He Pātaka Wai Ora Project

Environmental Monitoring on the Waikouaiti River

Fieldwork date

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Report date

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View of the Waikouaiti River Estuary with Hikaroroa (Mount Watkin, left) and Pahatea (Derdan Hill, right).

Foreword

I te timatanga mai, ko ngā atua Māori, nā rātou ngā mea katoa I hanga.

Kia maumahara tonu mātou ki a rātou.

E ngā mate kua hinga mai kua hinga atu. Moe mai rā.

Ki a tātou e ngā mataora,

Tēnā tātou katoa.

Mauri Ora

This project is a further collaboration between K̲āti Huirapa ki Puketeraki and researchers. This is a scientific report that adds one more piece to a puzzle. It represents a year of collecting information from our river.

This mahi forms part of an intergenerational restoration effort. The information within this report will help the community and kaitiaki in their decisions around our river restoration efforts.

He Pātaka Wai Ora is part of the relationship between K̲āti Huirapa and Otago University. Although the concept is old, the catalyst came maybe two or three years ago. It involved a typically cryptic conversation with one of our whānau, some old maps and the statement: "Do whatever you like with this stuff", or words to that effect.

It is hoped that this report, although restricted to Waikouaiti Awa, may encourage other Hapū, Whānau, and communities to use similar methods in understanding how their waterways are being impacted by land-use.

Importantly, it demystified, for us, some science, it confirmed some things that we knew, and answered some things that we did not know.

We wish to recognise the work and knowledge of our kaumātua and elders of the community, particularly the passion of our Taua Mahana Walsh, a rak̲atira of K̲āti Huirapa, and supporter of our kaitiakitak̲a. Moe mai rā e Taua.

Each passing has leaves a void; a space to be filled by their descendants. Equipped with Mātauraka Māori and an understanding of modern science, our young ones inherit a world very different from the one in those old maps.

Ko Hikaroroa te Mauka

Ko Waikouaiti te Awa

He Pātaka Wai Ora

From our mountain to the sea,

Our place will again be a rich food store.

Brendan Flack, Karitāne 18th of July 2016

Executive Summary

The Waikouaiti River is an integral part of the identity of Kāti Huirapa Rūnaka ki Puketeraki (Rūnaka). The river plays a crucial role in mahika kai[1] and kaitiakitaka, evident from the many significant cultural sites found in the catchment area. The Waikouaiti River and Estuary provide important habitat for many native species including īnaka and tuna. Kāti Huirapa ki Puketeraki and the wider community at Karitāne have raised concerns regarding the degradation of the river and local mahika kai sites as a result of anthropogenic activities such as farming and forestry.

The He Pātaka Wai Ora project was developed to enable Kāti Huirapa ki Puketeraki to identify river health issues in the Waikouaiti River, and prioritise restoration efforts in the catchment.. The aim of this yearlong project was to collect scientific information guided by Mātauraka Māori to provide a baseline understanding of the current state of the Waikouaiti River and important mahika kai sites. The information reported in this document was informed by a community hui and the monitoring of environmental and ecological parameters indicative of freshwater health. This ongoing Rūnaka led project is an important part of the 200-year plan to restore the pātaka of the Waikouaiti River.

The main conclusions drawn from a year of scientific / ecological monitoring include:

- Ammonium concentrations in lower catchment (estuary) sites often exceeded ANZECC (Australian and New Zealand Environment and Conservation Council) & ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand) trigger levels,
- A spike in nitrate concentrations observed in Winter is a regular occurrence in the Waikouaiti River,
- There is a low cover of canopy species and native vegetation,
- The upper catchment site (El Dorado) has low numbers of EPT (*Ephemoptera* / mayflies; Plectoptera / stoneflies and; *Trichoptera* / caddisflies) species which sensitive to pollutants,
- There is a clear pattern of increasing fine sediments in lower catchment / estuary sites,

[1] We have chosen to utilise the Kāi Tahu dialect which uses the 'k' rather than 'ng' because this is the primary dialect of Kāti Huirapa ki Puketeraki, the location of this research. For example, mahika instead of mahinga and for further clarity we have underlined the k, for example mahika.

- Clear patterns in conductivity suggest that the marine / estuarine influence reaches as high as Whakapatukutu (Orbell's Crossing), and

From these conclusions, several recommendations regarding the restoration of the Waikouaiti River have been established. These include:

1. Continue building awareness of river water quality and building relationships within the community.
2. Continue sampling at sites to add to the baseline information. Sampling once a month would be sufficient to detect and monitor trends over time and standard operating procedures for monitoring should be developed.
3. Develop cultural and ecological monitoring methods for the Waikouaiti Estuary. No suitable "pre-packaged" tools currently exist for estuarine environments. Any new tool should consider human use of the estuary as a primary indicator of estuary health.
4. Encourage the development of appropriate research projects by reporting findings and sharing with other researchers.
5. Investigate the Merton Tidal Arm and the possible nutrient source which was detected at Te Tauraka a Waka, a site which is likely influenced by this tributary. Consider the influence from other tidal arms on the water quality of the Waikouaiti Estuary.
6. Site A (The Culvert) and Site B (The Main Road) are not characteristic of the main branch of the river and dry out at certain times of the year. It is proposed that these sites be removed from regular sampling (and add sites elsewhere, see below).
7. Future environmental monitoring programmes should consider the influence of logging operations on the South Branch.
8. A site (or sites) should be added on the South Branch of the river and just above the confluence of the North Branch for future monitoring. This could aid in distinguishing catchment scale processes (which will be seen in both branches) and land use effects (which may be localised to one branch).
9. Develop a catchment re-vegetation and habitat restoration plan. The overall strategy should be coordinated to maximise the long-term improvement of water quality and habitat.
10. Continue building information regarding the cultural and historical knowledge of the sites.

The information gathered during He Pātaka Wai Ora will become more useful over time as the established framework can help monitor the success and failure of restoration efforts. While the general principles and approach taken during this project can be applied by other communities in New Zealand, it is important to highlight that the results and recommendations discussed are specific to the Waikouaiti River. The ongoing success of this project relies on the community's commitment to restoring the environment and the continued support of new and existing relationships with land owners, councils, researchers and others.

Acknowledgements

The people listed here have played a crucial role in the success of the work carried out on the Waikouaiti River. For example, two of the sites were only accessible through farmland and access would not have been achieved without community engagement. We appreciate the contribution of those who freely shared their knowledge and time to support this project. He Pātaka Wai Ora would not have been possible without the important contributions of those listed below and others not listed that contributed at the hui and in other ways.

We would like to thank:

Daniel Tipa, Nigel Scott, Matt Wylie, Justine Marshall, Jo Silich, Margaret McFarlane, Blake Hornblow, Isla Twigg, Rosa Edwards, Cairo Griffin, Hayley Bungard, Ben Russell, Landowners at Four Rivers Farms, Lex and Evan at Hurst Holdings, Peri Subritzky, Derek Richards, Waiariki Parata-Taiapa, Ian Gover, Hauteruruku ki Puketeraki, Anne-Marie Jackson and whānau, Tā Whakaea Hou, Patti and Joel Vanderburg, River Estuary Care Waikouaiti Karitāne ,the East Otago Taiāpure Management Committee and,Te Ohu Kai Moana.

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Background

Kāti Huirapa has had strong connections to the land and sea since their tūpuna arrived in Te Waipounamu (see Glossary for definition of Māori words and phrases). The histories and identities of Rapuwai, Waitaha, Hāwea, Kāti Mamoe and Kāi Tahu have formed the whakapapa of the hapū Kāti Huirapa, and the wider iwi, Kāi Tahu (Prebble & Mules 2004). The takiwā of Kāti Huirapa ki Puketeraki ranges from Waihemo, or Shag River, in the north to Purehurehu point, south of Whareakake Beach (also known as Murdering Beach) in the south. Inland it extends to the Main Divide. Kāti Huirapa ki Puketeraki also shares interests with southern rūnaka in the Ōtepoti, Ōtākou and inland Whakatipu-Waitai areas (Te Runanga o Ngai Tahu Declaration of Membership Order 2001). The takiwā centres at Karitāne and includes the mauka Hikaroroa, which represents the paramount ancestor and one of the crew members of Araiteuru, the ancestral waka (Te Runanga o Ngai Tahu Declaration of Membership Order 2001; Prebble & Mules 2004).

The landscape has many significant cultural sites indicative of the historical abundance of kai which encouraged the continued residence of the people and their connection to the environment (Kāti Huirapa ki Puketeraki 2014; Prebble & Mules 2004). These sites include pā at Huriawa and Mapoutahi, nohoaka, urupā, mahika kai sites, key habitats for taoka species and the Waikouaiti Fishing Easement granted in 1868, locally known as 'the hatchery' (Kāi Tahu ki Otago 2005; Hamel 2001; Kāti Huirapa ki Puketeraki 2014). Archaeological excavations of middens provide evidence for the variety and abundance of fish, bird and shellfish species once found in the area (Hamel 2001). Many narratives, passed down through generations, describe the strong associations with the land and the tikaka that have developed over successive generations (Kāi Tahu ki Otago 2005).

The identity of Kāti Huirapa ki Puketeraki is bound to the Waikouaiti River, which runs through this treasured landscape (Waikouaiti Mātaitai Application 2004). The Waikouaiti River encapsulates the idea of *Ki Uta Ki Tai* (from the mountains to the sea), providing a physical connection between the land and the sea. Historically, the river provided an abundance of resources and was important for Kāti Huirapa to have the ability to exercise kaitiakitaka and mana whenua, protecting the taoka for future generations (Kāi Tahu ki Otago 2005). The quantity of natural resources also allowed for manaakitaka, the ability for Kāti Huirapa to provide hospitality and welcome their guests with food. Many mahika kai sites were identified by Hori Kerei Taiaroa after a hui was held in Waikouaiti on the 26th May

1880 where those present identified areas of importance (Williams 2010). The Waikouaiti River and estuary provides habitat and spawning grounds for a variety of species (Prebble & Mules 2004; Kāti Huirapa ki Puketeraki 2014). These species include (see Glossary for common and scientific names):

- Tuna, pātiki, īnaka, kanakana
- Pipi, tuaki, tuatua, wai kōura, kākahi
- Pūtakitaki
- Watercress, harakeke, fern, puha, ti

The Waikouaiti River is situated 25 km north of Dunedin, with the river mouth located at Karitāne (Figure 1). The Waikouaiti catchment area is about 425km^2 and is made up of a northern branch (283km^2) originating near Macraes Flat, and a southern branch (87km^2), originating at Silver Peaks (Dale 2011; Otago Regional Council 2010). Despite the south branch being significantly smaller and shorter (27km long compared to 57km), the flow rate is similar between the two branches due to the higher annual rainfall that occurs in the southern catchment area (Dale 2011). The low and irregular rainfall in the catchment of the northern branch can sometimes result in extremely low flows (Prebble & Mules 2004). The two branches converge about 8km upstream from the river mouth; the lower 5km flows through an estuarine environment with inflow from the Merton Tidal arm, a tributary stream (Dale 2011; Otago Regional Council 2010). Due to the historical associations to the Merton Tidal Arm, Te Tauraka ā Pōti, it is recognised as a Statutory Acknowledged Area under the Ngāi Tahu Claims Settlement Act 1998, s60.

The Waikouaiti Estuary is considered a 'regionally significant wetland' under Schedule 9 of the Regional Plan: Water for Otago 2016 (Otago Regional Council 2016). Wetlands are important for mahika kai and provide essential habitat for adult and juvenile fish, and spawning sites for many native species (Kāi Tahu ki Otago 2005). The estuary is also a valuable feeding area for wading birds (Lloyd *et al.* 2015). The estuary has been significantly modified; by 1968 all tidal arms had been cut off from the estuary except for the Merton tidal arm and it had been estimated that by the 1980s, the estuary had been reduced by 40%. A court case provides evidence for the concern of this lost land (The Otago Acclimatisation Society v. The Otago Catchment and Regional Water Boards and Carter 1988).

The landscape surrounding the Waikouaiti River has been extensively modified for agriculture and logging which has resulted in the replacement of tussock and native forest with pasture and exotic trees (Dale 2011). Tussock grassland is particularly important for collecting precipitation such as fog and rain and therefore enhancing water yield and river flow (Mark & Dickinson 2008). The developments in the Waikouaiti catchment have resulted in increased levels of nutrients in the river due to fertiliser run-off and sewage discharge which can cause algal blooms and a reduction in oxygen (Abell *et al.* 2011a). Logging causes erosion which can lead to increased sediment input into river; the logging operation in the South Branch of the Waikouaiti River is a concern (Prebble & Mules 2004). Over time there has been a build-up of sediment in the Waikouaiti Estuary, which has reduced access to the area by waka or boat (Prebble & Mules 2004). These problems have been exacerbated by the loss of riparian vegetation which helps reduce nutrient input, and the reduction in flow from water abstraction which can help flush nutrients and sediment (Davies-Colley 2013; Dale 2011).

The significant role the Waikouaiti River plays in mahika kai, kaitiakitaka, ecological function and the spiritual connection of Kāti Huirapa ki Puketeraki to the land and sea, was the reason behind the establishment of the Waikouaiti Mātaitai (the Mātaitai) which was granted in March, 2016 (Fisheries Declaration of Waikouaiti Mātaitai Reserve Notice 2016). The Mātaitai, which aims to ensure the customary management and protection of fisheries resources and mahika kai for Kāi Tahu whānui on the Waikouaiti River, overlaps with the East Otago Tāiapure which was established in 1999 (Kāti Huirapa ki Puketeraki 2014; Hepburn *et al.* 2010). Both these management areas indicate the commitment that Kāti Huirapa ki Puketeraki and the wider community have to protecting and enhancing their connection to the environment and honouring their whakapapa for future generations.

Kāti Huirapa ki Puketeraki have noted the degradation of the river which has impacted their access to mahika kai and led to a loss of mana. The key threats to the Waikouaiti River have been identified in the Natural Resource Management Plan (Kāi Tahu ki Otago 2005) as:

- Algal blooms in the Waikouaiti Estuary due to increased nutrients
- Excessive water abstraction
- Sedimentation in the lower parts of the river impacting shellfish and reducing boat access

- Reduced riparian vegetation due to the grazing of livestock having an impact on spawning sites for īnak̲a
- Reclaimed land on estuary

As part of State of the Environment (SoE) reporting, water monitoring occurs at Whakapatukutu (Orbell's Crossing), upstream from the Waikouaiti Estuary. According to the Water Quality Index, the water quality of the Waikouaiti River was deemed to be "very good" between 2006 and 2010 and "excellent" between 2010 and 2015 (Ozanne 2012; Otago Regional Council 2015). Nutrient levels, *E. coli*, sediment and various other factors are measured to establish the index of water quality. However, Ministry for the Environment & Statistics New Zealand (2015) reported that overall, New Zealand's freshwater environments had shown increased levels of the nutrients nitrogen and phosphorous, and water quality had declined in areas that were used extensively for agriculture. Despite the improvement in water quality shown by the State of the Environment reports, the observations of K̲āti Huirapa ki Puketeraki (as described above, Kāi Tahu ki Otago 2005), which have been established over a longer time period, indicate that the health of the Waikouaiti River has declined. This shows the need to incorporate both Mātaurak̲a Māori and science when determining the health of the environment and how to successfully manage or restore it (Harmsworth et al. 2011).

In 2014, K̲āti Huirapa Rūnaka ki Puketeraki applied to Te Wai Māori Trust for funding through the Wai Ora Fund, a programme set up to help iwi and hāpu manage and protect their freshwater resources (Kāti Huirapa Rūnaka ki Puketeraki 2015; Wai Māori 2015). The aim was to initiate a Rūnak̲a led project that made better provisions for kaitiakitak̲a and the protection of mahik̲a kai on the Waikouaiti River. By collecting scientific information guided by Mātaurak̲a Māori, He Pātaka Wai Ora aimed to gain a baseline understanding of the state of the Waikouaiti River and mahik̲a kai, enabling K̲āti Huirapa ki Puketeraki to identify priority areas for restoration (Wai Māori Application 2014). The holistic approach taken in this project has been guided by that used in the State of the Takiwā, a reporting programme established by Te Rūnanga o Ngāi Tahu which enables tāk̲ata whenua to participate in the monitoring of the state of their natural resources and incorporates their values as part of the assessment (Te Rūnanga o Ngāi Tahu 2001).

This report provides the results of a yearlong project. It includes information gathered at a community hui and key environmental and habitat parameters indicative of river and estuarine health. The data in this report is primarily derived from Western science methodologies with information on key chemical, physical and ecological factors that reflect the health of the Waikouaiti River. The sampling programme was guided by Mātaurak̲a and other local knowledge held by kaitiaki and was designed to address local issues. The information provided is intended to empower the local community by providing an additional tool to use alongside the knowledge held by local people who know the Waikouaiti River best. The baseline information gathered in this project will be provided to Tāk̲ata Tiaki / Kaitiaki and managers of the East Otago Taiāpure and the Waikouaiti Mātaitai to help make informed decisions on the management and restoration of important mahik̲a kai sites. Identification of anthropogenic impacts on the Waikouaiti River will help prioritise restoration efforts, which is a key step in the 200-year plan to restore the pātaka of the River.

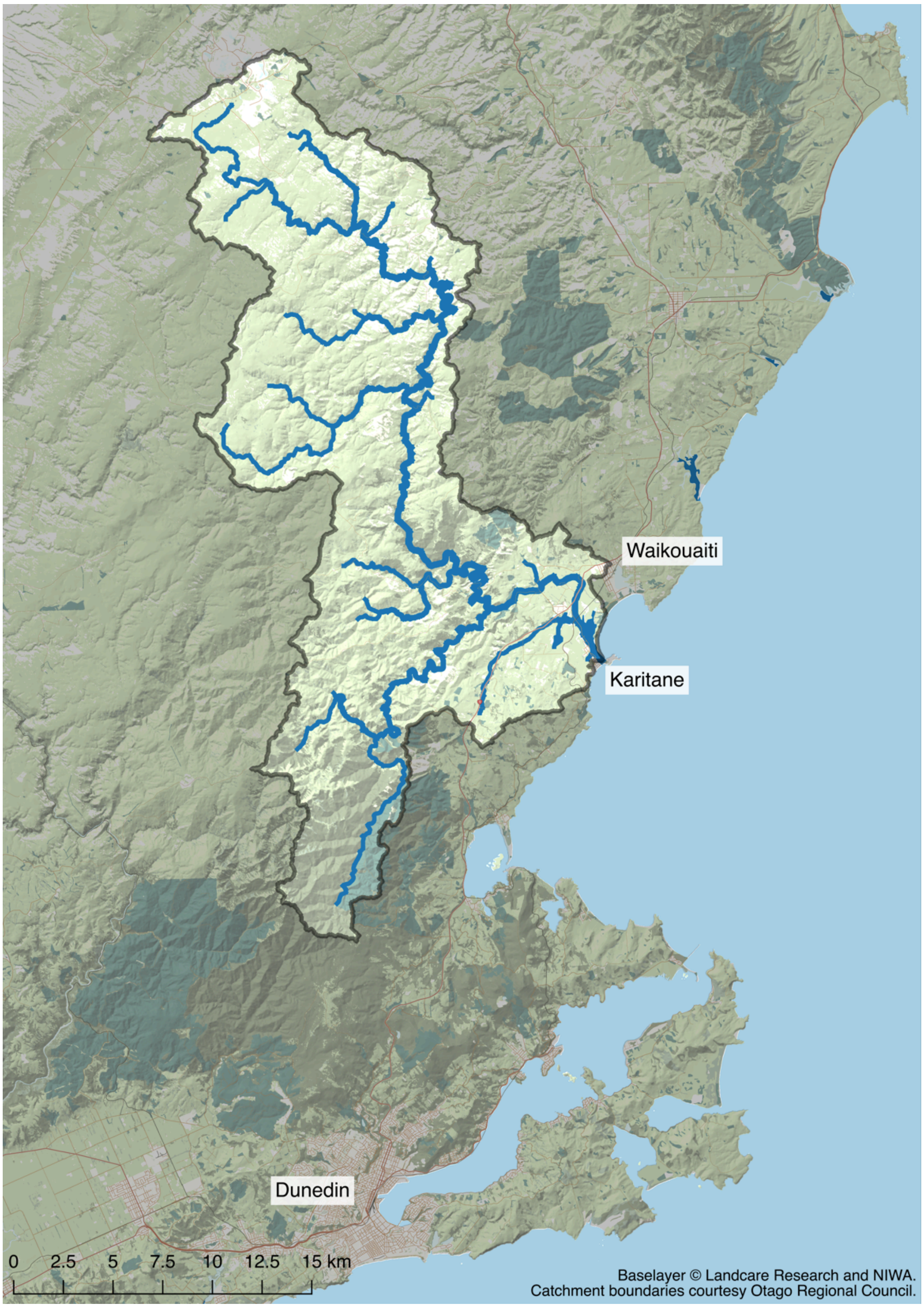

Figure 1: Map of the Waikouaiti River catchment showing the Waikouaiti River and Estuary and main tributaries.

Introduction

Freshwater systems are an important source of food and water for domestic and agricultural use; the systems also provide the means for power generation and a landscape for recreational activities (Malmqvist & Rundle 2002). The degradation of freshwater ecosystems due to pollution, water abstraction, invasive species, intensified agriculture and logging, nutrient loading and over-fishing have been documented globally (Meybeck & Helmer 1989; Allan & Flecker 1993; Kindler 1998; Jackson *et al.* 2001; Meyer & Wallace 2001; Postel & Richter 2003; Galloway *et al.* 2004; Mathers *et al.* 2016). This degradation has had a substantive impact on species biodiversity, ecosystem functions and the health of the people who rely on freshwater resources (Dudgeon *et al.* 2006). Within New Zealand, urban development and the intensification of agricultural practices have placed immense pressure on rivers, lakes and wetlands (Ministry for the Environment 2016). Rivers, in particular, are sensitive to any anthropogenic activity within the catchment area as any impact upstream can have lasting effect downstream, including the coastal waters into which the river flows (Malmqvist & Rundle 2002; Tysmans *et al.* 2013). Although point source pollution (discharge from pipes such as sewerage systems) in New Zealand waters has decreased over the last two decades, diffuse source pollution as a result of run-off from urban and agricultural land-use areas remains a significant problem. Farms account for 46% of the land surrounding New Zealand's rivers and are the source of excess sediment and nutrients such as nitrogen, phosphorus and ammonia; these issues are made worse by water abstraction which reduces river flow (Hickey & Vickers 1994; Ministry for the Environment 2016).

Environmental parameters as indicators of aquatic ecosystem health

A number of parameters are measured to indicate the health of rivers and estuaries; these include nutrient concentration (particularly nitrogen and phosphorus), conductivity, pH, dissolved oxygen, water temperature, and bioindicators such as invertebrates and riparian or instream vegetation. To interpret the measurement of these variables, "trigger values" have been established for physical (e.g. temperature) and chemical (e.g. nutrients) measurements in New Zealand freshwater environments. If these values are exceeded during monitoring, this indicates a potential problem with the water quality and therefore initiates or triggers a management response (ANZECC & ARMCANZ 2000). Trigger values have been developed by the National Institute of Water and Atmospheric Research (NIWA) based on 80^{th} and 20^{th} percentiles using ten years of data in the National Rivers Water Quality Network (NRWQN). These percentiles were chosen arbitrarily. With nutrient concentrations, for example, the 20^{th}

percentile, or lower limit, is an appropriate parameter value whereas the 80th percentile, or higher limit, indicates low water quality (Davies-Colley 2000).

Nutrients

Excessive nutrient levels, also known as eutrophication, is a major problem that reduces water quality in New Zealand (Ministry for the Environment & Statistics New Zealand 2015). While natural sources of nutrients in freshwater systems are crucial for supporting important food sources such as plant life and algae, the intensification of agriculture and the use of fertiliser has resulted in increased levels of nutrients entering New Zealand waterways (Abell *et al.* 2011b; Ministry for the Environment & Statistics New Zealand 2015). Eutrophication can lead to an excessive algal growth (algal blooms) which decreases dissolved oxygen, covers important habitat for macroinvertebrates and negatively impacts the aesthetics of the landscape (Biggs 2000; Abell *et al.* 2011a). Low dissolved oxygen levels are detrimental to plant, algae, fish and freshwater invertebrate populations (McDowell & Hamilton 2013). The cyanobacteria *Phormidium* can produce cyanotoxins that can impact the nervous system, liver or irritate the skin. These toxins have been known to cause the deaths of dogs in New Zealand and may have significant impacts on mahika kai species and people drinking from waterways where algal growth occurs (Hamill 2001; Wood *et al.* 2007). Common sources of excess nutrients in waterways include livestock excretion, fertiliser run-off, deforestation and sewage systems (Dodds 2002).

As part of the State of the Environment reporting programme, the Otago Regional Council monitors nutrient levels in the Waikouaiti River on a bi-monthly basis at Whakapatukutu (Orbell's Crossing). Nutrients of interest are ammoniacal nitrogen, total nitrogen and total phosphorus (Otago Regional Council 2008). Most algal growth in New Zealand freshwater systems is limited by the levels of nitrogen and phosphorus (Abell *et al.* 2011a). Consequently, an increase in either nutrient has the potential to change the balance of the ecosystem which is why monitoring these parameters is so important (Quilbé *et al.* 2006). Due to the dynamic nature of rivers, nutrient input may vary on a spatial and temporal scale. Spatially, nutrient load changes according to land-use along the river or the geomorphology of the catchment (Tysmans *et al.* 2013; Wagner *et al.* 2008). Temporal variability may be caused by nutrient pulses from fertiliser events, or heavy rainfall and these trends are often seasonal (Royer *et al.* 2006). The scale at which nutrients are measured in a river is therefore an important consideration in order to understand patterns of nutrient input and identify the possible sources, allowing for better management of water quality (Wagner *et al.* 2008).

Nutrient concentrations in water can be measured directly by analysing water samples. This method can be expensive, as it requires specialist equipment. Alternatively, indirect measurements can be made based on the effects nutrients have on the biological components of freshwater habitats such as algae, plants and animals.

Conductivity

Conductivity is the ability of water to conduct electricity and is measured based on the total number of ions (charged compounds) dissolved in water; the higher the concentration of dissolved ions, the higher the conductivity (Dodds 2002). Conductivity increases with low flows and decreased dilution, causing an increase in ion concentrations (Caruso 2002). Anions (negatively charged) such as carbonate (HCO_{3-}), sulphate (SO_4^{2-}) and chloride (Cl^-) and cations (positively charged) such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+) and potassium (K^+) are the main contributors to conductivity in freshwater systems (Wetzel 2001).

In estuaries, or freshwater environments with coastal influences, conductivity is related to salinity, the concentration of salt (sodium chloride), and provides information on the interaction between fresh river water and saline seawater (Wetzel, 2001). The Waikouaiti Estuary exhibits a salt wedge due to a distinctive vertical wedge-shaped boundary that exists between the river water and the sea water, formed by freshwater flowing over the denser salt water (Dale 2011). Conductivity can also be related to the concentration of nutrients in freshwater systems with conductivity increasing as nutrients increase (Dodds 2002). Many fertilisers are made up of nitrates (NO_2^- and NO_3^-), ammonium (NH_4^+) and phosphate (PO_4^{3-}), which in high concentrations can contribute to conductivity (Ministry for the Environment & Statistics New Zealand 2015; Wetzel 2001). Therefore, conductivity varies based on saltwater intrusion and runoff as well as other factors such as evaporation, rainfall and the local geology (Wetzel 2001; Moss 2010).

Conductivity is easy to measure, the quantitative unit being micro-Siemens (µS). The conductivity of seawater is usually above 50000µS, while the conductivity of freshwater is generally below 500µS (Wetzel 2001). Freshwater organisms exhibit a wide range of tolerance towards conductivity, however, conductivity above 1500µS can cause reduced growth rates in aquatic plants, and be toxic to macroinvertebrate communities (Nielsen *et al.* 2003; Hart *et al.* 1991).

pH (acidity)

pH is the concentration of hydrogen ions, and is measured on a scale of 0 (acidic) to 14 (basic or alkaline), most aquatic ecosystems have a neutral pH range of 6.0-8.0 (Dodds 2002). Changes in pH can reduce biodiversity and have an impact on the metabolic functions and community composition of freshwater ecosystems; low pH can also cause toxic metals to become more soluble (Weisse *et al.* 2006; Dodds 2002; Beklioğlu & Moss 1995). Pollution and increased carbon dioxide in the atmosphere can decrease the pH of freshwater (Moss 2010).

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen (O_2) dissolved in water and can vary according to temperature, atmospheric pressure, and the respiration and photosynthesis of instream biota (Dodds 2002). Warmer waters tend to have lower DO concentrations due to decreased solubility of O_2 and increased respiration of microbes (Townsend 1999). DO concentrations fluctuate daily and tend to increase during the day due to photosynthesis of algae and macrophytes, and decrease during the night due to respiration (Wetzel 2001).

Water bodies with decreased DO concentration are referred to as hypoxic or, if more extreme, anoxic (Biggs 2000). Hypoxic and anoxic environments in New Zealand are generally the result of eutrophication (Landman *et al.* 2005). The uptake of excessive nutrients by algae and aquatic plants causes excess growth followed by the depletion of nutrients and decomposition (McDowell & Hamilton 2013). The decomposition process requires oxygen, and DO concentrations can drop leading to the death of native and introduced fish species and impacts to invertebrate communities (Quinn & Gilliland 1989; Dean & Richardson 1999; Landman *et al.* 2005).

Water Temperature

Water temperature varies daily and seasonally. Daily fluctuations are due to sun exposure, while seasonally, maximum temperatures in New Zealand waters occur in February due to increased sun exposure and low water flows (Davies-Colley 2000). Increased water temperatures can be lethal for many freshwater fish species and can contribute to algal blooms (Tramer 1977; Stanley *et al.* 1997). The metabolic rate of most freshwater species increases with higher temperatures and as a result they require more oxygen. However, oxygen solubility decreases with increased water temperature (Kalff 2000). Consequently, increased water temperature results in reduced DO but also increased demand for DO significantly impacting freshwater communities (Ficke *et al.* 2007).

Habitat and biological indicators of aquatic ecosystem health

Freshwater invertebrates have an important role in freshwater ecosystems as predators, filterers, grazers and a food source for many fish (Wallace & Webster 1996). Most rivers have a high biodiversity of macroinvertebrate species, which exhibit a wide range of known water quality tolerances (Lenat 1993). As a result, invertebrates are good indicators of the impact of anthropogenic factors on freshwater ecosystems (Karr 1993; Wallace & Webster 1996). The use of invertebrates as biological indicators in the monitoring of freshwater environments is becoming more popular as they are easy to collect (Harris & Silveira 1999). In terms of mahi<u>k</u>a kai on the Waikouaiti River, important invertebrates include kōura (freshwater crayfish; *Paraephrops sp.*) and kākahi (freshwater mussel; *Hyridella menziesii*; Prebble & Mules 2004).

Vegetation growing on the edges of waterways, also known as riparian vegetation, plays an important role in filtering run-off and reducing the amount of nutrients, contaminants and sediment going into the water (Dodds 2002). The vegetation in the Waikouaiti River catchment has been extensively modified due to agriculture and forestry (Dale 2011). The presence of native vegetation is an important indicator in cultural health assessments in New Zealand and provides valuable habitat and breeding areas for mahi<u>k</u>a kai species (Pauling 2007).

There are several commonly used methods to measure freshwater health in New Zealand, including the Macroinvertebrate Community Index (MCI) and the Stream Health Monitoring and Assessment Kit (SHMAK) (Biggs *et al.* 2002; Caruso 2002). These assessment tools measure biological indicators such as macroinvertebrates and vegetation, and various physical and chemical water quality parameters to establish a rating that indicates how healthy the freshwater system of interest is. These assessment tools yield comparable results in regard to the health of freshwater environments (Kilroy & Biggs 2002). The MCI was developed in New Zealand in 1985 and is widely used throughout the country to assess the health of streams and rivers (Stark 1985; Ozanne 2012). This system uses the variable tolerances of certain macroinvertebrates to pollution and establishes a score between 0 and 200 which indicates the health of the water (Ozanne 2012; Stark 1985). Low values indicate the presence of macroinvertebrate groups that are highly tolerant to pollution while high values indicate the presence of groups found only in healthy waters (Stark 1985). The SHMAK was developed in New Zealand in 1998 with the aim of encouraging farming communities to assess the health of their streams (Biggs *et al.* 2002). An updated version was released in 2002 which provided the wider community and kaitiaki with a tool to monitor freshwater ecosystems and better manage resources (Biggs *et al.* 2002). This assessment kit has simplified versions of the methodology found in the MCI assessment and is easier and cheaper to implement (Biggs *et al.* 2002).

Methods

Hui

A hui was held on the 14th April 2015 at Puketeraki Marae to discuss the He Pātaka Wai Ora Project with the community. More than 40 people attended, representing interest groups such as members of K̲āti Huirapa ki Puketeraki, the local community, tāk̲ata tiaki, local farm owners, commercial eeling, recreational fishers, Department of Conservation, Otago Regional Council, Dunedin City Council, University of Otago Zoology, Marine Sciences Departments and School of Physical Education, Sport and Exercise Sciences, River-Estuary Care, Beyond Orokonui, and Fish and Game. The meeting minutes for the hui were recorded.

An overview of the project was discussed including the basic objectives and particular focus was placed on the mahik̲a kai sites on the Waikouaiti River and their restoration. A GIS overview was provided with a focus on existing information to provide spatial context and highlight the extent of the river. Historical maps of the area dating back to 1885 were presented to give an idea of, and evidence for, how the river had changed over time. The intended outcomes of the project were discussed, these were to provide the means to co-ordinate any restoration effort on the Waikouaiti River by indicating areas of priority, particularly where habitat for mahik̲a kai species had degraded, and to provide an established project when applying for future funding.

A series of A0 pieces of paper were placed on the wall of the wharenui, with seven different titles which included: places of value; species of value; memories of the river; areas of concern; how will the future look (the river in 100 years); offers of help/contributions; comments/thoughts. Those attending the meeting were encouraged to write their thoughts regarding these themes on Post-it notes and place them under the appropriate title. Following this process, an active discussion with participants took place, focusing on issues, values, and aspirations regarding the project and the Waikouaiti River.

Site selection and physical characterisation

Site selection

Information gathered from the hui detailed above, and historical documents regarding the Waikouaiti River and mahik̲a kai from Toitū Otago Settlers Museum and HK Taiaroa (1880) were used to guide the selection process for the monitoring sites for the He Pātaka

Wai Ora Project. Sites were chosen to represent freshwater, estuarine and marine environments.

Nine mahika kai sites were selected as a result of the information collected at the hui (see Results, below) and from the historical documents (Figure 2). Two additional sites, Site A and Site B, were added later in October 2015 as a result of discussions with the local landowner who intended to carry out restoration at these sites. The ability to quantify the current state of these sites was important in order to establish the effectiveness of this proposed restoration.

Four sites were classified as Waimāori (freshwater): El Dorado, Hakariki, Te Pari Kouau and Whakapatukutu (Orbell's Crossing). Six sites were classified as Waimāori/Waitai (estuarine): Site A, Site B, Okauia, Te Tauraka a Waka (waka landing site), Te Taumata a Puaka, and Ohinepouwera. One site was classified as Waitai (salt water): Huriawa.

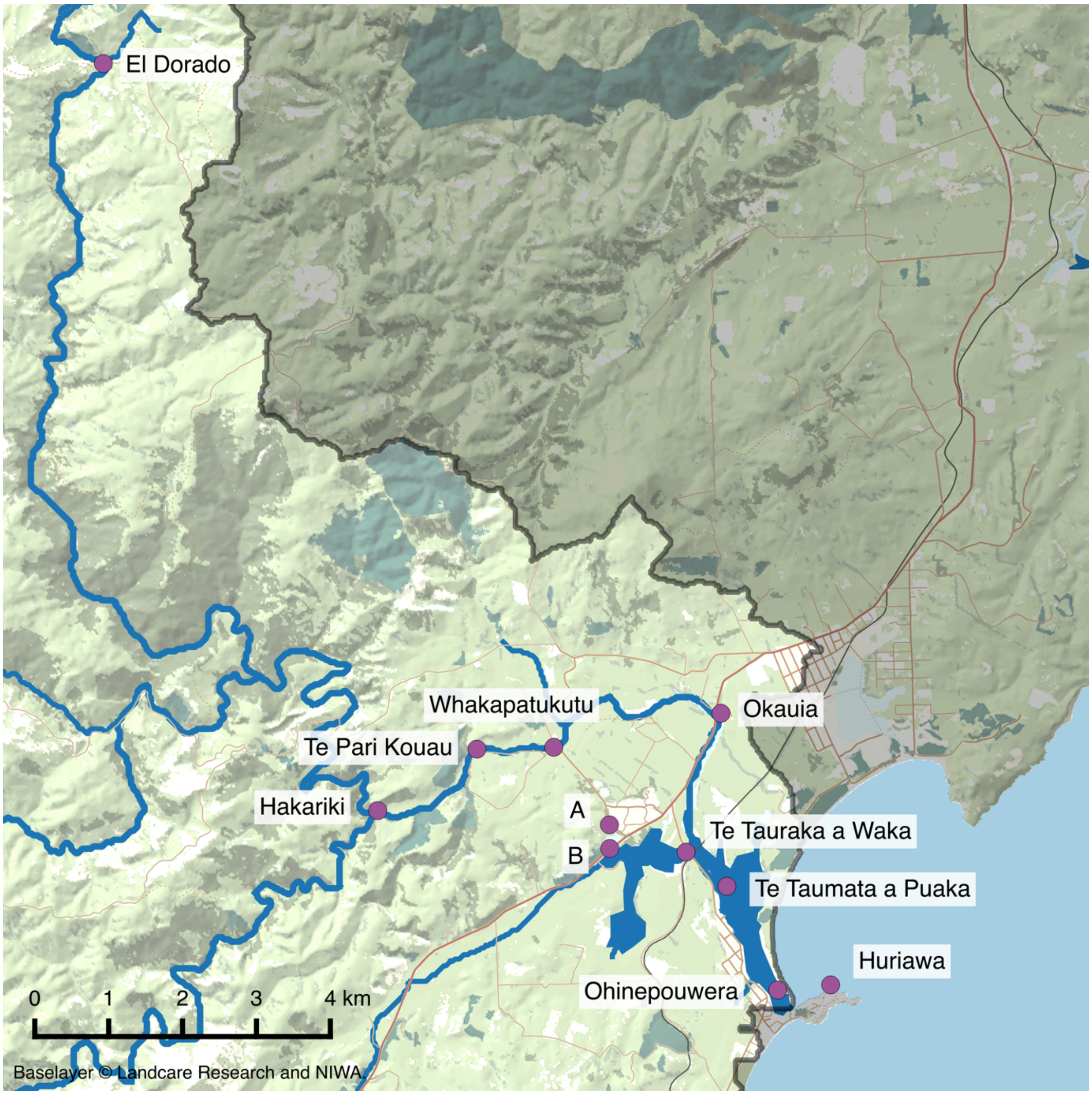

Figure 2: Map of the Waikouaiti River showing the 11 study sites (purple dots). Place names indicate the 9 mahi<u>k</u>a kai sites and the two additional sites are labelled A and B.

Site physical characterisation

Photos of all the sites were taken and physical aspects such as substrate type, stream width, and stream depth were measured. Other characteristics were also recorded such as fence value (0 = no fencing present, 10 = site was completely fenced), fence distance (length of the fence in metres), accessibility of the aquatic environment for stock, presence of stock, and notes regarding vegetation and man-made modifications were taken (Blackwell *et al.* 2006). Site locations were recorded with a hand-held GPS (Garmin Etrex 30, Garmin USA)

Ten-metre transects along the river, encompassing the entire width of the river, were established at each sampling site (Figure 3). Photos were taken of each site at three different points along the transect: upstream; the cross section; and downstream. The stream bed composition (substrate type), was estimated at freshwater and estuarine mahika kai sites using a modification of the 'Wolman walk'. The surveyor walked down the 10 m strip of the river and at 10 haphazardly chosen points the substrate type was recorded. Substrate types were classified according categories defined in the SHMAK manual: bedrock, boulders (> 25 cm), large cobbles (12 – 25 cm), small cobbles (6 – 12 cm), gravels 0.2 – 6 cm), sand, mud/silt, man-made, woody debris, water plants (rooted in the stream bed; Biggs *et al.* 2002).

River width (m) and depth (mm) were measured at wadeable freshwater sites only at 0, 5 and 10 m along the transect line. Depth measurements were taken at the true left (the left side of the river when facing downstream), centre, and true right (the right side of the river when facing downstream), with width measurements taken between wetted edges (Figure 3).

Figure 3: (Above) Ten metre transect line along the Waikouaiti River indicating the sampling area for site characteristics and the wider ecological survey. (Below) Measuring the width of the river at the upper end of the 10m transect line.

Water quality

Measurements of temperature, pH, conductivity, dissolved oxygen, and nutrient water samples were taken at mahika kai sites from 3 June 2015, and at Sites A and B from 3 October 2015. Water quality monitoring at these sites is ongoing, however only available data (to April 2016) is presented in this report. The intention was to sample at least once a month, and more often when possible. To remove the marine influence in the tidal arm of the estuary, all sites were sampled on the falling tide to ensure the river was consistently flowing downstream.

Multiparameter and handheld probes

Temperature (ºC), pH, conductivity (µS/cm) and dissolved oxygen (mg/L) were measured using a multiparameter probe (U-50 Horiba; Horiba Instruments Incorporated, Irvine, USA). The multiparameter probe was lowered upright into the river, perpendicularly to the river flow, in areas of undisturbed flowing water (Figure 4). If there was low or no flow at a site, the multiparameter probe was moved through the water to avoid localised depletion of dissolved oxygen. The multiparameter probe remained in the water until the parameter values stabilised and five measurements were taken; the average of these measurements was recorded. The U-50 Horiba was calibrated to a marine environment for conductivity. When the U-50 Horiba was unavailable, a YSI 6600 V2 Sonde multiparameter probe (YSI Incorporated, Ohio, USA) was used instead. At the freshwater sites conductivity was also measured with a portable conductivity meter (TDScan 3, Eutech). This provided a second measure of conductivity and is a low cost option compared the U-50 Horiba.

Water nutrient sampling

At each site, three replicate water samples were taken using a Luer-lock syringe and then filtered on-site using a Whatman GF/C glass microfiber filter in a 25mm Swinnex filter holder (Figure 4). Before use, the equipment was all acid-washed (10% HCl) and prior to sampling, was rinsed with 30 ml of water from the site. The three samples were filtered into 25 ml acid-washed tubes, placed in a chilled bin with icepacks and then frozen immediately on return to the field station (<3 hours) to be analysed later at the laboratory. Analysis of water samples was done using a QuickChem 8500 Automated Ion Analyser (Lachat Instruments, Milwaukee, USA). Nutrients of interest were nitrate (NO_3^- and NO_2^-), ammonium (NH_4^+), and phosphate (PO_4^{3-}). Nutrient concentrations were reported as mg/L of Total Oxidised Nitrogen (NO_x), Ammoniacal Nitrogen (NH_4) and Dissolved Reactive

Phosphorus (PO_4), these categories correspond to those reported by Land Air Water Aotearoa (LAWA; https://www.lawa.org.nz/).

Figure 4: Taking water samples for nutrient analysis (foreground) and using a multiparameter probe to measure the physical and chemical parameters (background) within the Waikouaiti River.

Ecological survey

A wider ecological survey was carried out on the Waikouaiti River on 10 and 17 January 2016 which included surveys of riparian and instream vegetation, and macroinvertebrate communities. Some methods corresponded directly to, or were modified from, methods described in the SHMAK Stream Monitoring Manual, Version 2K (Biggs *et al.* 2002). They are described here, including any modifications. At each site, a 10 m transect line was placed along the river, as described earlier for the site characterisation methods. The location of the transect was chosen based on the presence of a riffle, areas where substrates such as gravel, cobble or larger rocks cause the water flow to break (Biggs *et al.* 2002).

Riparian vegetation

A survey of the vegetation outside the river was conducted at all freshwater and estuarine mahika kai sites. Surveys were carried out on both banks of the river and included the riparian vegetation, the stream margin vegetation, and a general visual survey of all visible vegetation surrounding the river (Figure 5). The true right and true left banks were surveyed separately.

The riparian vegetation survey covered the length of the 10 m transect and a 10 m wide strip of riparian vegetation (10 m x 10 m area); this area included the stream margin transect (Figure 5; Figure 6). The stream margin survey area included the length of the 10 m transect line and extended to a width of 10 cm away from the wetted edge of the river (Figure 5). The vegetation in this strip was identified to species level and percentage cover was recorded. The general visual survey was done by standing on the bank of the river, facing away from the river, within the 10 m x 10 m area where the riparian vegetation survey occurred (Figure 5; Figure 6). All vegetation, bare ground or artificial structures that could be seen were classified into percentage cover (to the nearest 5 %) of 10 categories. The categories recorded were native trees; wetland vegetation; tall tussock grassland (not improved); introduced trees (willow, polar); other introduced trees (conifer); scrub; short tussock grassland (improved); rock, gravels; pasture grasses and weeds; bare ground, roads, buildings (Biggs *et al.* 2002).

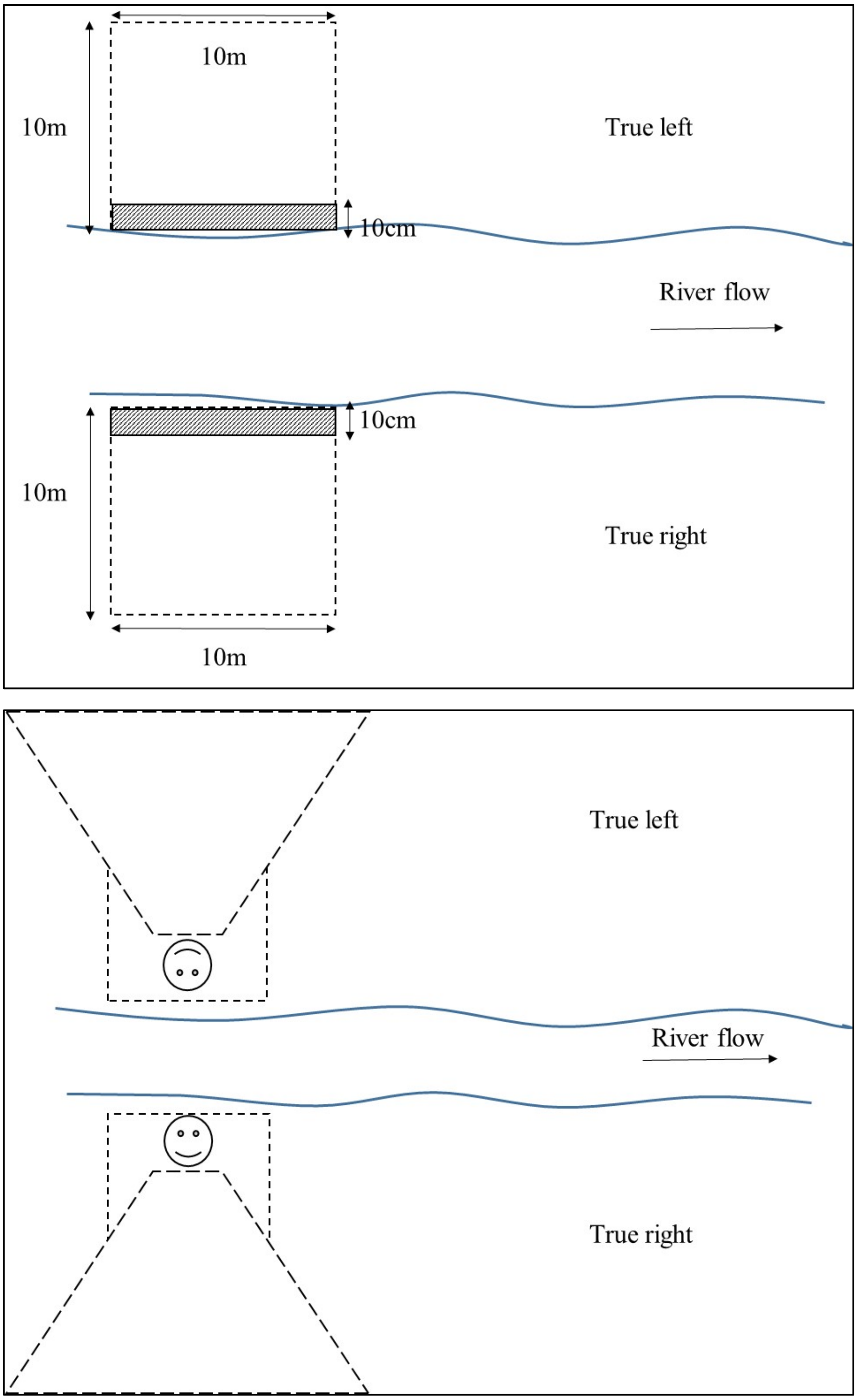

Figure 5: (Above) Diagram of the 10 m x 10 m area where the riparian vegetation survey was carried out. The dotted transect (10 m x 10 cm) inside this area represents the area where the stream margin survey was carried out. (Below) Diagram of the general visual survey.

Figure 6: (Above) Riparian vegetation survey within a 10 m x 10 m area carried out along the Waikouaiti Estuary. (Below) General vegetation survey being conducted on the bank of the Waikouaiti River by Gretchen Brownstein and Brendan Flack.

Instream vegetation

An instream vegetation survey was completed and included quantifying the percent cover of aquatic plants, also known as macrophytes, and periphyton. The survey was completed across the whole river width at each study site.

Aquatic plants and algae within the study site were recorded as a percentage cover (to the nearest 5 %) of the categories: emergent, surface or submerged (Collier *et al.* 2014). Identification to species level was also carried out. Emergent macrophytes were defined as plants with parts rising out of the water; surface macrophytes were those extending to the surface but not coming out of the water; and submerged macrophytes were those beneath the surface (Collier *et al.* 2014).

Periphyton sampling was carried out on 10 random points along the 10 m stretch of river at freshwater sites only. This was a modified version of SHMAK methods (Biggs *et al.* 2002). Moving from the downstream point of the 10 m transect to avoid disturbing sites upstream, the researcher selected 10 random points. A single unit of substrate (stones, gravel, or plant debris) measuring 4-10 cm at these points were haphazardly selected. To avoid size being a confounding factor, substrates of similar size to each other were selected. If the substrate was loose such as gravel or sand, a small sieve was used to scoop up the sample which was then placed in a container. Rocks or water plant were removed and transferred into separate containers. Periphyton percent cover of each periphtyon type (e.g. long-green-filamentous, thin-black) was recorded to the nearest 5% (see Appendix 1 Table 1 for full periphyton classification details; Biggs *et al.* 2002).

Invertebrates

Macroinvertebrate community surveys were conducted at freshwater sites only, using the same 10 sampling units as in the periphyton survey described above. For each of the 10 samples per site, macroinvertebrates were identified and counted according to categories described in the SHMAK manual (Appendix 1 Table 2; Biggs *et al.* 2002).

Data analysis

All data manipulation and analyses were carried out using the R statistical software package (v 3.1.2, R Core Team 2015) and Quantum GIS (QGIS, v 2.14). No formal statistical tests were applied to these data, but simple visual summaries were produced to facilitate comparison with future surveys.

Site selection and characterisation

Site locations from the GPS were imported into a structured QGIS project and visualised against freely available aerial imagery (Land Information New Zealand) and symbolic baselayers (Landcare New Zealand Limited). Three separate summary tables were created for freshwater and estuarine mahika kai sites. The first table summarised the survey date, site ID, wadeable freshwater classification (yes or no), latitude and longitude (WGS84, decimal degrees), fencing, stock access, and stock present values (all 0 to 10), and notes for vegetation and man-made modification. A second table summarised the percent cover (%) of each substrate type. A third table summarised the stream width (m), depth (mm) and average depth (mm) for wadeable freshwater sites only.

Water quality

The results from the multiparameter probe and the nutrient water samples for mahika kai sites were plotted. Spatial and temporal trends in each water quality and nutrient concentration measurement (± 1 standard error) were plotted separately.

Wider ecological survey

The mean percent cover of riparian and stream-margin vegetation on the true left and true right was calculated for each site, and categorised into five life forms: grass, herb, sedge, shrub and tree. The proportion of each category was calculated for both the riparian transects (the total number of species found in the two 10 m x 10 m transects at each site) and stream-margin vegetation (just the species found in the two 10 m x 0.1 m transects at each site). The results of the survey were plotted as the proportion cover of each vegetation class and proportion of native and non-native species found at each site (scaled to 100 % cover for each site). The combined percent cover of the three classes of instream macrophytes was calculated. Average (± 1 standard error) periphyton cover at each freshwater site was plotted along with the proportion of total cover in each periphyton category. The mean number (± 1 standard error) of invertebrates and percentage of each invertebrate category was plotted for each site.

SHMAK scores

SHMAK scores were calculated for wadeable freshwater sites only. Habitat quality data was analysed according to SHMAK methods and scores were established for each parameter and then combined for an overall site habitat quality score (Biggs *et al.* 2002). The parameters analysed for overall habitat quality included pH, temperature, conductivity, substrate type (composition of the stream bed) and percentage cover of riparian vegetation established in the general visual survey. As the analysis in SHMAK uses additional measures such as flow velocity, water clarity, and deposits, which were not measured in this project, the SHMAK scores were proportionately scaled to the available data. Therefore, in the future, if additional information is to be collected, the data can still be comparable to what was collected during this baseline study. To account for any missing values (e.g. no pH data due to a faulty meter), the mean of the three summer months (December – February) was used. For bank vegetation, results from the wider visual survey were used. This is a modification of the SHMAK methods which uses data from a defined riparian transect (Biggs *et al.* 2002). The overall habitat score for each site was then used to define the site habitat quality on a scale from "Poor" to "Very Good" (Biggs *et al.* 2002).

The analysis of periphyton percent cover and macroinvertebrate counts also followed SHMAK methods (Biggs *et al.* 2002). Periphyton scores were calculated by multiplying the percentage cover of a category by the category score; each category of periphyton had an associated score. Invertebrate scores were calculated by multiplying the number of invertebrates found per category by the category score. As with periphyton, each invertebrate category has an associated score.

The overall score for invertebrates was assessed against the habitat quality score (described above) to establish the overall health of the site; definitions ranged from "Very Poor" to "Excellent" (Biggs *et al.* 2002). A modification of the SHMAK figure to indicate the health score placement of each site was produced.

Results

Hui

Most participants mentioned cultural sites and important river habitat as places of value on the Waikouaiti River (Appendix 1 Table 3). In particular, emphasis was placed on sites that had long historical significance or still had an historical place name; there were suggestions to place information panels in these areas. Those present at the hui described mahik̲a kai species, and species that had historically been present on the Waikouaiti River, as species of value (Appendix 1 Table 3). Various bird and plant species were also mentioned, and the importance of the younger generation being able to learn from these groups and their habitat.

Participants were concerned about the land-use impacts and water quality of the Waikouaiti River. Land-use concerns such as the impact of Macraes Mine, flood gates, invasive predators, pollution and whitebait overharvesting were described (Appendix 1 Table 3). Water quality and river health concerns were mentioned including sediment and nutrient input, river flow and temperature, and loss of mahik̲a kai species, their habitat, and riparian vegetation.

Memories of the Waikouaiti River described how the river had changed and participants remembered the presence of particular species that were no longer seen in the area (Appendix 1 Table 3). Almost all participants envisioned the future of the river as a restored and intact ecosystem where recreational activities were possible (Appendix 1 Table 3). The resilience of the river to climate change was also mentioned. Offers of help and contributions from participants included equipment, peoples' knowledge and time, and the potential for collaboration to share the work effort and costs involved in restoration of the Waikouaiti River and surrounding areas (Appendix 1 Table 3).

Additional comments from participants included the suggestion to keep the community informed on any progress so as to streamline effort. This would also allow them to know what has been done before and who is responsible for certain aspects of the river's management (Appendix 1 Table 3).

Site physical characterisation

El Dorado

The stream bed composition at El Dorado was mostly small cobbles (91%) with some gravel present (Figure 18, Appendix 1 Table 4).

Table 1: Descriptions of the physical characteristics of El Dorado (Site 1). Sampling was conducted 10 January 2016.

Ecological Survey Date	2016-01-10
Site ID	1
Wadeable / Freshwater Site	Yes
Latitude	-45.52348
Longitude	170.5478
Fencing	10 No Fencing [0] [10] Fully Fenced
Stock Access	10 Complete Access [10] [0] No Access
Stock Present	10 Observed [10] [0] Not Present
Site notes (Man-made modifications)	There was a bridge below the site and farm buildings within 300m.

Table 2: Stream width, depth and average depth at three points (downstream, centre and upstream) along the 10m transect line at El Dorado (Site 1). Sampling was conducted 10 January 2016.

	Stream Width (m)	Depth Centre (mm)	Average Depth (mm)
Downstream	5.5	251	104
Centre	3.1	110	53
Upstream	2.9	57	34

Figure 7: El Dorado (Site 1) showing an upstream (top), cross section (middle), and downstream (bottom) view.

Hakariki

The stream bed composition of Hakariki was mostly large cobbles (95%) with some water plants present (Figure 18, Appendix 1 Table 4).

Table 3: Descriptions of the physical characteristics of Hakariki (Site 2). Sampling was conducted 10 January 2016.

Ecological Survey Date	2016-01-10
Site ID	2
Wadeable / Freshwater Site	Yes
Latitude	-45.61539
Longitude	170.5914
Fencing	0 No Fencing [0] [10] Fully Fenced
Stock Access	10 Complete Access [10] [0] No Access
Stock Present	10 Observed [10] [0] Not Present
Site notes (Vegetation)	True left side of the river was sparse vegetation on rock and gravel substrates.
Site notes (Man-made modifications)	There was an old fence at the site

Table 4: Stream width, depth and average depth at three points (downstream, centre and upstream) along the 10m transect line at Hakariki (Site 2). Sampling was conducted 10 January 2016.

	Stream Width (m)	Depth Centre (mm)	Average Depth (mm)
Downstream	7.3	120	52
Centre	6.5	170	76
Upstream	8.9	460	173

Figure 8: Hakariki (Site 2) showing an upstream (top), cross section (middle), and downstream (bottom) view.

Te Pari Kouau

The stream bed composition sampled at Te Pari Kouau was mostly gravel (95%) with some water plants present (Figure 18, Appendix 1 Table 4).

Table 5: Descriptions of the physical characteristics of Te Pari Kouau (Site 3). Sampling was conducted 10 January 2016.

Ecological Survey Date	2016-01-10
Site ID	3
Wadeable / Freshwater Site	Yes
Latitude	-45.60827
Longitude	170.609
Fencing	0 No Fencing [0] [10] Fully Fenced
Stock Access	10 Complete Access [10] [0] No Access
Stock Present	10 Observed [10] [0] Not Present
Site notes (Man-made modifications)	There was a road near the site and water intake.

Table 6: Stream width, depth and average depth at three points (downstream, centre and upstream) along the 10m transect line at Te Pari Kouau (Site 3). Sampling was conducted 10 January 2016.

	Stream Width (m)	Depth Centre (mm)	Average Depth (mm)
Downstream	4.15	53	38
Centre	6.3	115	47
Upstream	5.9	90	52

Figure 9: Te Pari Kouau (Site 3) showing an upstream (top), cross section (middle), and downstream (bottom) view.

Whakapatukutu (Orbell's Crossing)

The stream bed composition sampled at Whakapatukutu was mostly gravel (88%) with some small cobbles (10%) and water plants (Figure 18, Appendix 1 Table 4).

Table 7: Descriptions of the physical characteristics of Whakapatukutu (Site 4). Sampling was conducted 10 January 2016.

Ecological Survey Date	2016-01-10
Site ID	4
Wadeable / Freshwater Site	Yes
Latitude	-45.60832
Longitude	170.6223
Fencing	0 No Fencing [0] [10] Fully Fenced
Stock Access	0 Complete Access [10] [0] No Access
Stock Present	0 Observed [10] [0] Not Present
Site notes (Man-made modifications)	There was a bridge downstream from the site.

Table 8: Stream width, depth and average depth at three points (downstream, centre and upstream) along the 10m transect line Whakapatukutu (Site 4). Sampling was conducted 10 January 2016.

	Stream Width (m)	Depth Centre (mm)	Average Depth (mm)
Downstream	14.8	200	143
Centre	13.1	195	69
Upstream	14.3	184	75

Figure 10: Whakapatukutu (Site 4), also called Orbell's Crossing, showing an upstream (top), cross section (middle), and downstream (bottom) view.

Okauia

The stream bed composition at Okauia was mostly mud or silt (90%) with some man-made substrate (e.g. concrete; Figure 18, Appendix 1 Table 4).

Table 9: Descriptions of the physical characteristics of Okauia (Site 5). Sampling was conducted 17 January 2016.

Ecological Survey Date	2016-01-17
Site ID	5
Wadeable / Freshwater Site	No
Latitude	-45.60479
Longitude	170.6514
Fencing	10 No Fencing [0] [10] Fully Fenced
Stock Access	5 Complete Access [10] [0] No Access
Stock Present	5 Observed [10] [0] Not Present
Site notes (Vegetation)	There was a park on the true right, therefore, no 10x10m survey was done on this side of the river.
Site notes (Man-made modifications)	There was a highway bridge 50m upstream from the site.

Figure 11: Okauia (Site 5) showing an upstream (top), cross section (middle), and downstream (bottom) view.

Te Tauraka a Waka

The stream bed composition at Te Tauraka a Waka was entirely mud or silt (Figure 18, Appendix 1 Table 4).

Table 10: Descriptions of the physical characteristics of Te Tauraka a Waka (Site 6). Sampling was conducted 17 January 2016.

Ecological Survey Date	2016-01-17
Site ID	6
Wadeable / Freshwater Site	No
Latitude	-45.62156
Longitude	170.6447
Fencing	0 No Fencing [0] [10] Fully Fenced
Stock Access	0 Complete Access [10] [0] No Access
Stock Present	0 Observed [10] [0] Not Present
Site notes (Man-made modifications)	There was a railway bridge and a road within 50m of the site.

Figure 12: Te Tauraka a Waka (Site 6), also known as the Waka landing site, showing an upstream (top), cross section (middle), and downstream (bottom) view.

Te Taumata a Puaka

The stream bed composition at Te Taumata a Puaka was a mix of sand (50%) and mud or silt (50%; Figure 18, Appendix 1 Table 4).

Table 11: Descriptions of the physical characteristics of Te Taumata a Puaka (Site 7). Sampling was conducted 17 January 2016.

Ecological Survey Date	2016-01-17
Site ID	7
Wadeable / Freshwater Site	No
Latitude	-45.62586
Longitude	170.6516
Fencing	10 No Fencing [0] [10] Fully Fenced
Stock Access	5 Complete Access [10] [0] No Access
Stock Present	10 Observed [10] [0] Not Present
Site notes (Vegetation)	There were car tracks on both sides of the saltmarsh and floodgates on the true right going under the road.
Site notes (Man-made modifications)	There was road 100m away. A berm (raised bank) ran from the north to south of the site.

Figure 13: Te Taumata a Puaka (Site 7) showing an upstream (top), cross section (middle), and downstream (bottom) view.

Ohinepouwera

The stream bed composition at Ohinepouwera was 100% sand (Figure 18, Appendix 1 Table 4).

Table 12: Descriptions of the physical characteristics of Ohinepouwera (Site 8). Sampling was conducted 17 January 2016.

Ecological Survey Date	2016-01-17
Site ID	8
Wadeable / Freshwater Site	No
Latitude	-45.63867
Longitude	170.6599
Fencing	0 No Fencing [0] [10] Fully Fenced
Stock Access	0 Complete Access [10] [0] No Access
Stock Present	0 Observed [10] [0] Not Present
Site notes (Vegetation)	There was a sand dune on the true left of the site and a boat launching area and road on the true right.

Figure 14: Ohinepouwera (Site 8) showing an upstream (top), cross section (middle), and downstream (bottom) view.

Huriawa

Huriawa was a marine site with influence from the Waikouaiti River. Physical characteristics and ecological information were not collected at this site.

Figure 15: Huriawa (Site 9) showing an upstream (top), cross section (middle), and downstream (bottom) view.

The Culvert (Site A)

Figure 16: The Culvert (Site A) showing an upstream (top) and downstream (bottom) view.

The Main Road (Site B)

Figure 17: The Main Road (Site B) showing an upstream (top) and cross section (bottom) view.

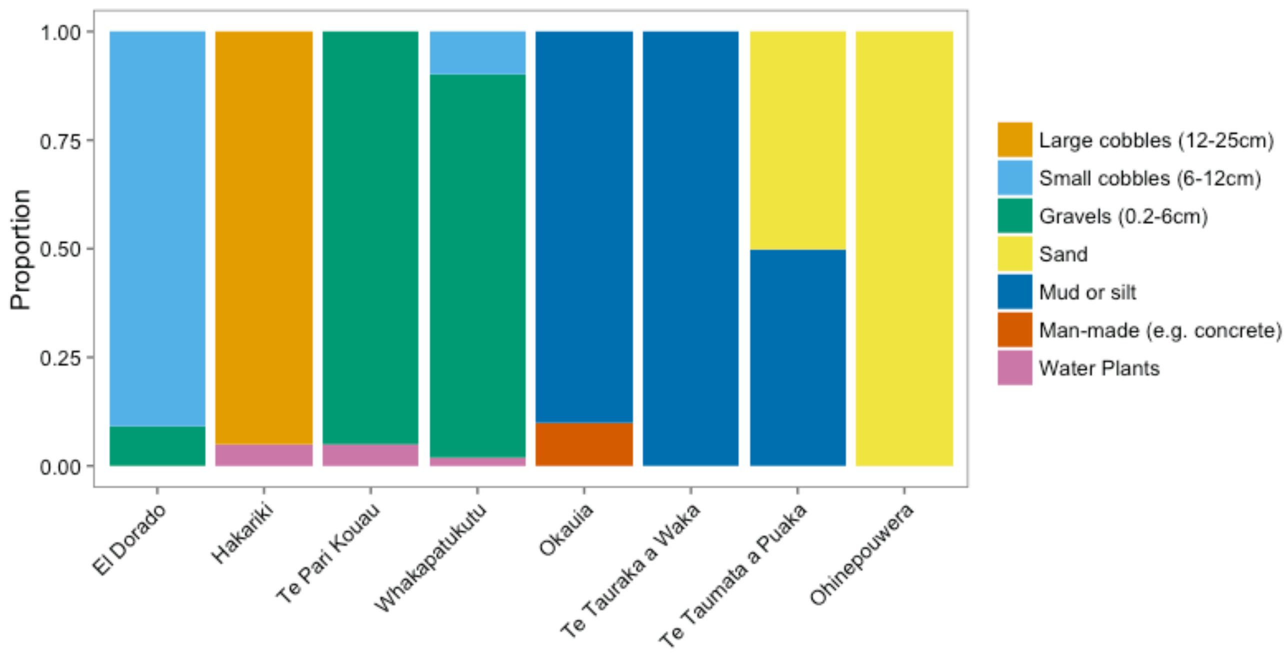

Figure 18: Proportion of substrate types making up the stream bed at each of the freshwater and estuarine mahika kai sites. Sampling was carried out on 10 replicate units at each site (n=10). Note that the categories of bedrock, boulders, and woody debris have been excluded as they did not appear at any of the sites. Categories from SHMAK (Biggs *et al.* 2002).

Water quality

During the He Pātaka Wai Ora Project, the nine mahika kai sites were sampled 21 times between 3 June 2015 and 29 April 2016. The two additional sites, the Culvert (Site A) and Main Road (Site B), were sampled 11 times between 3 October and 16 April. Generally, all sites were visited and sampled in a single day with the exception being the Culvert (Site A), which could not be sampled when found to be dry on 10 February 2016 and remained so for the rest of the period of the study.

Multiparameter and handheld probes

Mahika kai sites

Water temperature showed seasonal variation with both the lowest temperature of 0.5ºC and the highest temperature of 24.6ºC recorded at El Dorado (Site 1) in July and February, respectively (Figure 19). There does not appear to be any variation in water temperature between the sites (Figure 20). Conductivity did not show any trends over time (Figure 19) but conductivity was generally higher at sites further downstream (Figure 20). Average conductivity was lowest at Hakariki (166 ± 13 µS/cm; Site 2), and highest at Huriawa (48901 ± 1646 µS/cm; Figure 20). pH values did not show any clear trends over time (Figure 19), but showed a clear transition between freshwater sites (e.g. Te Pari Kouau, 7.5 ± 0.3) and marine / estuarine sites (e.g. Huriawa 8.1 ± 0.5, Figure 20). Dissolved oxygen showed no clear temporal trends (Figure 19) but varied between sites, with higher values at the upstream sites and a decreasing trend downstream (Figure 20). Average dissolved oxygen values ranged from 10.8 ± 0.96 mg/L at Te Taumata a Puaka to 16.3 ± 1.54 mg/L at Hakariki.

Site A and B

Water temperature, conductivity, pH and dissolved oxygen values at the Culvert (Site A) and the Main Road (Site B) did not show any trends over time (Figure 21). Overall, the Main Road site (Site B) had higher water temperature, conductivity, pH and dissolved oxygen than the Culvert site (Figure 22). Average water temperature for the Main Road was 20.6 ± 1.5ºC compared to 12.8 ± 0.7ºC for the Culvert. Average conductivity for the Main Road was 48981 ± 2197 µS/cm compared to 574 ± 102 µS/cm for the Culvert. Average values for pH and dissolved oxygen at the Main Road were 7.9 ± 0.1 and 10.1 ± 1.2 mg/L, respectively. At the Culvert, these values were 7.6 ± 0.6 and 7.3 ± 1.9 mg/L, respectively.

Nutrient concentration results

Mahika kai sites

Ammonium and nitrate values did not show any clear trends over time. The exception to this was a peak in nitrate concentrations at all sites at the start of July (Figure 23). Phosphate showed a weak temporal pattern, with values increasing over the winter months and decreasing during summer (Figure 23). Between sites, average ammonium concentration increased downstream from El Dorado (Site 1) to Ohinepouwera (Site 8). Te Tauraka a Waka (Site 6) was an outlier to this pattern (0.073 ± 0.0073 mg/L; Figure 24). Nitrate concentration did not show any clear trend between sites (Figure 24). Phosphate concentrations appeared to have two distinct groups with low values at the freshwater/upper estuary sites (Sites 1 to 5; ranging from 0.0031 ± 0.0004 mg/L to 0.0059 ± 0.0002 mg/L) and higher values at lower estuary/marine sites (Sites 6 to 9; ranging from 0.0049 ± 0.0004 mg/L to 0.0082 ± 0.0009 mg/L; Figure 24).

Site A and B

Nutrient concentrations increased over time at both sites A and B (Figure 25). The Culvert site had higher average nutrient concentrations than the Main Road site (Figure 26). Average ammonium concentration was 1.0 ± 0.17 mg/L at the Culvert compared to 0.19 ± 0.047 mg/L at the Main Road and average nitrate concentration was 0.025 ± 0.010 mg/L at the Culvert compared to 0.009 ± 0.002 mg/L at the Main Road. Average phosphate concentration at the Culvert was 0.013 ± 0.002 mg/L compared to 0.009 ± 0.002 mg/L at the Main Road site.

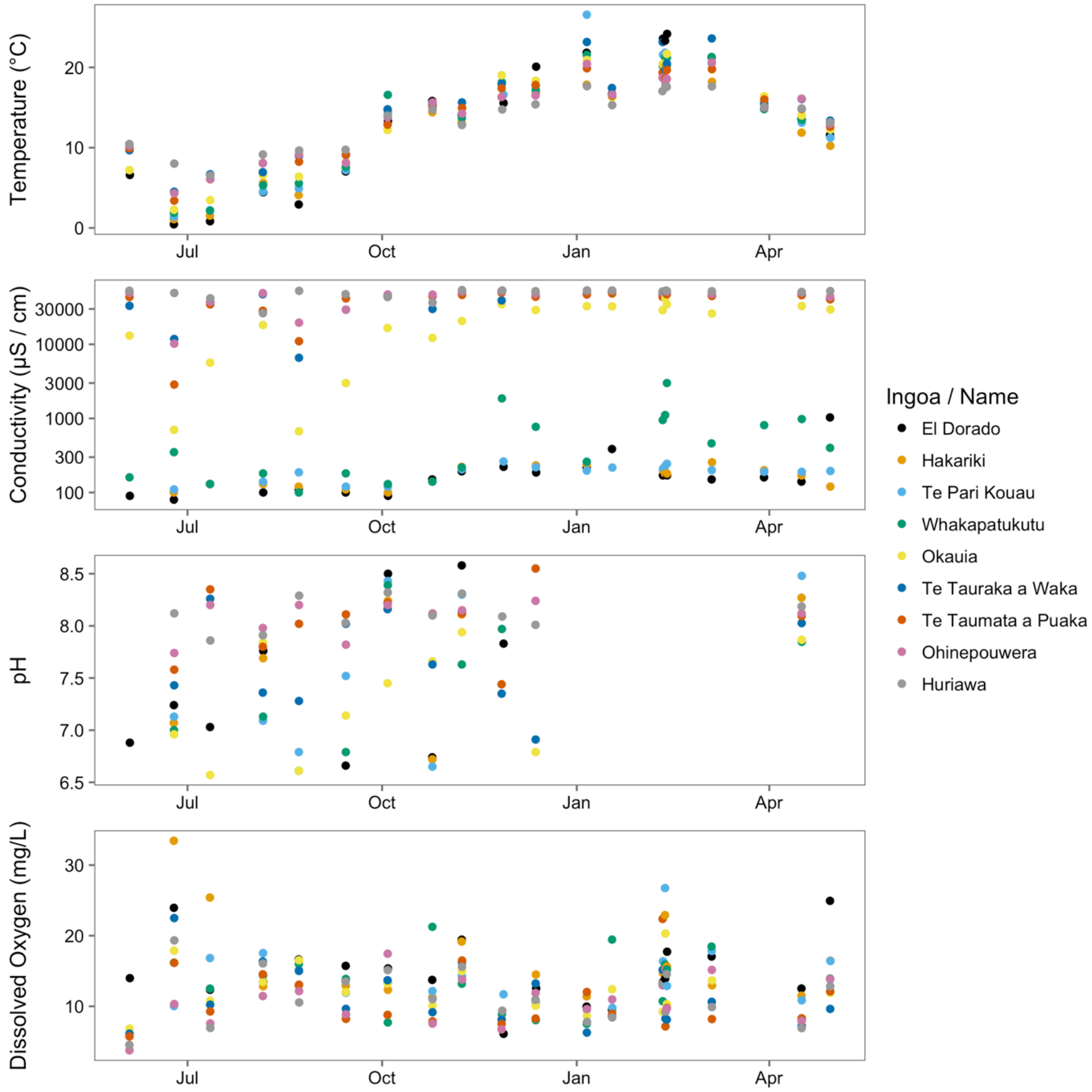

Figure 19: Water quality measurements for water temperature, conductivity, pH and dissolved oxygen over time at the nine mahik̲a kai sites (Sites 1-9). Sampling was conducted from 3 June 2015 to 29 April 2016.

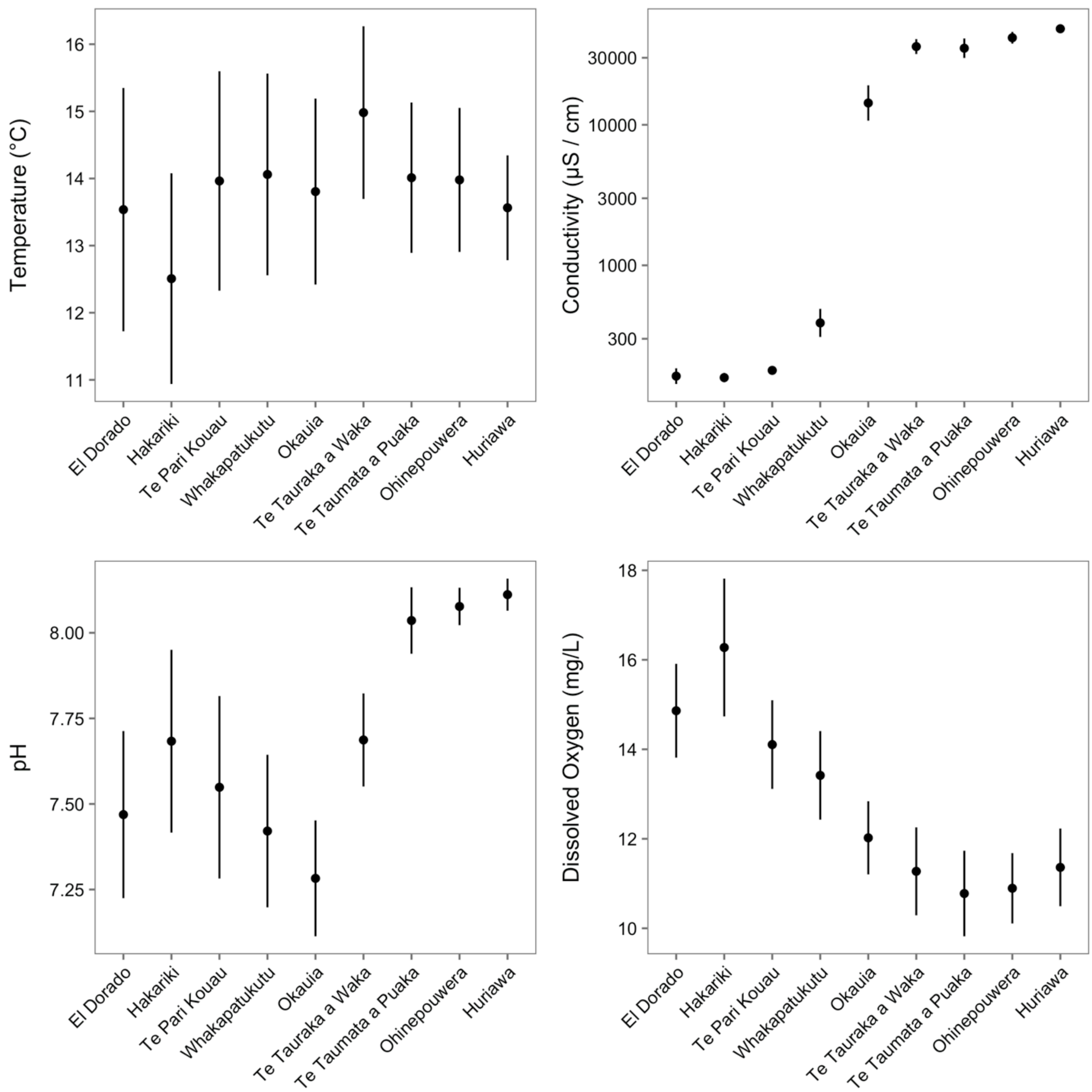

Figure 20: Average (± standard error) measurements of water temperature, conductivity, pH and dissolved oxygen for the nine mahi<u>k</u>a kai sites (Sites 1-9). Sampling was conducted from 3 June 2015 to 29 April 2016.

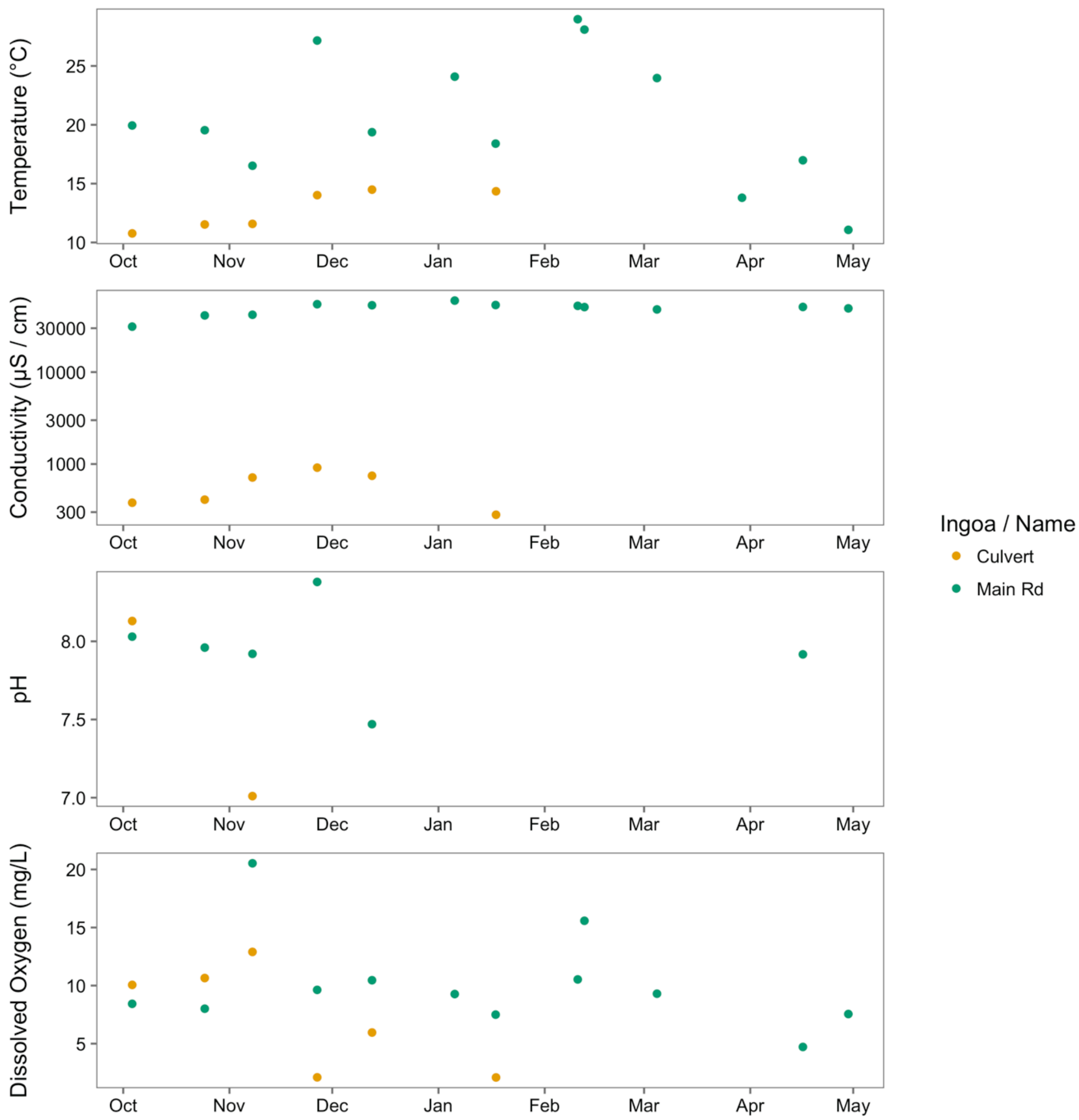

Figure 21: Water quality measurements for water temperature, conductivity, pH and dissolved oxygen over time at the Culvert and Main Road sites (Sites A and B). Sampling was conducted at the Culvert site from 3 October 2015 until 17 January 2016 when the site dried up, and at the Main Road site from 3 October 2015 to 29 April 2016.

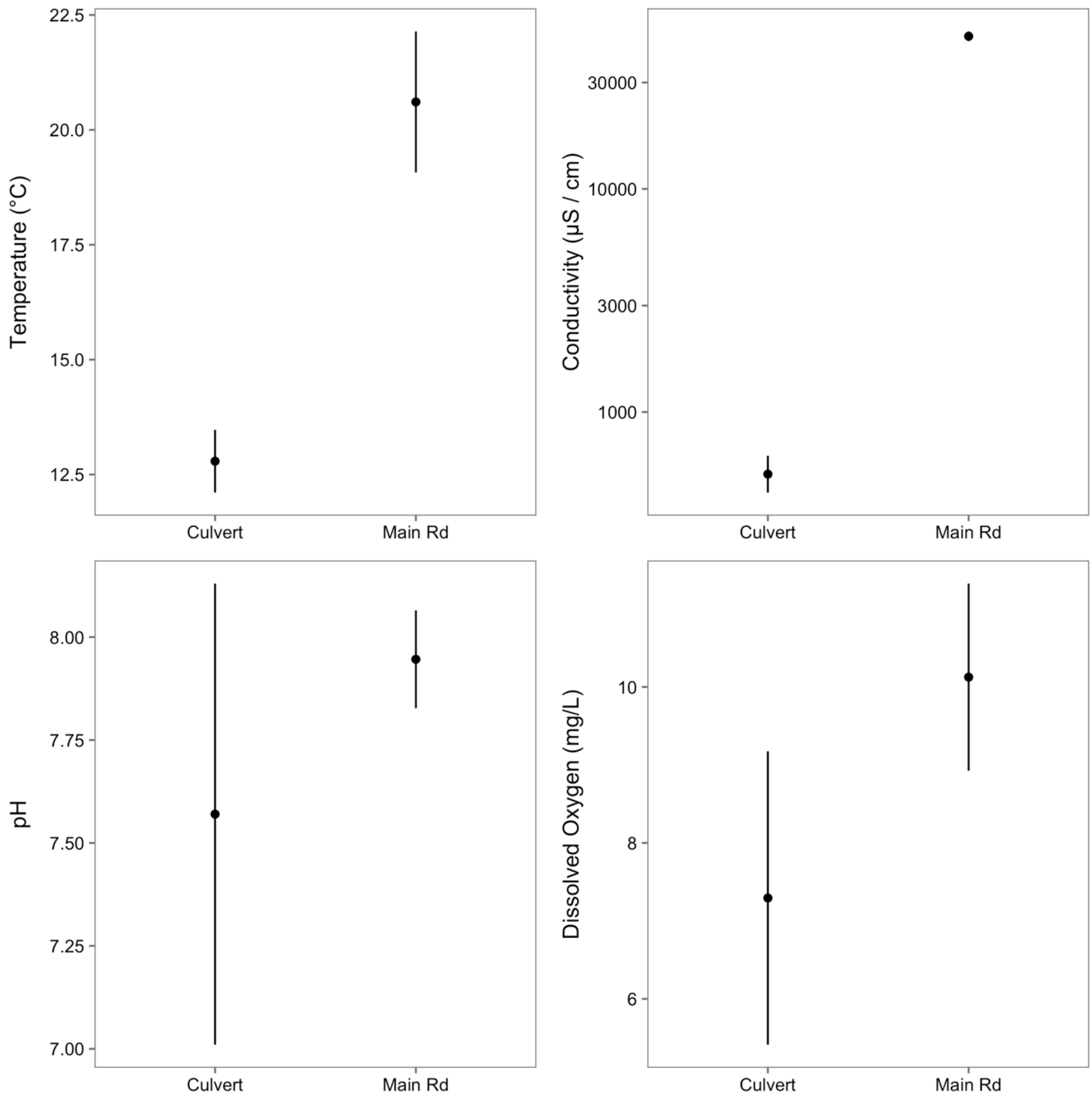

Figure 22: Average (± standard error) measurements of water temperature, conductivity, pH and dissolved oxygen for the Culvert and Main Road sites (Sites A and B). Sampling was conducted at the Culvert site from 3 October 2015 until 17 January 2016 when the site dried up, and at the Main Road site from 3 October 2015 to 29 April 2016.

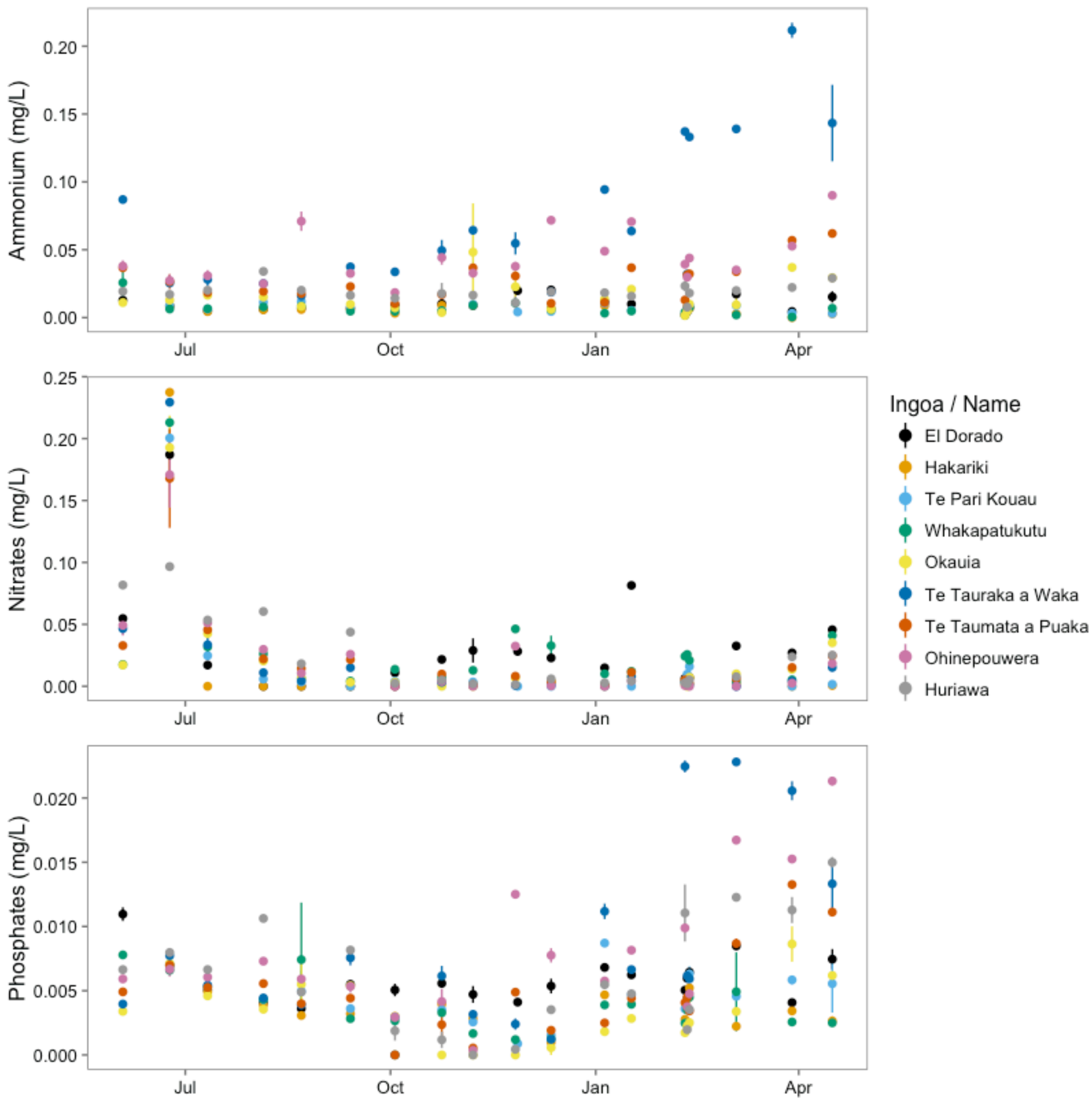

Figure 23: Average (± standard error) concentrations of ammonium, nitrates and phosphates over time at the nine mahika kai sites (Sites 1-9). Sampling was conducted from 3 June 2015 to 16 April 2016.

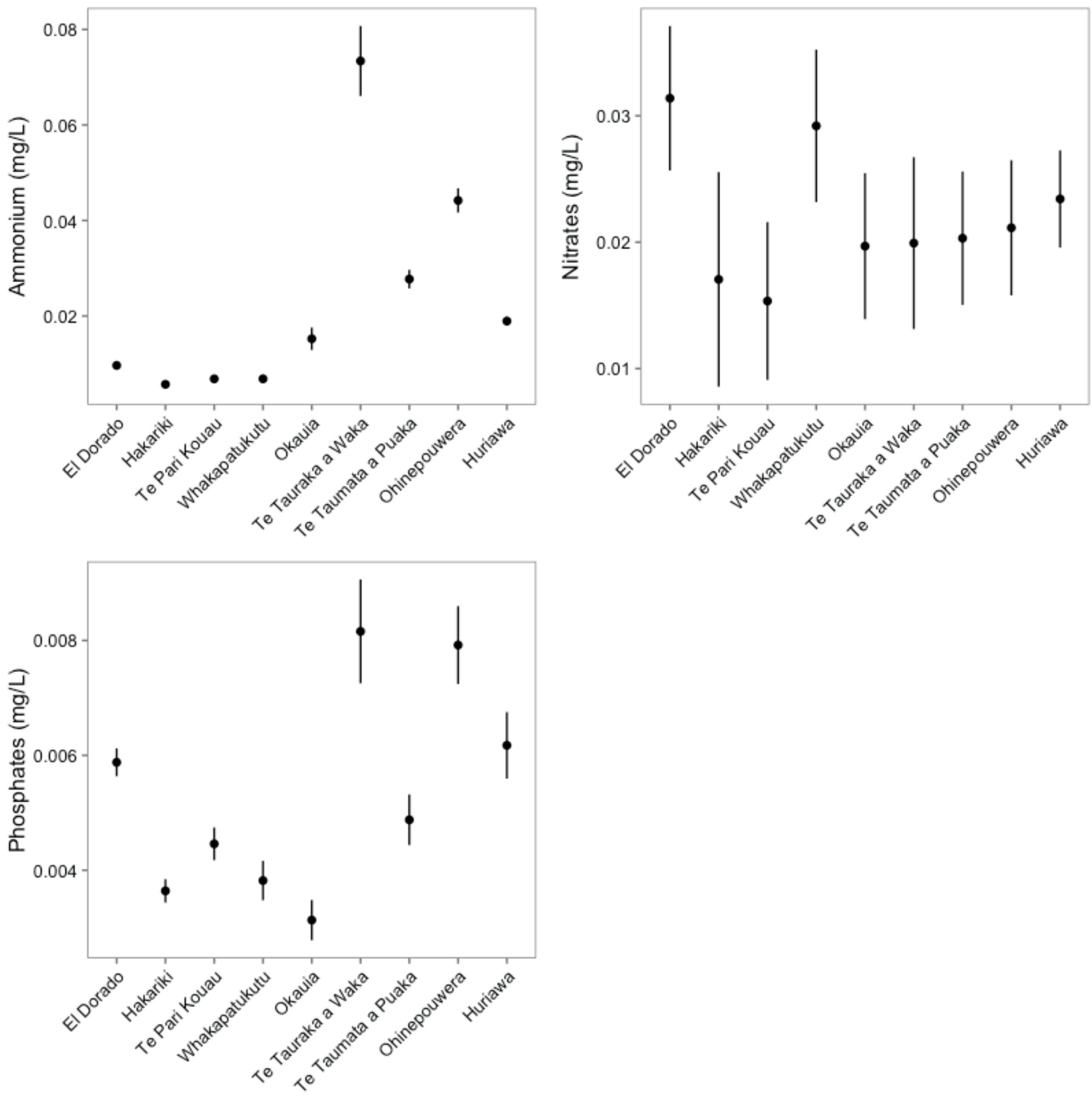

Figure 24: Average (± standard error) concentrations of ammonium, nitrates and phosphates for the nine mahika kai sites (Sites 1-9). Sampling was conducted from 3 June 2015 to 16 April 2016.

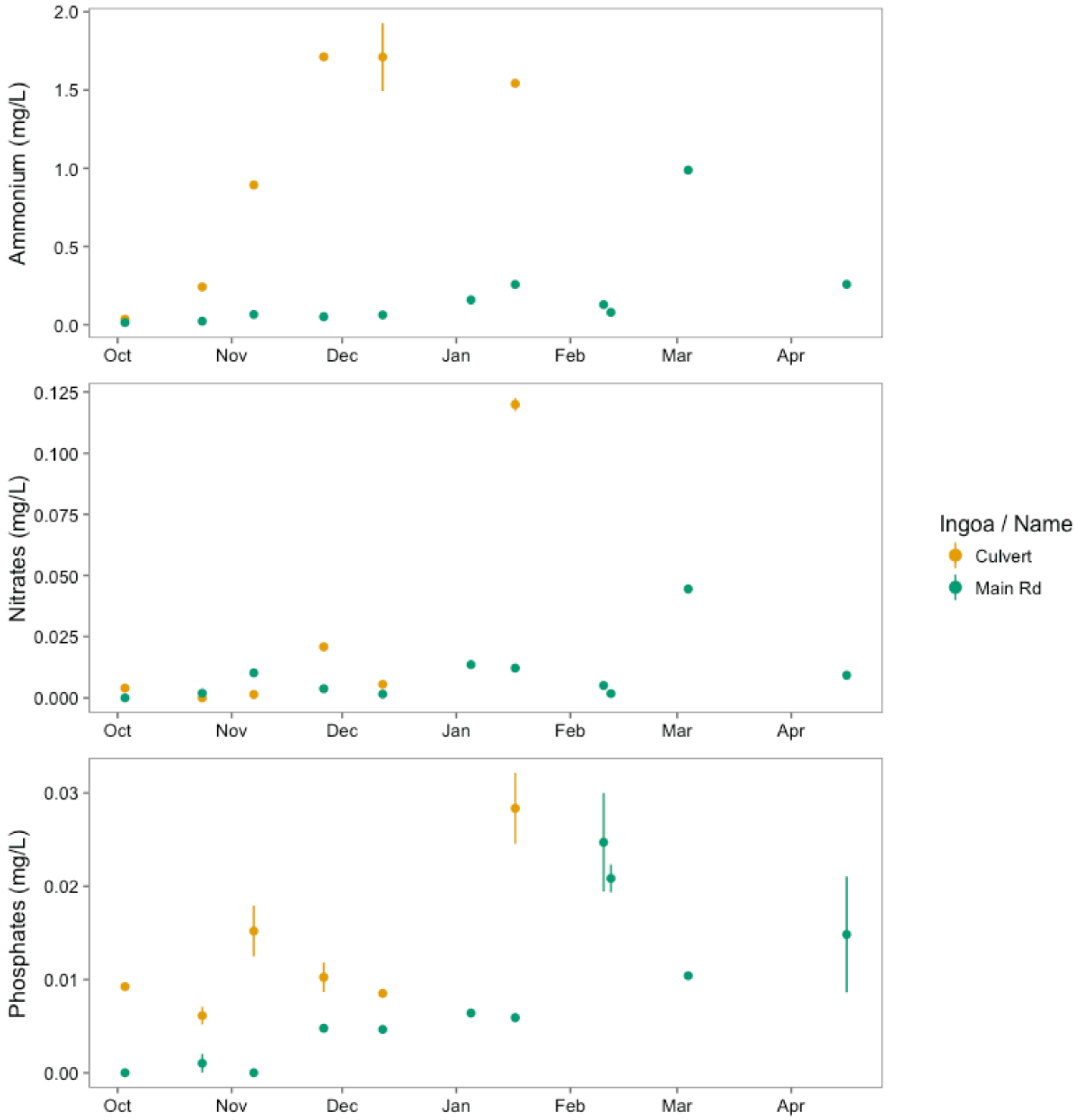

Figure 25: Average (± standard error) concentrations of ammonium, nitrates and phosphates over time at the Culvert and Main Road sites (Sites A and B). Sampling was conducted at the Culvert site from 3 October 2015 until 17 January 2016 when the site dried up, and at the Main Road site from 3 October 2015 to 16 April 2016.

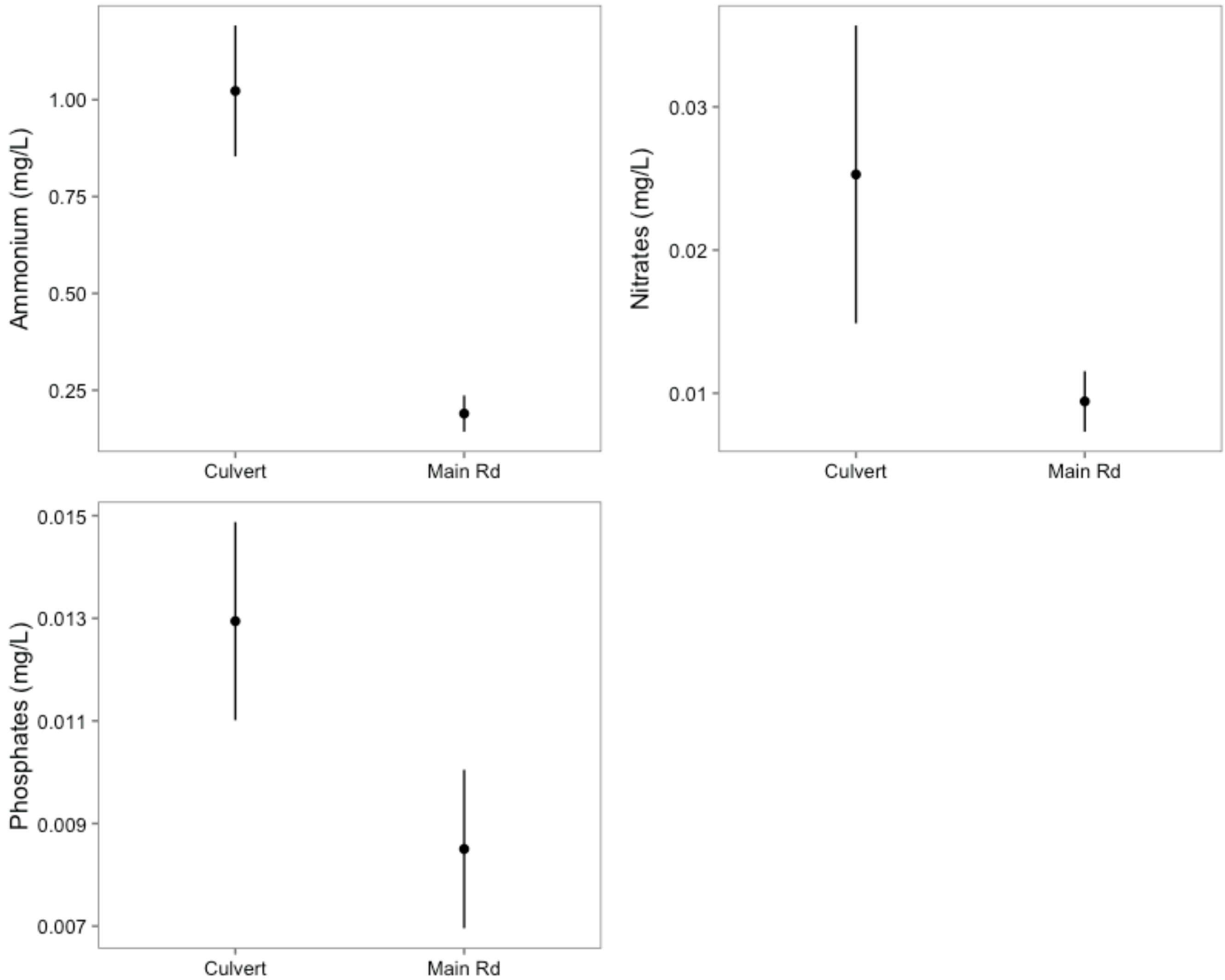

Figure 26: Average (± standard error) nutrient concentrations of ammonium, nitrates and phosphates for the Culvert and Main Road sites (Sites A and B). Sampling was conducted at the Culvert site from 3 October 2015 until 17 January 2016 when the site dried up, and at the Main Road site from 3 October 2015 to 16 April 2016.

Ecological survey

Riparian vegetation

The total percent cover of riparian and stream-margin (mean of the true left and true right banks) varied between sites and exceeded 100% in areas where species were overlapping (Figure 27). Riparian vegetation percent cover was highest at Whakapatukutu (128%) and lowest at Hakariki (64%; Figure 27, top). The stream-margin vegetation cover was highest at Okauia (100%) and lowest at El Dorado (51%; Figure 27, bottom). The proportion of life form groups comprising this total percent cover varied between sites, but overall, grass dominated both the riparian and stream-margin vegetation (Figure 28). The exception to this was the stream-margins at Te Tauraka a Waka and Te Taumata a Puaka where the cover was made up entirely of herbaceous species (Figure 28). The number of species found in the riparian vegetation transect decreased downstream and ranged from 26 species at El Dorado to 7 species at Ohinepouwera (Figure 29). Fewer vegetation species were identified in the stream-margin which ranged from 10 species at Hakariki and Whakapatukutu to 1 species identified at Ohinepouwera and Te Taumata a Puaka (Figure 29). Overall, the majority of the riparian and stream-margin vegetation at each site was made up of non-native species (Figure 30). The exception was at Te Taumata a Puaka where the riparian vegetation cover was almost entirely made up of native species (Figure 30). At Te Tauraka a Waka, all the stream-margin vegetation was comprised of native species while the entire riparian transect area was mostly covered by non-natives (Figure 30).

The general visual survey indicated that pasture made up the majority of all vegetation visible from the river bank at El Dorado, Whakapatukutu, Okauia, Te Tauraka a Waka and Ohinepouwera (Figure 31). Hakariki and Te Pari Kouau had a mixture of vegetation classes, the largest proportion being scrub, while Te Taumata a Puaka was dominated by wetland vegetation (Figure 31).

Instream vegetation

The percentage of macrophyte cover at the wadeable freshwater mahika kai sites varied from 0% cover at El Dorado to 5% cover at both Hakariki and Te Pari Kouau (Table 13). Two species of macrophyte were identified: *Ranunculus trichophylus* at Hakariki and Te Pari Kouau and *Limosella lineta* at Whakapatukutu (Table 13).

Average periphyton cover (%) of the 10 sampling units ranged from 41 ± 4.6% at Hakariki to 62 ± 8.9% at Te Pari Kouau (Figure 32). The periphyton categories making up the majority of this average percent cover included thin black periphyton at El Dorado, long brown/red filamentous periphyton at Hakariki, thin black periphyton at Te Pari Kouau, and thin green periphtyon at Whakapatukutu (Figure 33).

Invertebrates

The average number of invertebrates was highest at El Dorado with 100 ±7.7 and lowest at Hakariki with 55 ±9.8 (Figure 34). The proportion of invertebrate categories that made up the number of invertebrates varied between sites (Figure 35). The invertebrate categories that comprised the majority of invertebrates for each site included pointed *Potamopyrgus* snails at El Dorado and Whakapatukutu, rough-cased caddisfly larvae at Hakariki, and crustaceans (e.g. amphipods) at Te Pari Kouau (Figure 35).

SHMAK Scores

SHMAK scores could only be calculated for wadeable freshwater sites. Habitat scores varied from “Very Good” at Hakariki to “Poor” at Whakapatukutu, invertebrate SHMAK scores were “Moderate” for all sites, and periphyton scores were “Good” for all sites except Hakariki which was defined as “Moderate” (Table 14). The overall health score of each site, which takes into account habitat and invertebrate scores, was ‘Moderate’ for El Dorado and Hakariki and “Very Poor” for Te Pari Kouau and Whakapatukutu (Figure 36).

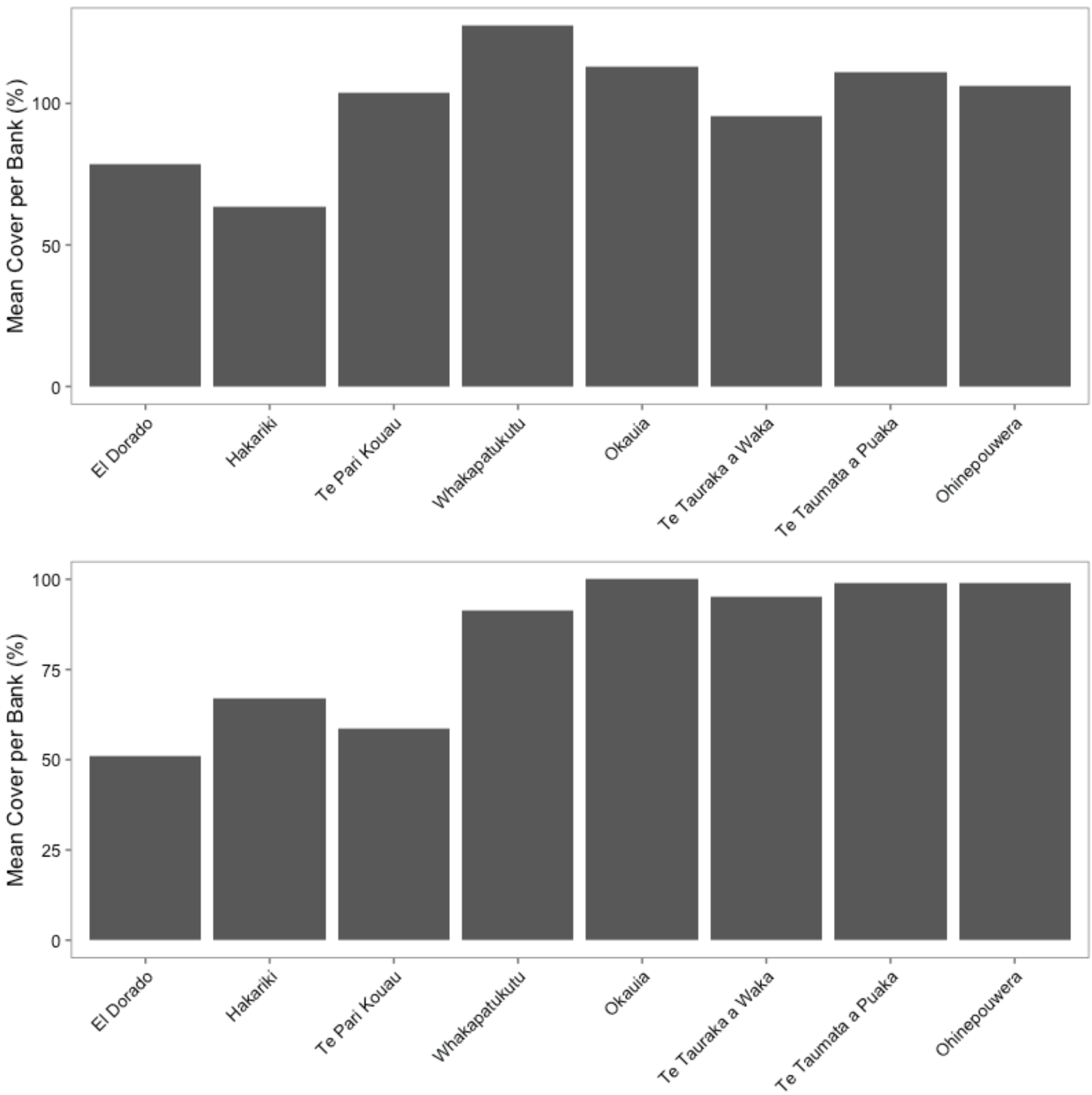

Figure 27: Total cover (%) of riparian vegetation (top) and stream-margin vegetation (bottom) at the eight freshwater and estuarine mahika kai sites. Values are the mean of the true left and true right bank cover.

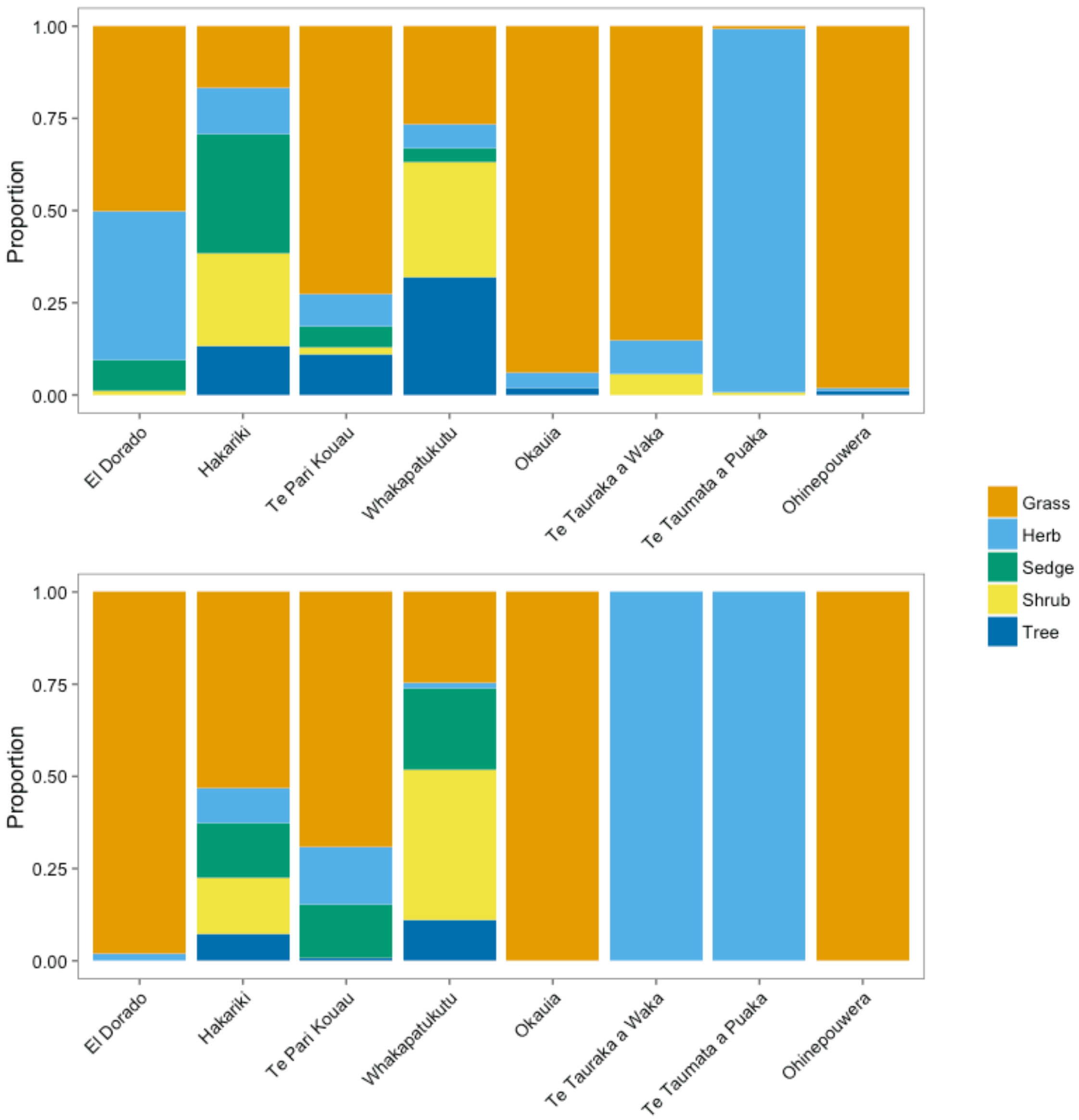

Figure 28: Proportion of vegetation types that make up the total cover of the riparian (top) and stream-margin (bottom) at each of the eight freshwater and estuarine mahika kai sites.

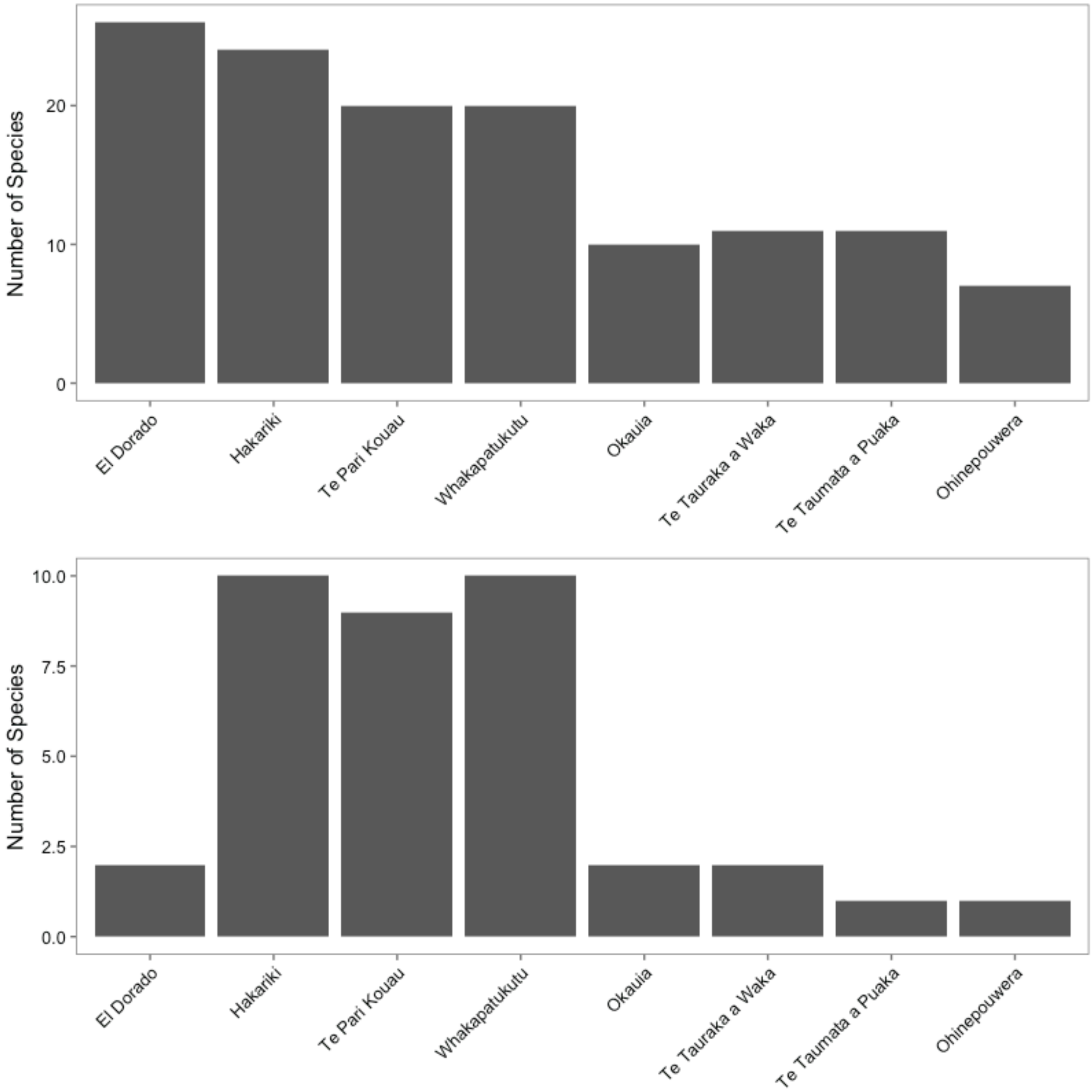

Figure 29: Number of riparian (top) and stream-margin (bottom) vegetation species found at each of the eight freshwater and estuarine mahika kai sites.

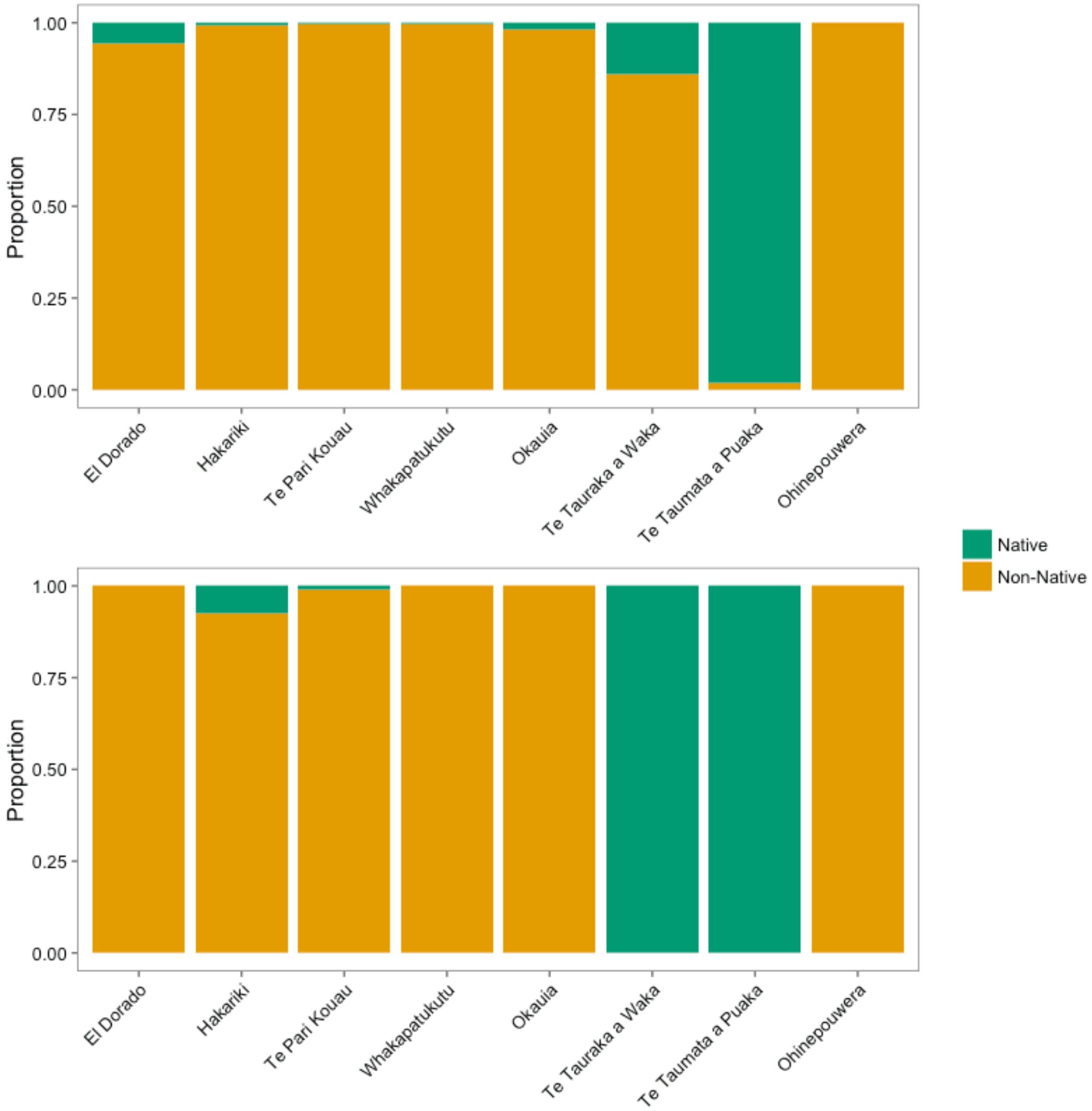

Figure 30: Proportion of native and non-native species that make up the total vegetation cover of the riparian (top) and stream-margin (bottom) vegetation at each of the eight freshwater and estuarine mahika kai sites.

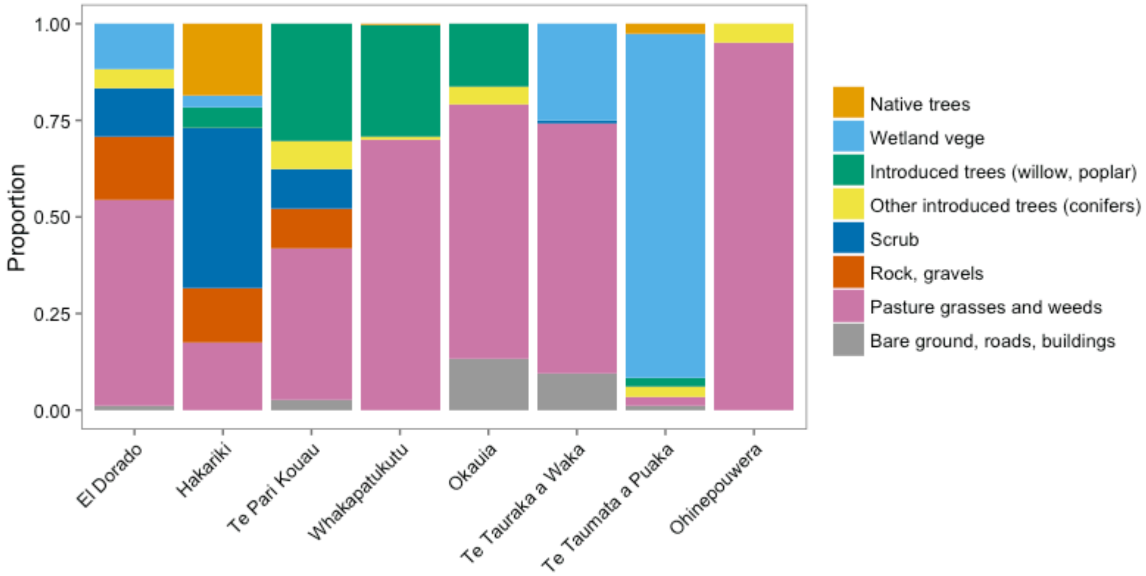

Figure 31: Proportion of vegetation categories making up the total vegetation cover visible from the river banks of the eight freshwater and estuarine mahika kai sites in the general visual survey. Values are the means of the true left and true right side of the river. Note that the categories of tall tussock grassland (not improved) and short tussock grassland (improved) have been excluded as they did not appear at any of the sites. Categories from SHMAK (Biggs *et al.* 2002).

Table 13: Summary of percent cover and species of instream macrophytes sampled at the four wadeable freshwater mahika kai sites.

	El Dorado	Hakariki	Te Pari Kouau	Whakapatukutu
Percent Cover	0	5	5	2
Species	NA	*Ranunculus trichophyllus*	*Ranunculus trichophyllus*	*Limosella lineta*

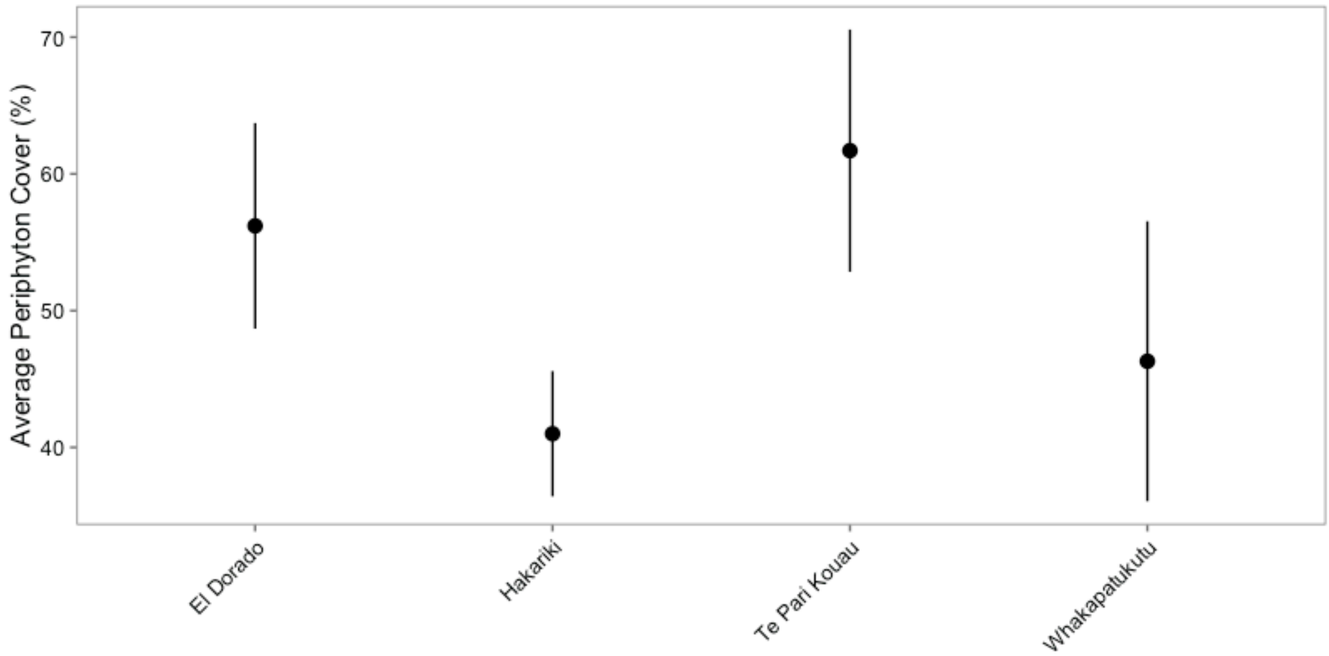

Figure 32: Average (± 1 standard error) periphyton cover (%) of sampling units at the four wadeable freshwater mahika kai sites on the Waikouaiti River (n=10).

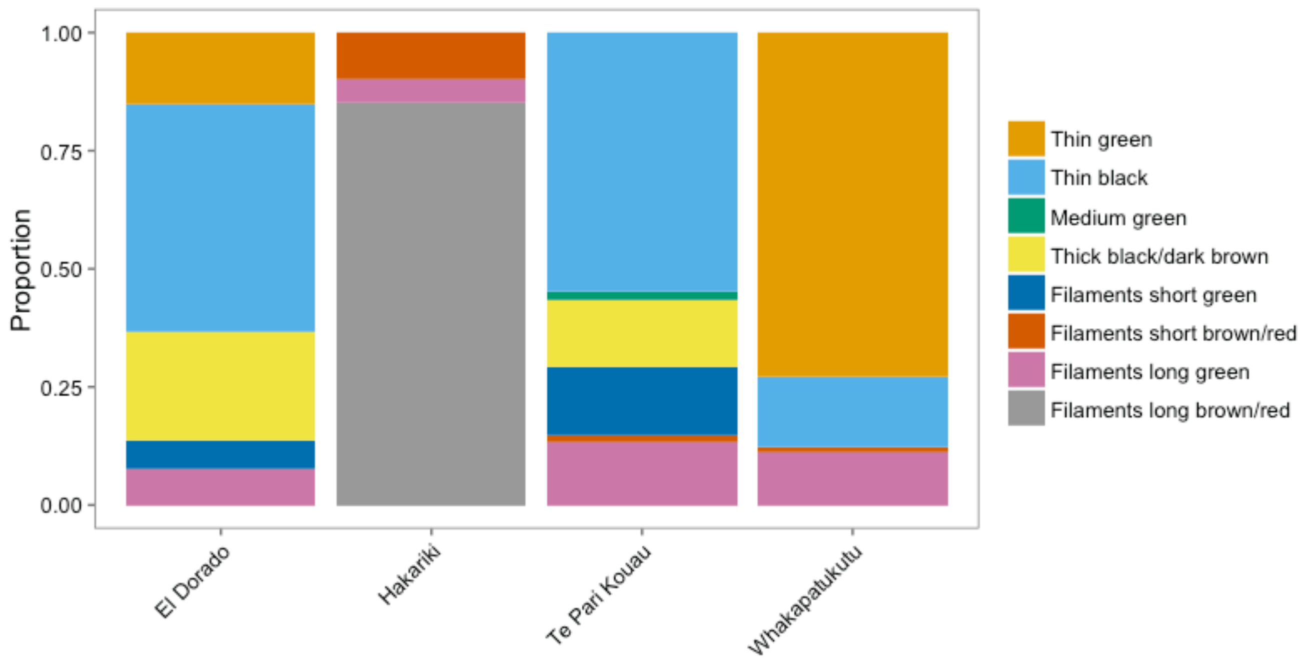

Figure 33: Proportion of periphyton categories making up the total periphyton cover for each wadeable freshwater mahi<u>k</u>a kai site (n = 10). Note that the categories of thin light brown, medium light brown, medium black/dark brown and thick green/light brown have been excluded as they did not appear at any of the sites. Categories from SHMAK (Biggs *et al.* 2002).

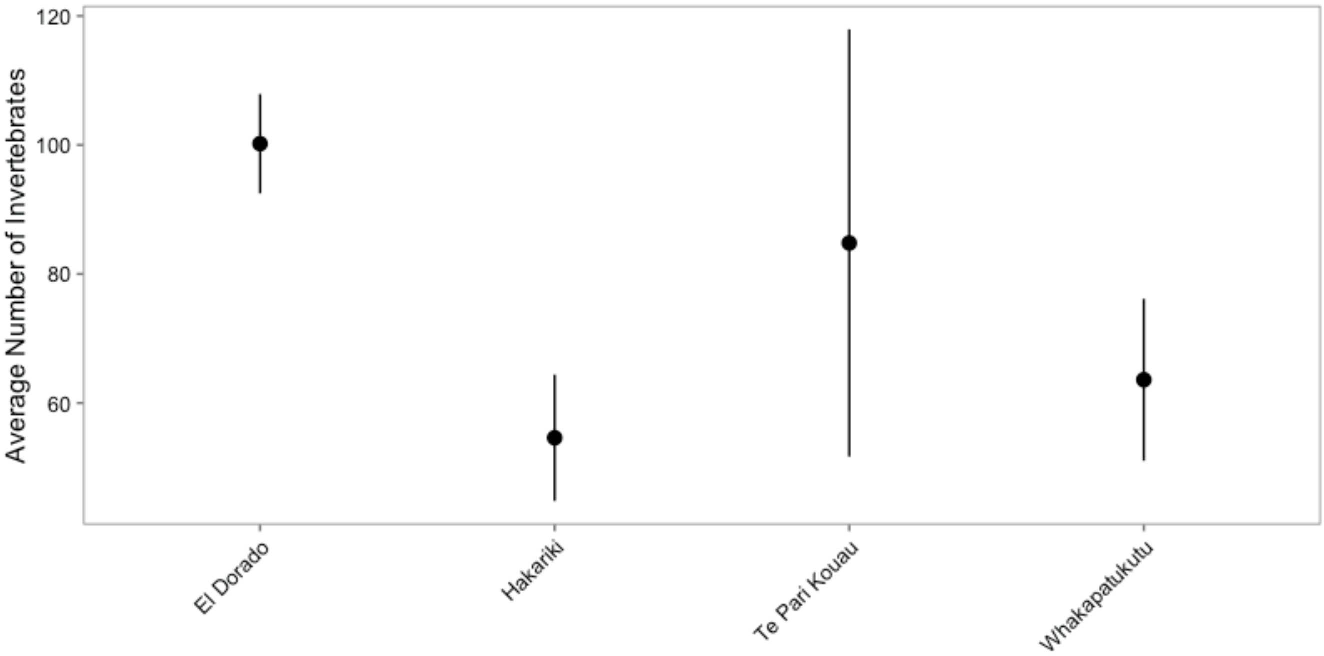

Figure 34 Average (± 1 standard error) number of invertebrates found at each wadeable freshwater mahika kai site on the Waikouaiti River (n=10).

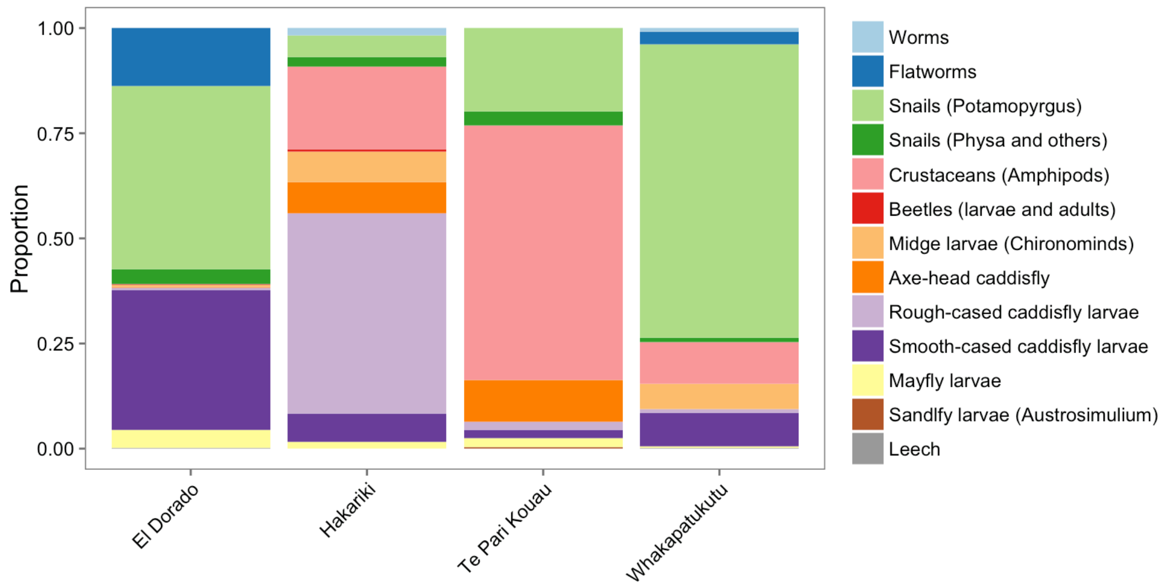

Figure 35: Proportion of invertebrate categories making up the total number of invertebrates at each wadeable freshwater mahika kai site (n = 10). Note that the categories of small bivalves, limpet-like molluscs, ostracods, cranefly larvae, spiral caddis and stonefly larvae have been excluded as they did not appear at any of the sites. Categories from SHMAK (Biggs *et al.* 2002).

Table 14: Summary of stream category and SHMAK scores for habitat, invertebrates, and periphyton for each of the wadeable freshwater mahika kai sites.

	Category	Habitat Score	Invertebrate Score	Periphyton Score
El Dorado	Stony	43.3 (Good) [-50] [100]	5.7 (Moderate) [0] [10]	7.9 (Good) [0] [10]
Hakariki	Stony	62.8 (Very Good) [-50] [100]	5.3 (Moderate) [0] [10]	4 (Moderate) [0] [10]
Te Pari Kouau	Stony	27 (Moderate) [-50] [100]	4.7 (Moderate) [0] [10]	7.5 (Good) [0] [10]
Whakapatukutu	Stony	0.5 (Poor) [-50] [100]	4.3 (Moderate) [0] [10]	6.8 (Good) [0] [10]

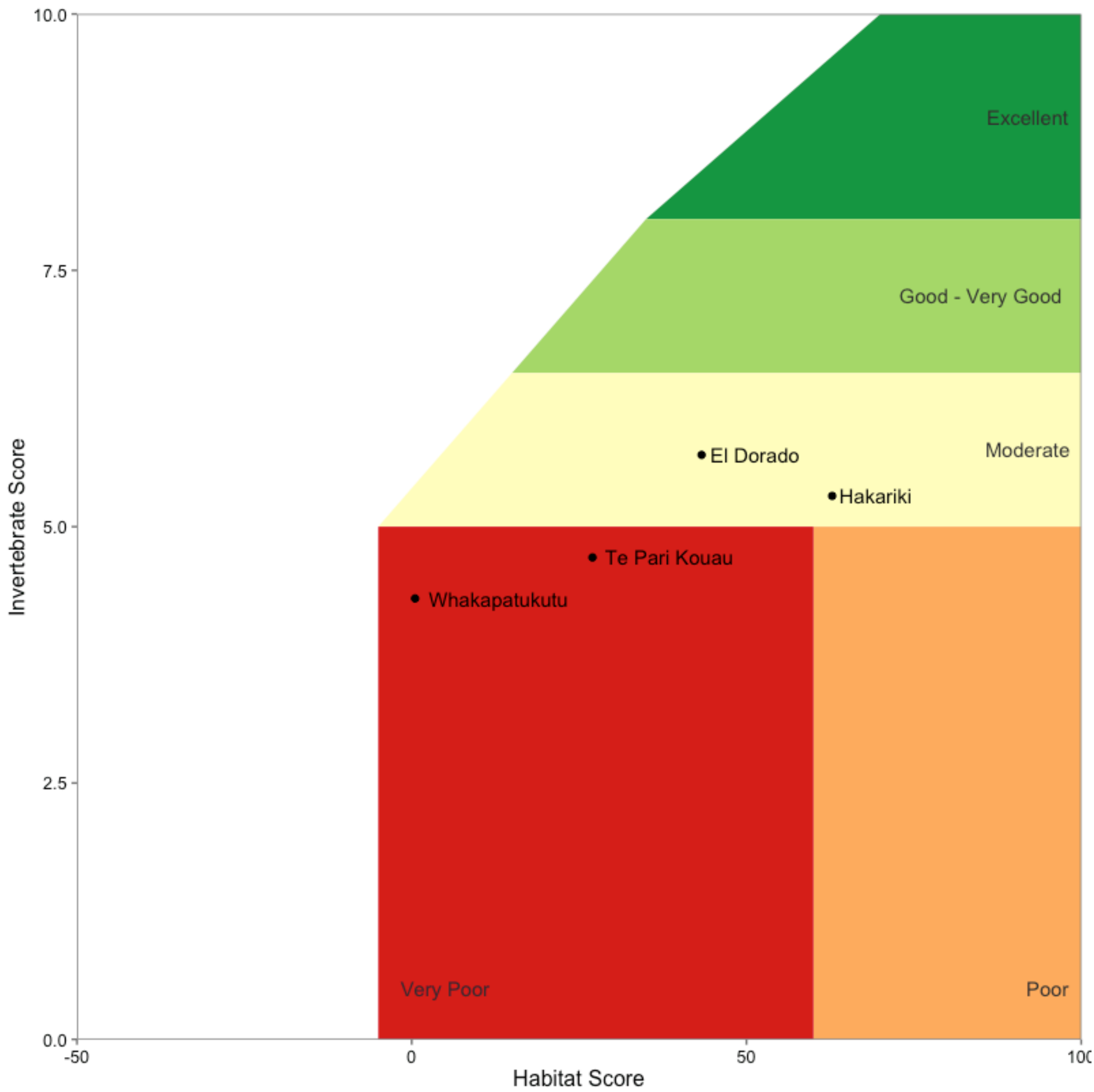

Figure 36: Overall health score for each wadeable freshwater mahika kai site (black dots). Overall score is calculated using the invertebrate and habitat scores. Figure modified from SHMAK manual (Biggs *et al.* 2002).

Discussion

The purpose of the He Pātaka Wai Ora fieldwork was to provide a baseline understanding of the health of the Waikouaiti River to support the management of mahika kai sites by Kāti Huirapa ki Puketeraki and help the Rūnaka direct restoration efforts on the river. The full value of these data will only be realised in subsequent years as trends become clearer. However, several key observations warrant further discussion at this stage and are discussed below.

Lower catchment ammonium concentrations

The lowland river trigger value for ammonium is 0.021 mg/L (ANZECC & ARMCANZ 2000). New Zealand does not have recommended trigger values for ammonium in estuaries, however ANZECC & ARMCANZ guidelines suggest Southeast Australian values may be appropriate (0.015 mg/L, ANZECC & ARMCANZ 2000). In either case, the average values for ammonium concentration at Te Tauraka a Waka, Te Taumata a Puaka and Ohinepouwera exceeded these trigger values. All sites, except for Hakariki, exceeded this value during at least one sampling event. Te Tauraka a Waka is a particular concern for ammonium concentrations with an average more than three times the trigger value (0.073 ±0.007 mg/L) and the maximum recorded concentration, more than ten times the trigger value (0.223 mg/L). Te Tauraka a Waka and sites downstream have an influence from another tributary, the Merton Tidal Arm. As the sites were sampled on a falling tide to represent conditions upstream, the high ammonium levels found at Te Tauraka a Waka are likely to be a signal from the Merton Tidal Arm, rather than the main branch of the river. The levels remain high until they reach the ocean and are diluted. Consequently, monitoring carried out at Whakapatukutu (Orbell's Crossing) by Otago Regional Council may underestimate ammonium concentrations lower down in the Waikouaiti River. This influence from the Merton tributary stream warrants further investigation.

Winter spike in catchment nutrient concentrations

In contrast, concentrations of nitrate and phosphate at the nine mahika kai sites never exceeded the lowland river trigger values of 0.444 mg/L for nitrate and 0.033 mg/L for phosphate (ANZECC & ARMCANZ 2000). The highest value measured for nitrate was 0.238 mg/L at Hakariki and for phosphate, 0.023 mg/L at Te Tauraka a Waka. The clearest temporal pattern in nitrate concentration was a spike at all sites in June. Based on Otago

Regional Council Data available on the LAWA website (https://www.lawa.org.nz/) for the Waikouaiti River, this appears to be a regular pattern occurring annually in winter since at least 2007. These data show, for the first time, that this event occurs at all sites, not just at the long-term ORC monitoring site at Whakapatakutu (Orbell's Crossing). This spike was evident from El Dorado, with concentrations increasing with distance downstream. This pattern may be indicative of catchment-scale diffuse discharge, rather than point-source or discharge from a specific land use activity. To clarify this, it would be useful for future monitoring to include at least one site in the South Branch of the Waikouaiti River. Further investigation into this annual spike in nitrate is also recommended.

Low cover of canopy species and native vegetation

Water temperature showed seasonal variation in the Waikouaiti River which is to be expected with higher temperatures over summer months due to increased solar radiation (Davies-Colley 2000). Water temperature is also very dependent on the coverage of riparian vegetation as the cover prevents solar radiation penetrating surface water (Collier *et al.* 1995). Between sites, temperature did not vary and this is likely due to a consistent lack of dense riparian vegetation cover which was evident in the ecological surveys. There were very few tall native trees along the riparian margin of the Waikouaiti River; these can play a very important role in shading the stream (Allan 2004). Streams with riparian vegetation dominated by pasture have higher mean temperatures than native forest streams (Quinn *et al.* 1997). Increased water temperature, particularly in drought years, was a concern that was brought up by participants during the hui. Increased water temperature can have impacts on dissolved oxygen levels, fish mortality and cause algal blooms (Tramer 1966; Stanley *et al.* 1997). In addition, riparian vegetation is an essential source of leaf litter and associated allochthonous material. This material supports invertebrate shredders and is therefore the primary food (energy) source for these ecosystems (Delong & Brusven 1994). This supply of food is particularly important in the upper catchment, as this has flow-on effects for downstream communities (Vannote *et al.* 1980). The Waikouaiti catchment once had extensive coverage of broadleaf podocarp forest, with stands of houi (*Plagianthus divaricatus*) around the estuary (Prebble & Mules 2004), restoring this native vegetation along the riparian margins would help regulate stream temperature and provide a source of leaf litter and allochthonous material.

Downstream sites showed a decreasing number of riparian species and an increase in the proportion of pasture species covering the stream bank. This is a common trend along rivers which have increased agricultural activity downstream (Niyogi *et al.* 2007). The Waikouaiti River catchment has been significantly modified by agriculture, particularly sheep and beef with some dairy farming in the lower reaches (Dale 2011). Most of the vegetation along the river was not native, another common impact of agricultural intensification which favours exotic grasses over native forest (Otago Regional Council 2010). The buffering effect of riparian vegetation has been shown to reduce nutrient and sediment input into rivers (Collier *et al.* 1995; Williamson *et al.* 1996, Tabacchi *et al.* 1998, Bernhardt & Palmer 2011, Olley *et al.* 2015). Larned *et al.* (2004) found that nutrient concentrations were significantly higher in sites dominated by pasture vegetation than native riparian sites. Hui participants were concerned about the loss of native vegetation along the river and suggested planting native plants to reduce nutrient and sediment loading.

In estuarine environments, such as those present in the lower portion of the Waikouaiti River, vegetation abundance generally decreases and changes to halophytes (e.g. harakeke, oioi, houi and māakoaka), which are tolerant of higher salinity (Tabacchi *et al.* 1998; Atkinson 2004). The data presented here indicate that there is a high proportion of native vegetation at Te Tauraka a Waka and Te Taumata a Puaka (the two sites within the saltmarsh proper). A concern is the high potential for disturbance from vehicles driving on the fragile vegetation due to both sites having roads and other manmade structures nearby. At the hui, participants mentioned the native saltmarsh vegetation as species of significant value, and the estuary as a place of value. While portions of the Waikouaiti Estuary have been highly modified, it stills contains extensive areas of native vegetation of significant ecological value (Lloyd 2004). Further work should be undertaken to better understand how best to protect and enhance the Estuary.

Lack of pollution sensitive taxa at some sites

Invertebrate monitoring showed a relatively high proportion of taxa tolerant to poor environmental conditions, even at the most upstream site (El Dorado). More than half of the invertebrate taxa at Hakariki were EPT (*Ephemoptera* / mayflies; Plectoptera / stoneflies and; *Trichoptera* / caddisflies) species which are sensitive to poor stream health (Otago Regional Council 2015). In contrast, Potamopyrgus snails, which are highly tolerant of pollutants, were dominant at El Dorado and Whakapatuku (Biggs *et al.* 2002). The dominance of

Crustaceans (amphipods) at Te Pari Kouau is likely to be due the abundance of macrophytes at this site. These taxa tend to be strongly associated with macrophytes (Jeppesen *et al.* 1998).

Studies have shown that a change from native vegetation to pasture has impacts on macroinvertebrate communities with an increase in taxa that are more tolerant to poor stream health (Quinn & Hickey 1990; Harding & Winterbourn 1995; Quinn *et al.* 1997; Collier *et al.* 2000). With this land-use modification, communities generally change from shredders and collectors to grazer-scrapers which tend to thrive on algae which grows as a result of enrichment (Moss 2010). Common groups of invertebrates that are more tolerant of enrichment and increased sedimentation include snails and chironomids (Parkyn *et al.* 2003).

The lack of EPT taxa is concerning as El Dorado is situated in the upper reaches of the Waikouaiti catchment and the headwaters of rivers are generally the most pristine section; any activities at the headwaters can have lasting impacts downstream (Niyogi *et al.* 2007). The predominant periphyton present at El Dorado was more indicative of healthy stream conditions (Biggs *et al.* 2002). The presence of pollution-tolerant invertebrates, and the lack of EPT taxa at the site furthest up the catchment (El Dorado) suggests that a whole-catchment approach to restoration is required.

A higher proportion of fine sediment in lower catchment sites

The substrate type of the Waikouaiti River bed changed from cobbles at the upper sites to finer substrate such as silt, mud and sand at the lower sites. This is common as smaller substrates are carried further downstream as suspended particles in the water column (Closs *et al.* 2004). Large substrate such as cobbles provide ideal habitat for invertebrates and native fish species while gravel provides some habitat but is less stable and can scour periphyton and detach invertebrates (Biggs *et al.* 2002). Sand, mud and silt are highly mobile and provide very little interstitial space and therefore provide poor habitat for stream biota. These fine sediments can also decrease water clarity which impacts recreational activity such as swimming and fishing (Biggs *et al.* 2002; Ministry for the Environment & Statistics New Zealand 2015). A concern of participants at the hui was an increase in fine sediment in the estuary and at the river mouth; further investigation into this impact would be recommended to allow K̲āti Huirapa ki Puketeraki to better manage this sediment load. A priority would be to investigate the potential impact of sediment from the forestry operations in the South Branch of the Waikouaiti River.

Estuarine influence extends to Whakapatakutu

The spatial variability in conductivity was expected and clearly shows that the marine influence from the estuary reaches at least as far as Whakapatakutu (Orbell's Crossing). The extent of this saline intrusion is well known and has been studied by many students from the University of Otago as part of an Aquaculture and Fisheries paper in the Department of Marine Science. Many important native fish species are diadromous, inhabiting both freshwater and seawater environments, and their lifecycles rely on access to the marine environment (Charteris *et al.* 2003). Īnak̲a were identified as species of value by hui participants and the īnak̲a spawning ground just downstream from Whakapatukutu was described as a place of value. Riparian vegetation in areas where freshwater transitions to saline water, as is the case at Whakapatukutu, is the preferred habitat for īnak̲a spawning. Successful spawning is crucial to the survival of īnak̲a populations as most adults die after spawning (Richardson & Taylor 2002). Therefore, suitable riparian vegetation, such as native rush and harakeke, is very important to facilitate the reproductive cycle of īnak̲a (Taylor 2002). Although some exotic vegetation can support īnak̲a spawning, many grasses do not provide suitable habitat. As the majority of riparian vegetation cover at Whakapatukutu was non-native pasture grass, this may be an important site to focus riparian restoration efforts. Spawning sites in pasture areas are vulnerable to stock damage and attract predators such as mice and rats which tend to breed at the same time as īnak̲a spawning (Taylor 2002; Baker 2006). Carrying out predator control while īnak̲a are spawning was recommended at the hui.

Site A (The Culvert) and Site B (The Main Road)

The results from sites A (The Culvert) and B (The Main Road) are likely to have been confounded by both sites drying up over the summer months which makes the site data difficult to interpret. The Culvert dried up completely in January and prior to this showed increasing nutrient concentrations. The Main Road also started drying up and followed the same trend of increasing nutrient concentrations. However, it is likely that this site re-connected with the river between March and April as values dropped again. Despite the drying of these sites over summer, the high nutrient concentrations observed at sites A and B indicate that when they are flowing they may contribute a disproportionately high amount of nutrients to the Waikouaiti Estuary. These sites have been the focus of restoration with volunteers planting 300 – 400 native plants as part of the Ki Uta Ki Tai: From the Mountains to the Sea volunteer week (Kāti Huirapa Rūnaka ki Puketeraki, 2013). While these sites are not representative of the health of the main branch of the Waikouaiti River, an important focus for Sites A and B would be to enhance the quality of the water flowing through these sites and reduce nutrient inputs into the Waikouaiti Estuary.

General Conclusions

In 2016 the Waikouaiti River is in a moderate state of health compared to lowland rivers elsewhere in New Zealand today. However, it is unlikely that the elders of Waikouaiti, interviewed by H K Taiaroa in the 1880s, would recognise the river in its present state. The forests have disappeared, along with many of the bird species, and habitat for freshwater fishes. While it may not be possible to return to a past where the river and forest provided for the bulk of the community's needs, continued restoration, targeting key sites, will support the connection of future generations to their cultural landscape. What is clear is that a long path of restoration lies ahead if the aspirations of tāk̲ata tiaki, and the local community that surround this iconic river and estuary, are to be met. The good news is that the Waikouaiti River is currently in a reasonable state of health, therefore, it is reasonable to expect that restoration efforts will show positive results within a realistic time frame. The degradation of the Waikouaiti River predominantly occurred between the 1850s and 1990s; it is realistic to assume that restoration could occupy a similar timeframe.

The concerns discussed by the hui participants have generally been supported by the conclusions drawn from this baseline monitoring period. Identifying critical nutrient sources and increasing the amount of targeted native riparian vegetation, with a focus on tree species, are the primary recommendations. The state of the river is reflected in the range of data gathered and provides an indication of river and estuarine health today. This information and the monitoring framework provided here will become more useful as it is built on over time, helping direct restoration and inform decision makers. Importantly, ongoing management can monitor successes and failures, building on the former and adjusting approaches for the latter. The general principles and approach taken in the He Pātaka Wai Ora Project can be applied to other rivers throughout New Zealand. However, the results and measurements in this report are specific to this awa, the Waikouaiti. The lessons learned through this Rūnak̲a led research could be valuable to other communities who wish to embark on a similar project on their river. This work has been built on more than 15 years of work in the region by a large number of people and organisations, many of whom remain directly involved in this work (see Acknowledgements, above). The success of this project in the future will require a community that is committed to restoring and managing the environment, and one which continues to support new and existing relationships with land owners, local and regional councils, researchers and others.

An important outcome from this project was the reconnection of local people to some areas of the river that had not been accessed for many years. These sites were important mahik̲a kai for the tūpuna of this place. The measurement of this outcome is beyond the scope of this report, but it provides a strong platform for the waiora of the river and hauora of the people.

Recommendations

1. Continue building relationships within the community and fostering awareness of impacts on water quality and habitat. When considering areas for habitat restoration, this should include a consideration of access to the sites. It is likely that if people can access replanted / restored sites they will feel more connected to the Waikouaiti River. Fostering a sense of guardianship and "ownership through involvement" will provide sustainability for this project in the long term. If access to some sites (e.g. "land-locked sites") is not immediately available (e.g. through existing relationships), pathways and funding sources to improve access should be identified.
2. Continue sampling at sites. The baseline that has been developed during this project should be continued. Data presented in this report suggest that water quality sampling once a month would sufficient to detect and monitor trends over time. It would be valuable to develop standard operating procedures for monitoring to ensure consistency of sampling methods over time. For example, although differences between pH at some sites were identified, examination of trends over time was hampered by variable calibration of the pH electrode. Advice from experts in this field should be sought prior to the development of an ongoing sampling plan.
3. Develop / investigate ecological monitoring methods for the Waikouaiti Estuary. The methods used at the freshwater wadeable sites were based on the well-developed SKMAK methodology that was written specifically for community groups such K̲āti Huirapa ki Puketeraki. It would be useful to develop (or find) similar methods for the estuary sites to better understand the ecology and capture changes in estuary health. Existing tools (e.g. the Marine Cultural Health Index or State of the Takiwā monitoring forms) may provide a starting point and it may be sensible to incorporate human use of the estuary (e.g. for food or recreation) as a potential indicator of estuary health.
4. Encourage the development of appropriate research projects by reporting findings from the sampling programme, and providing data to support the development of new studies on the river and estuary. For example, data collected during this project could be provided to support an ongoing Otago Regional Council project that is investigating the impact of low river flows on the ecology of the Waikouaiti Estuary.
5. Investigate the Merton Tidal Arm and the possible nutrient source that was detected at Te Tauraka a Waka. Even without any of the insight provided by the data collected in

the He Pātaka Wai Ora Project, the importance of this site has been identified. For example, it has been the site of restoration (planting and carving pou) by Tā Whakaea Hou, a ‘by youth, for youth’ initiative funded by the Ministry of Youth Development (Kāti Huirapa Rūnaka ki Puketeraki 2016). The status of the Main Road and Culvert sites could inform further study of the Merton Tidal Arm. At these sites, reductions in water quality appear to be linked to periods where flow (or flushing) is low. Restoring natural flow (or flushing) may improve water quality at these sites and within the Merton Tidal Arm, generally. Consideration should also be given to the influence of the other tidal arms on the water quality of the Waikouaiti (e.g. delivering ammonium to the estuary). Existing student reports (Department of Marine Science, University of Otago) could be used as a starting point to establish if trends in the Merton Tidal Arm identified here are indicative of those in other tidal arms of the Estuary.

6. Site A (The Culvert) and Site B (The Main Road) are not characteristic of the main branch of the river and dry out at certain times of year. Due to this, it is proposed that these sites be removed from regular sampling (and add sites elsewhere, see below). However, it is likely that the catchment upstream of these sites is contributing relatively high nutrient concentration to the Merton Tidal Arm. Some further investigation is required to understand the influence of Site A and B on mahik̲a kai downstream, the importance of these sites in providing habitat for mahik̲a kai species, the implications of intensive restoration at this site, and the implications of the site drying out on the sample results. The priority for such work is open to discussion.
7. An environmental monitoring programme regarding the potential influence of logging operations on the South Branch is needed. It was identified at the initial hui that logging has the potential for significant negative impacts (e.g. increased sediment loading) on the river, estuary, coastal marine area, and on mahik̲a kai sites. Engagement with City Forests and Otago Regional Council is required to ensure any environmental degradation is minimised and the river and estuary is effectively monitored before, during, and after logging operations.
8. Consider adding a site (or sites) on the South Branch of the river and an additional site just above the confluence of the North Branch for future monitoring. This would support the implementation of several of the above recommendation and could aid in distinguishing catchment scale processes (which will be seen in both branches) and land use effects (which may be localised to one branch).

9. Develop a catchment re-vegetation and habitat restoration plan. Although the focus of this project was on relatively small and discrete mahika kai sites, some of the data collected during this project (e.g. increasing ammonium concentrations down the catchment) suggest that some of the undesirable changes to water quality accumulate over the entire length of the catchment. Therefore, this plan should provide catchment-scale coordination of re-vegetation and habitat restoration. This is consistent with established scientific principles and with a Ki Utu Ki Tai management strategy for the Waikouaiti River. The plan should address different scales of improvement and management. For example, initially, change should be effected through small, site-specific improvements to address critical sources that may degrade water quality in the Waikouaiti. The longer-term strategy, however, should aim to improve physical access to the river (thus fostering wider engagement, see Recommendation 1 above) and support broader restoration goals to improve ecological, recreational or cultural values of the site (e.g. planting riparian vegetation to improve īnaka habitat at Whakapatukutu / Orbell’s Crossing).
10. Further investigate the cultural and historical importance of the awa and the mahika kai sites as well as examining the impacts of the awa on waiora and hauora of the people now, and for generations to come.

Glossary

awa	river, stream
hapū	subtribe
harakeke	New Zealand flax, *Phormium tenax*
hauora	health, vigour
Hāwea	early tribe in the South Island
houi	ribbonwood, *Plagianthus divaricatus*
hui	meeting
īnaka	whitebait, *Galaxias maculatus*
iwi	tribe
kai	food
Kāi Tahu	"Kāi Tahu are the iwi comprised of Ngāi Tahu whānui; that is, the collective of the individuals who descend from the five primary hapū of Kāi Tahu, Kāti Māmoe and Waitaha, namely Kāti Kurī, Kāti Irakehu, Kāti Huirapa, Kāi Tūāhuriri and Kāi Te Ruahikihiki" (Te Rūnanga o Ngāi Tahu, 1996).
kākahi	freshwater mussel, *Hyridella menziesii*
kanakana	lamprey, *Geotria australis*
Kāti Huirapa Rūnaka ki Puketeraki	One of the 18 local councils of Kāi Tahu. "The takiwā of Kāti Huirapa ki Puketeraki centres on Karitāne and extends from Waihemo to Purehurehu

	and includes an interest in Ōtepoti and the greater harbour of Ōtākou. The takiwā extends inland to the Main Divide sharing an interest in the lakes and mountains to Whakātipu-Waitai with Rūnaka to the south" (Kāi Tahu Ki Otago, 2005, p. 153).
Kāti Mamoe	Early inhabitants of Te Waipounamu
kaitiakitaka	guardianship
kererū	New Zealand woodpigeon, *Hemiphaga novaeseelandiae*
Ki Uta Ki Tai	from the mountains to the sea
kōtare	kingfisher, *Halcyon sancta*
mahika kai	collection and consumption of resources
mana	prestige, authority, influence, status
manaakitaka	hospitality, generosity
māakoako	sea primrose, *Samolus repens*
mana whenua	authority over land or territory
Mātaitai	"means an identified traditional fishing ground established as a mātaitai reserve under regulation 20" (s2,"Fisheries (South Island Customary Fishing) Regulations ", 1999)
Mātauraka Māori	traditional knowledge gained through the experiences of previous generations

mauka	mountain
Mauri	life force
nohoaka	dwelling
oioi	native rush, *Apodasmia similes*
Ōtepoti	Dunedin
Ōtākou	Important historical settlement near Dunedin
Whakatipu-Waitai	Lake McKerrow, Fiordland
pā	fortified village
pātaka	storehouse
pātiki	flounder, *Rhombosolea plebeia*
pipi	edible bivalve, *Paphies australis*
puha	sowthistle, *Sonchus* spp.
pūtakitaki	Paradise Shelduck, *Tadorna variegata*
Rapuwai	early tribe in the South Island
Rūnaka	local councils
ruru	Morepork, *Ninox novaeseelandiae*
Taiāpure	local fishery
Takiwā	tribal area
Tākata	people
Tākata whenua	people of the land
Tākata Tiaki/Kaitiaki	"means any person or persons appointed as Tākata Tiaki/Kaitiaki under these regulations who are members of the tākata whenua, or of any tākata whenua

	organisation or their nominated representatives” (s2,"Fisheries (South Island Customary Fishing) Regulations ", 1999).
taoka	treasure, prized objects
Te Tauraka ā Pōti	Merton Tidal Arm
Te Waipounamu	South Island
ti	cabbage tree, *Cordyline australis*
tikaka	correct way of doing things
tuaki	cockle, *Chione stutchburyi*
tuatua	edible bivalve, *Paphies subtriangulata*
tuna	eel, *Anguilla* spp.
tūpuna	ancestors
urupā	cemetery, burial ground
wai kōura	freshwater crayfish, *Paranephrops zealandicus*
waiora	pure water, health
Waitaha	Early inhabitants of Te Waipounamu
wharenui	meeting house

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Appendix 1

Appendix 1 Table 1: Periphyton categories, table modified from SHMAK Stream Monitoring Manual, Version 2K (pg. 3.8; Biggs et al. 2002).

Periphyton Categories
Thin (<0.5mm thick)
Green
Light brown
Black/dark brown
Medium (0.5-3mm thick)
Green
Light brown
Black/dark brown
Thick (>3mm thick)
Green/light brown
Black/dark brown
Filaments, short (<2cm long)
Green
Brown/reddish
Filaments, long (>2cm long)
Green
Brown/reddish

Appendix 1 Table 2: List of invertebrate categories, table modified from SHMAK Stream Monitoring Manual (pg 3.8; Biggs et al. 2002).

Invertebrate Categories
Worms (e.g. thin brown/red *Tubifex*)
Flatworms, leeches
Snails (1-3mm across, pointed end)
Snails (4-6mm across, rounded)
Small bivalves (up to 4mm across)
Limpet-like molluscs (*Latia*, up to 8mm wide)
Freshwater crustaceans (amphipods, water fleas)
Ostracods ("seed shrimps"; up to 2mm long)
Beetle larvae and adults
Midge larvae (3-7mm long, white-red)
Cranefly larvae
"Axe-head" caddis (*Oxyethira*, 2-3mm long)
Caddisfly larvae (rough stony cases, or cases of sticks, etc. and free-living)
Smooth-cased caddisfly larvae (*Olinga*, up to 10mm long, chestnut-brown colour)
Spiral caddis (*Helicopsyche*, up to 3mm wide)
Mayfly larvae (2-15mm long)
Stonefly larvae (large species, up to 20mm)

Appendix 1 Table 3: Titles of the themes discussed by participants at the Hui at Puketeraki Marae on the 14 April 2015 and a summary of the Post-it notes that were placed under each title.

Title	Summary of Post-it notes
Places of value	Important cultural sites were mentioned such as the waka landing site, the hatchery, historic mahika kai sites, and in general, places with historic names. Recommendations for these areas included constructing information panels and restoration Important habitat was also mentioned such as the saltmarsh, riparian vegetation along the river, native vegetation, and the headwaters
Species of value	Mahika kai/historically significant species: Tuaki, pipi, īnaka, tuna, kōura, kanakana (lamprey), kākahi (freshwater mussel) Birds: Ruru, kererū, kōtare, waders, pūkeko, godwits, fernbirds, tui, bellbirds Plants: Saltmarsh, tussock, remnant native forest, kowhai Mentioned the importance of children being able to learn from the species, their habitat and the benefits of restoration for the species
Memories of the river	Previous state of the river and species that were once presents such as the Kaka Suggestions to interview people, or look at old documents such as photos, old maps, diaries and archaeological records
Areas of concern	Land use/modification/human impact Macraes Flood gates Invasive species – wilding pines, spartina, animal pests (rats, mice, cats, mustelids), pigs, goats, gorse, Chilean flame creeper Pollution – farming, forestry, sewage

	Extent of whitebaiting River quality Sediment – build up in the estuary, identify source and future risks e.g. forestry Species – eels, low adult pātiki numbers, Nutrient loading – algal blooms Native vegetation – planting of riparian veg to buffer nutrients and sediments, retention of tussock in headwaters Low flows and temperature
How will the future look (the river in 100 years)	All mention a restored ecosystem with a healthy and clean river, regenerated native vegetation, food security, safe recreational activities, flourishing wildlife native birds, ability to respond to rising sea levels
Offers of help	Equipment: Maps, monitoring equipment, truck, quad, boat People: Time, knowledge, analysis, Collaboration with various groups
Comments/thoughts	Planning and reporting Keeping the community up to date Incorporating different groups for collaboration but also understanding what has been done already Encouraging groups to take action when an issue is their responsibility Change of place names since the 1800s, many historic names were based on the species that were present

Appendix 1 Table 4: Percent (%) cover of substrate types that make up the stream bed composition at each of the freshwater and estuarine mahika kai sites along the Waikouaiti River. Categories from SHMAK manual (Biggs et al. 2002).

	El Dorado	Hakariki	Te Pari Koua u	Whakapatukutu	Okauia	Te Tauraka a Waka	Te Taumata a Puaka	Ohinepouwera
Bedrock	0	0	0	0	0	0	0	0
Boulders (>25cm)	0	0	0	0	0	0	0	0
Large cobbles (12-25cm)	0	95	0	0	0	0	0	0
Small cobbles (6-12cm)	91	0	0	10	0	0	0	0
Gravels (0.2-6cm)	9	0	95	88	0	0	0	0
Sand	0	0	0	0	0	0	50	100
Mud or silt	0	0	0	0	90	100	50	0
Man-made (e.g. concrete)	0	0	0	0	10	0	0	0
Woody debris	0	0	0	0	0	0	0	0
Water Plants	0	5	5	2	0	0	0	0