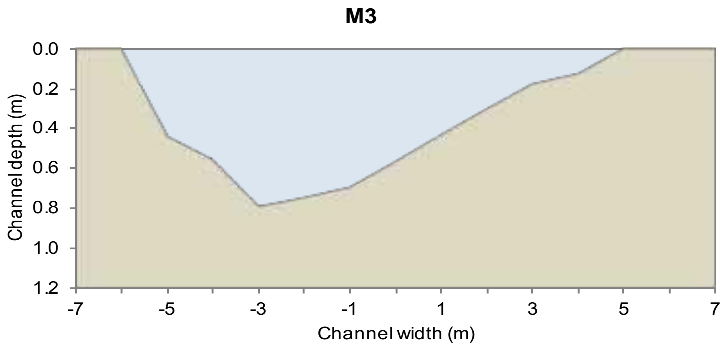
Figure 5. Cross-sections of the Kai Iwi Estuary showing bed height, substrate type and aRPD depth. The estuary was unstratified and no seagrass was present.



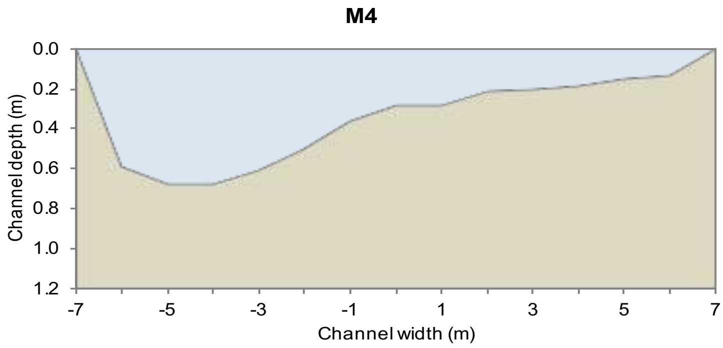
M1 Firm sand, aRPD >50mm



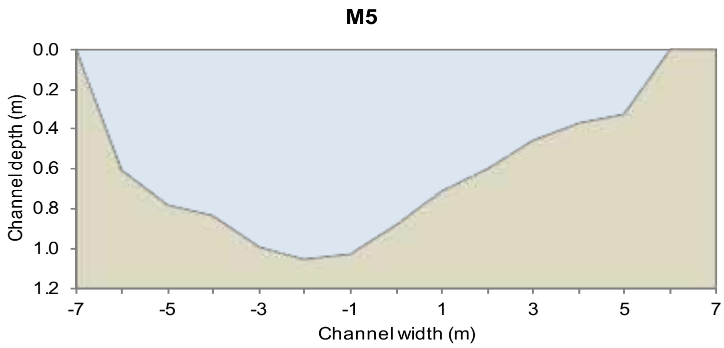
M2 Firm sand, aRPD >50mm



M3 Mud over firm sand, aRPD >50mm



M4 Soft mud on sand, aRPD 30mm



M5 Soft mud on sand, aRPD 25mm

Figure 6. Cross-sections of the Mowhanau Estuary showing bed height, substrate type and aRPD depth. The estuary was unstratified and no seagrass was present.

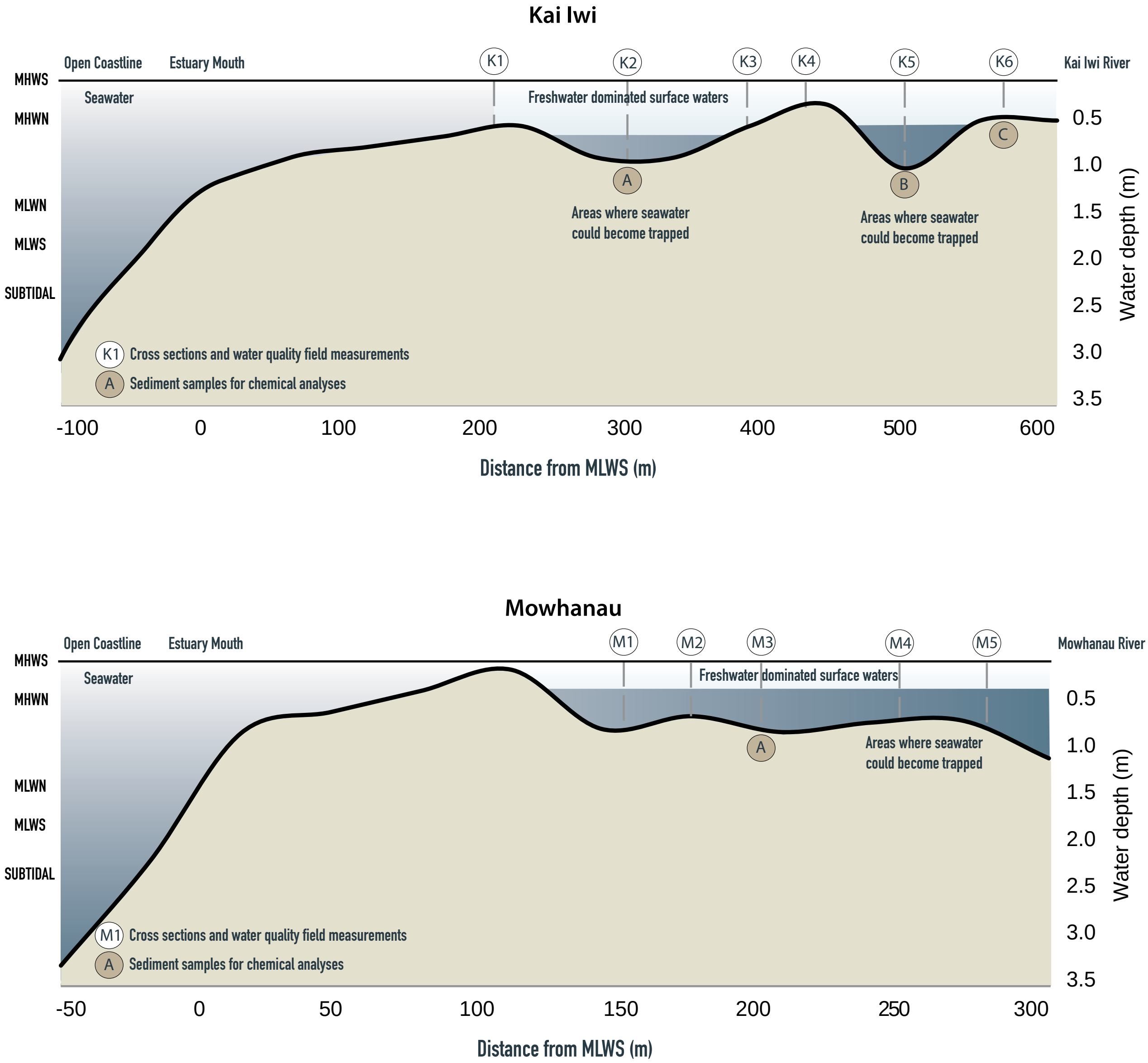


Figure 7. Simplified longitudinal cross-section of the Kai Iwi and Mowhanau estuaries showing bed height, sediment sampling sites and location of channel cross-sections.

The sea is shown on the left and the rivers on the right. Where sand builds up at the mouth of the estuary, a raised sill is present which constricts the flow of water to the sea. Tidal seawater floods into the estuary at high tide, and freshwater and seawater mix and flow out at low tide. Because seawater is more dense than freshwater, freshwater floats on top of seawater. This can trap seawater where it can support the growth of phytoplankton blooms causing water quality to degrade. This commonly occurs in deeper pools in the upper estuary under periods of low flow.

ary, moderate (12%) in the upper estuary, and high (40%) in the deeper middle estuary. At the two upstream sites (K5 and K6), sands present beneath a surface mud layer appeared to have a relatively low mud content, suggesting that surface deposits of mud are likely flushed from the estuary and are not accumulating to a significant extent in the underlying sediment matrix.

A similar situation was evident in the Mowhanau Estuary, with a low mud fraction recorded (6%). This reflects the presence of only a thin layer (1-5mm) of fine mud over clean marine sands.

5.2.2 Total organic carbon and nutrients

Total organic carbon (TOC) and nutrient (TN and TP)values were generally correlated with sediment grain size, being highest in the muddier sediments. Kai Iwi Site K5 generally had the highest values and this deep site in the middle estuary appears to be where fine sediments and organic matter preferentially accumulate. However, the highest TP concentration was recorded from Mowhanau, despite the mud content being low. This suggests there may be differences in land use between the two catchments contributing to higher TP inputs in the Mowhanau.

5.2.3 Trace contaminants

Trace metal and metalloid concentrations were low at all sites, and less than ANZECC (2000) ISQG-low values (Table 3).

5.3 INTERPRETATION OF ECOLOGICAL HEALTH AGAINST CONDITION RATINGS

Table 3 summarises the ecological condition scores for key indicators of sediment chemistry. Broad scale indicators and those used to calculate an ETI score are summarised in Table 4. Criteria and ratings are summarised in Table 1, with 2016 broad scale habitat mapping and synoptic data (Robertson & Stevens 2016) used to supplement the data in the current study.

Data show that the estuary condition rating in relation to catchment sediment inputs was 'poor'. While the extent of muddy sediment in the Mowhanau was relatively low (a rating of 'very good'), this is largely an artifact of the defined estuary boundary including larger beach-dominated intertidal flats than the more confined Kai Iwi. The presence of thin mud on the surface of much of the middle and upper estuary suggests mud deposits occur in most of the estuary above where the mouth regularly constricts. Consequently the mud extent in the Mowhanau more accurately reflects the same 'poor' conditions found in the Kai Iwi.

TOC and sediment nutrients were rated 'moderate' in the deepest part of the Kai Iwi Estuary, and 'very good' in the Mowhanau, again reflecting the generally low mud content.

The absence of nuisance macroalgae and high enrichment conditions (HECs) meant both these metrics were rated 'very good'. This is consistent with HRC monthly water quality sampling in Kai Iwi estuary over the 5-year period from 2013-2017 showing a median phytoplankton concentration of 2.9ug/l, a rating of 'very good'. Long-term chlorophyl-a data are not available from the Mowhanau but one-off observations in 2016 and field measures in 2019 indicate phytoplankton concentrations appear higher ('moderate' rating) in this estuary compared to the Kai Iwi. The limited monitoring data means the overall ETI score (see below) is tentative for this estuary.

Data from Robertson & Stevens (2016) showed salt marsh was not present in the channelised and modified Mowhanau Estuary ('poor' rating), and was relativel sparse in the Kai Iwi ('moderate' rating).

Trace contaminant results were all low and indicate that the estuary is unlikely to have any significant sediment contamination issues, hence trace contaminants were assigned a rating of 'very good'.

Overall, the ETI score for each estuary, calculated using Table 4 data and NIWAs online Tool 2 calculator (https://shiny.niwa.co.nz/Estuaries-Screening-Tool-2/) was:

Kai Iwi ETI score 0.37

Mowhanau ETI score 0.41

Both these scores fall in the Band 'B' (Good) category.

Table 3. Sediment grain size, nutrient, aRPD, trace metal and metalloid results for composite samples collected at four sites in 2019. Colour coded cells reflect a comparison against ratings in Table 1.

Estuary	Site	Gravel %	Sand %	Mud %	TOC %	TN mg/kg	TP mg/kg	aRPD mm	As mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg
Kai Iwi	K2 (A)	< 0.1	88	12	0.1	< 500	350	50	2.2	0.016	10.8	4.0	< 0.02	7.7	3.5	33
	K5 (B)	< 0.1	60	40	1.6	1100	440	10	2.8	0.038	15.3	6.2	0.02	10.6	6.5	42
	K6 (C)	< 0.1	91	9	0.2	< 500	220	50	1.8	0.011	7.6	2.3	< 0.02	5.2	2.4	21
Mowhanau	M3	< 0.1	94	6	0.2	< 500	650	>50	3.6	0.015	13.1	5.2	< 0.02	8.0	3.2	46

Refer to Fig. 1 for site locations and Table 1 for condition rating colour codes and thresholds.

Table 4. Summary of broad scale spatial indicators and general indicators reflecting the most impacted 10% of the estuary.

		Kai Iwi		Mowhanau	
Indicator	**Unit**	**Value**	**Rating**	**Value**	**Rating**
Sediment Quality					
Mud content	%	40	Poor	6	Good
aRPD depth	mm	10	Poor	>50	Very Good
Total nitrogen	mg/kg	1100	Moderate	<500	Very Good
Total organic carbon	%	1.6	Moderate	0.2	Very Good
Trace elements	mg/kg	low	Very Good	low	Very Good
Water Quality					
Dissolved oxygen	mg/l	6.8	Very Good	7	Very Good
Phytoplankton (chl-a)	ug/l	2	Very Good	10	Moderate
Broad scale spatial indicators					
Mud extent	% of estuary	33	Poor	5	Very Good
Macroalgae (OMBT)	EQR	1	Very Good	1	Very Good
Seagrass	% decrease from baseline	-	na	-	na
Salt marsh extent	% of intertidal area	5-10	Moderate	<5	Poor
200m terrestrial margin	% densely vegetated	<25	Poor	<25	Poor
High Enrichment Conditions	ha or % of estuary	0	Very Good	0	Very Good
Sedimentation rate	CSR:NSR ratio	9	Poor	17	Poor

6. SYNTHESIS AND RECOMMENDATIONS

6.1 SYNTHESIS

Neither Kai Iwi or Mowhanau estuaries are currently expressing significant symptoms of eutrophication. Phytoplankton was low in the Kai Iwi (consistent with long-term HRC data) and moderate in the Mowhanau although the latter is based on a single field measurement and so is very much a tentative finding. Dissolved oxygen levels were high, sediment oxygenation was good throughout the vast majority of each estuary, and there were no areas of high enrichment conditions (HEC; low oxygen, elevated TOC, mud and nutrients) present. The upper sections of each estuary indicated elevated catchment inputs of muds although these do not appear to be accumulating to a significant extent in the estuaries.

The ETI ratings, which present combined average scores across multiple indicators, were in the 'good' category for both estuaries.

6.2 RECOMMENDATIONS

In terms of SOE estuary monitoring, it is recommended that:

1. Both estuaries continue to be evaluated on a 5-10 yearly basis with the need for reassessment determined by both the long-term water quality results being collected by HRC, any major changes observed (i.e. algal blooms, low oxygen) in the estuaries when water quality sampling is being undertaken, or following any major change in catchment land use that would be expected to lead to significant increases in contaminant mass loads.
2. Undertake a desktop assessment of potential catchment sources of nutrients to the Mowhanau Estuary to determine if the relatively high level of phosphorus may relate to specific land use activities.
3. Chlorophyll-a measures be included as part of the long-term water quality suite currently being monitored in Mowhanau Estuary

7. REFERENCES CITED

Atkinson IAE. 1985. Derivation of vegetation mapping units for an ecological survey of Tongariro National Park Nth Island, NZ. NZ Journal of Botany, 23; 361-378.

FGDC. 2012. Coastal and Marine Ecological Classification Standard Catalog of Units, Federal Geographic Data Committee FGDC-STD-018-2012. p343.

Robertson B, Gillespie P, Asher R, Frisk S, Keeley N, Hopkins G, Thompson S, Tuckey B. 2002a. Estuarine environmental assessment and monitoring: A national protocol part A. Development of the monitoring protocol for New Zealand estuaries. Introduction, rationale and methodology. Sustainable Management Fund Contract No. 5096, Cawthron Institute, Nelson, New Zealand. 93p.

Robertson B, Gillespie P, Asher R, Frisk S, Keeley N, Hopkins G, Thompson S, Tuckey B. 2002b. Estuarine environmental assessment and monitoring: a national protocol part B: development of the monitoring protocol for New Zealand Estuaries. Appendices to the introduction, rationale and methodology. Sustainable Management Fund Contract No. 5096, Cawthron Institute, Nelson, New Zealand. 159p.

Robertson B, Gillespie P, Asher R, Frisk S, Keeley N, Hopkins G, Thompson S, Tuckey B. 2002c. Estuarine environmental assessment and monitoring: a national protocol part C: application of the estuarine monitoring protocol. Sustainable Management Fund Contract No. 5096, Cawthron Institute, Nelson, New Zealand. 40p.

Robertson B, Stevens L. 2016. Manawatu-Wanganui Estuaries. Habitat Mapping, Vulnerability Assessment and Monitoring Recommendations Related to Issues of Eutrophication and Sedimentation. Prepared for Envirolink Medium Advice Grant: 1624-HZLC127 Assessment of the susceptibility of Horizons' estuaries to nutrient enrichment and sedimentation. MBIE/NIWA Contract No:CO1X1513. 102pp + appendices.

Robertson BM, Stevens L, Robertson BP, Zeldis J, Green M, Madarasz-Smith A, Plew D, Storey R, Hume T, Oliver M. 2016a. NZ Estuary Trophic Index. Screening Tool 1. Determining eutrophication susceptibility using physical and nutrient load data. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 47p.

Robertson BM, Stevens L, Robertson BP, Zeldis J, Green M, Madarasz-Smith A, Plew D, Storey R, Hume T, Oliver M. 2016b. NZ Estuary Trophic Index. Screening Tool 2. Screening Tool 2. Determining Monitoring Indicators and Assessing Estuary Trophic State. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 68p.

Stevens LM. 2018. Tokomairiro Estuary: Broad Scale Habitat Mapping 2018. Report prepared by Wriggle Coastal Management for Otago Regional Council. 40p.

Stevens LM, Forrest BM. 2019. Broad scale intertidal habitat mapping of Delaware Inlet. Salt Ecology Report 011 prepared for Nelson City Council.

Stevens LM, Robertson BM. 2012. Waimatuku Estuary 2012. Fine Scale Monitoring and Macrophyte Mapping. Report prepared by Wriggle Coastal Management for Environment Southland. 14p.

Stevens LM, Robertson BM, Robertson BP 2016. Hutt Estuary: 2016 Broad Scale Habitat Mapping. Report prepared by Wriggle Coastal Management for Greater Wellington Regional Council. 35p.

WFD-UKTAG. 2014. UKTAG Transitional and Coastal Water Assessment Method Macroalgae Opportunistic Macroalgal Blooming Tool. Water Framework Directive – United Kingdom Technical Advisory Group. Retrieved from: http://www.wfduk.org/sites/default/files/Media/Characterisation of the water environment/Biological Method Statements/TraC Macroalgae OMBT UKTAG MethodStatement.PDF

Zeldis J, Whitehead A, Plew D, Madarasz-Smith, A, Oliver M, Stevens L, Robertson B, Storey R, Burge O, Dudley B. 2017. The New Zealand Estuary Trophic Index (ETI) Tools: Tool 2 - Assessing Estuary Trophic State using Measured Trophic Indicators. Ministry of Business, Innovation and Employment Envirolink Tools: C01X1420.

APPENDIX 1. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS

Vegetation was classified using an interpretation of the Atkinson (1985) system, whereby dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram grass, *Ammophila arenaria***,** was coded as Amar. An indication of dominance is provided by the use of ( ) to distinguish subdominant species e.g. Amar(Caed) indicates that marram grass was dominant over ice plant (*Carpobrotus edulis*). The use of ( ) is not always based on percentage cover, but the subjective observation of which vegetation is the dominant or subdominant species within the patch. A measure of vegetation height can be derived from its structural class (e.g. rushland, scrub, forest).

VEGETATION (mapped separately to the substrates they overlie).

Forest: Tree and shrub cover in the canopy is >80% and tree cover exceeds that of shrubs. Trees are woody plants ≥10 cm diameter at breast height (dbh). Tree ferns ≥10cm dbh are treated as trees. Commonly sub-grouped into native, exotic or mixed forest.

Treeland: Trees cover in the canopy is 20-80%. Trees are woody plants >10cm dbh. Commonly sub-grouped into native, exotic or mixed treeland.

Scrub: Shrub and tree cover in the canopy is >80% and shrub cover exceeds that of trees (cf. FOREST). Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed scrub.

Shrubland: Cover of shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed shrubland.

Tussockland: Tussock cover is 20-100% and exceeds that of any other growth form or bare ground. Tussock includes all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >100 cm height. Examples occur in all species of *Cortaderia, Gahnia,* and *Phormium*, and in some species of *Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla,* and *Celmisia*.

Duneland: Sand dune vegetation (commonly Spinifex, Pingao or Marram grass) is 20-100% and the dune vegetation cover exceeds that of any other growth form or bare ground.

Grassland: Grass cover (excluding tussock-grasses) is 20-100%, and exceeds that of any other growth form or bare ground.

Sedgeland: Sedge cover (excluding tussock-sedges and reed-forming sedges) is 20-100% and exceeds that of any other growth form or bare ground. "Sedges have edges." If the stem is clearly triangular, it's a sedge. If the stem is flat or rounded, it's probably a grass or a reed. Sedges include many species of *Carex, Uncinia,* and *Scirpus*.

Rushland: Rush cover (excluding tussock-rushes) is 20-100% and exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant. Iincludes some species of *Juncus* and all species of *Leptocarpus*.

Reedland: Reed cover is 20-100% and exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either round and hollow – somewhat like a soda straw, or have a very spongy pith. Unlike grasses or sedges, reed flowers will each bear six tiny petal-like structures. Examples include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata,* and *Baumea articulata*.

Cushionfield: Cushion plant cover is 20-100% and exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

Herbfield: Herb cover is 20-100% and exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

Lichenfield: Lichen cover is 20-100% and exceeds that of any other growth form or bare ground.

Introduced weeds: Introduced weed cover is 20-100% and exceeds that of any other growth form or bare ground.

Seagrass meadows: Seagrasses are the sole marine representatives of the Angiospermae. They all belong to the order Helobiae, in two families: Potamogetonaceae and Hydrocharitaceae. Although they may occasionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive underground root/rhizome system which anchors them to their substrate. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries and are mapped separately to the substrates they overlie.

Macroalgal bed: Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain cholorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope. Macroalgal density, biomass and entrainment are classified and mapped separately to the substrates they overlie.

SUBSTRATE (physical and zoogenic habitat)

Artificial substrate: Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates. Commonly sub-grouped into artificial: boulder, cobble gravel, sand or barriers (seawalls, bunds etc).

Rock field: Land in which the area of basement rock exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Boulder field: Land in which the area of unconsolidated boulders (>200mm diam.) exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Cobble field: Land in which the area of unconsolidated cobbles (>20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Gravel field: Land in which the area of unconsolidated gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Mobile sand: Granular beach sand characterised by a rippled surface layer from strong tidal or wind-generated currents. Often forms bars and beaches.

Sand: Sand flats may be mud-like in appearance but are granular when rubbed between the fingers and no conspicuous fines are evident when sediment is disturbed e.g. a mud content <1%. Classified as firm sand if an adult sinks <2 cm or soft sand if an adult sinks >2 cm.

Firm mud/sand (Low mud content): A sand/mud mixture dominated by sand with a low mud fraction (e.g. 1-10%), the mud fraction conspicuous only when sediment is mixed in water. The sediment appears brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm or soft mud, and very soft mud. When walking you'll sink 0-2 cm. Granular when rubbed between the fingers.

Firm mud/sand (Moderate mud content)
A subjective division may be applied where the sand/mud mixture remains dominated by sand, but with an elevated mud fraction (e.g. 10-25%), the mud fraction visually conspicuous when walking on it. The surface appears brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm mud/sand with a low mud content, firm or soft mud, and very soft mud. When walking you'll sink 0-2 cm. Granular when rubbed between the fingers, but with a smoother consistency than firm muddy sand with a low mud fraction.

Firm or soft mud/sand (High mud content): A mixture of mud and sand where mud is a major component (e.g. >25%-50%mud). Sediment rubbed between the fingers retains a granular component but is primarily smooth/silken. The surface appears grey or brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm muddy sand, firm sandy mud, and very soft mud. Classified as firm mud if an adult sinks <2 cm (usually if sediments are dried out or another component e.g. gravel prevents sinking) or soft mud if an adult sinks 2-5 cm.

Very soft mud/sand (Very high mud content): A mixture of mud and sand where mud is the major component (e.g. >50% mud), the surface appears brown, and may have a black anaerobic layer below. When walking you'll sink >5 cm unless another component e.g. gravel prevents sinking. From a distance appears visually similar to firm muddy sand, and firm or soft mud. Sediment rubbed between the fingers may retain a slight granular component but is primarily smooth/silken. From a distance appears visually similar to firm muddy sand, and firm or soft mud.

Mud (Very high mud content): A >90% mud dominated substrate with sand a minor component. Smooth/silken when rubbed between the fingers. When walking you'll sink >5 cm unless another component e.g. gravel or sediment drying prevents sinking.

Cockle bed /Mussel reef/ Oyster reef: Area that is dominated by both live and dead cockle shells, or one or more mussel or oyster species respectively.

Sabellid field: Area that is dominated by raised beds of sabellid polychaete tubes.

Shell bank: Area that is dominated by dead shells.

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Certificate of Analysis

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SPv1

Client:	Salt Ecology Limited	**Lab No:**	2119220
Contact:	Leigh Stevens C/- Salt Ecology Limited 21 Mount Vernon Place Washington Valley Nelson 7010	**Date Received:**	05-Feb-2019
		Date Reported:	27-Mar-2019
		Quote No:	97111
		Order No:	
		Client Reference:	Waikawa, Kai Iwa and Mowhanau Estuaries
		Submitted By:	Leigh Stevens

Sample Type: Sediment

Sample Name:		MOWHANAU 01-Feb-2019	KAIIWI A 01-Feb-2019	KAIIWI B 01-Feb-2019	KAIIWI C 01-Feb-2019
Lab Number:		2119220.1	2119220.2	2119220.3	2119220.4
Individual Tests					
Dry Matter of Sieved Sample	g/100g as rcvd	78	80	64	79
Total Recoverable Phosphorus	mg/kg dry wt	650	350	440	220
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	0.11	< 0.05
Total Organic Carbon*	g/100g dry wt	0.19	0.13	1.59	0.22
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg					
Total Recoverable Arsenic	mg/kg dry wt	3.6	2.2	2.8	1.8
Total Recoverable Cadmium	mg/kg dry wt	0.015	0.016	0.038	0.011
Total Recoverable Chromium	mg/kg dry wt	13.1	10.8	15.3	7.6
Total Recoverable Copper	mg/kg dry wt	5.2	4.0	6.2	2.3
Total Recoverable Lead	mg/kg dry wt	3.2	3.5	6.5	2.4
Total Recoverable Mercury	mg/kg dry wt	< 0.02	< 0.02	0.02	< 0.02
Total Recoverable Nickel	mg/kg dry wt	8.0	7.7	10.6	5.2
Total Recoverable Zinc	mg/kg dry wt	46	33	42	21
3 Grain Sizes Profile					
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	93.6	88.4	60.0	91.1
Fraction < 63 µm*	g/100g dry wt	6.3	11.6	40.0	8.8

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-8
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-8
Dry Matter for Grainsize samples	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-8
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-8
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-8
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-8
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-8
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-8
3 Grain Sizes Profile			
Fraction >/= 2 mm*	Wet sieving with dispersant, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-8
Fraction < 2 mm, >/= 63 µm*	Wet sieving using dispersant, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-8
Fraction < 63 µm*	Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-8

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental

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