He Pataka Wai Ora Methods and Results

He Pataka Wai Ora Project Team (Kāti Huirapa Rūnaka ki Puketeraki / University of Otago)

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This document is automatically generated. The data contains a subset of information collected as part of the He Pataka Wai Ora Project. The intention is that this report can be easily updated as further information is collected as part of the ongoing monitoring of the Waikouaiti River undertaken as part of the Ministry for the Environment (MfE) / Statistics New Zealand freshwater domain report.

This document contains the methods and results from the He Pataka Wai Ora Project and will be updated as further information becomes available.

Summary statistics and plots are included to give a sense of what has been done with these data within the He Pataka Wai Ora Project. Most of these data are written to `.csv` format and can be supplied if needed. Some of these data do not lend themselves to tabular representation (e.g. site summaries). They can be supplied as RData objects if required.

Raw data

This report is accompanied by two CSV files containing raw data, these are:

- Water Quality
  - Temperature:
    - Code: temp
    - Units: °C
  - Conductivity:
    - Code: cond_comb
    - Units: µS / cm
  - pH:
    - Code: ph
    - Units: Dimensionless (log H+ concentration)
  - Dissolved Oxygen
    - Code: do
    - Units: mg / L
- Nutrients
  - Nitrates:
    - Code: NOX_mgL
    - Units: mg / L
    - LAWA Equivalent: Total Oxidised Nitrogen
  - Ammonium
    - Code: NH4_mgL
    - Units: mg / L
    - LAWA Equivalent: Ammoniacal Nitrogen
  - Phosphate
    - Code: PO4_mgL
    - Units: mg / L
    - LAWA Equivalent: Dissolved Reactive Phosphorus

Some pre-processing has been done as part of the He Pataka Wai Ora Project and can be documented for / discussed with MfE and Stats New Zealand if required. This pre-processing produces two objects `wq_melt` and `nuts_melt`. These are "long form" data frames, suitable for plotting and analysis. The following code chunk below demonstrates the relevant modification of these dataframes, prior to the production of plots and summary statistics below.

```
    # Water Quality
    ## DO (as a %) is not needed and is not used.
    indx <- wq_melt$variable == "do_perc"
    wq_melt <- wq_melt[!indx, ]
    write.csv(wq_melt, file="./output/raw_water_quality.csv", row.names
= FALSE)
    # Nutrients
    ## Convert to mg/L
    rename <- c('NH4_ugL' = 'NH4_mgL', 'PO4_ugL' = 'PO4_mgL', 'NOX_ugL'
= 'NOX_mgL')
    nindx <- match(nuts_melt$variable, names(rename))
    nuts_melt$variable_rnme <- as.character(rename[nindx])
    nuts_melt$value_mgl <- nuts_melt$value/1000
    write.csv(nuts_melt, file="./output/raw_nutrients.csv", row.names =
FALSE)
```

Background

In 2014, Kāti 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. The aim was to initiate a rūnaka led project that made better provisions for kaitiakitanga and the protection of mahinga kai on the Waikouaiti River. By collecting scientific information and mātauranga māori, He Pataka Wai Ora aimed to gain a baseline understanding of the state of the Waikouaiti River and mahinga kai, enabling Kāti Huirapa ki Puketeraki to identify priority areas for restoration. 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 tangata whenua to participate in the monitoring of the state of their natural resources and incorporates their values as part of the assessment. The baseline information gained in this project will be provided to the managers of the East Otago Taiāpure and the Waikouaiti Mātaitai to help make informed decisions on the management of important mahinga kai sites, native fish habitat and anthropogenic impacts on the Waikouaiti River.

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. A clear discrepancy exists between the observations of Kāti Huirapa ki Puketeraki and the results in the State of the Environment reports regarding the health of the Waikouaiti River. This shows the importance of incorporating mātauranga māori (traditional knowledge gained through the experiences of previous generations) and science when determining the health of the environment and how to successfully manage or restore it.

The aim of the He Pataka Wai Ora Project is to incorporate scientific methods and matauranga māori to establish a baseline understanding of the state of the Waikouaiti River. The results from this rūnaka-led project will help Kāti Huirapa ki Puketeraki manage important mahinga kai sites and help the rūnaka direct restoration efforts on the river. As the rūnaka formerly relied on the Otago Regional Council for monitoring data coming from one site at Whakapatukutu (Orbell's Crossing), this project also aims to investigate how representative this site is when comparing it to the more spatially intensive and higher frequency sampling undertaken in this project.

Methods

Site selection

Information gathered from a preliminary project hui and historical documents regarding the Waikouaiti River and mahinga kai from Toitū Otago Settlers Museum and HK Taiaroa (1880) were used to guide the selection process for the monitoring sites for He Pataka Wai Ora Project (Figure 1).

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

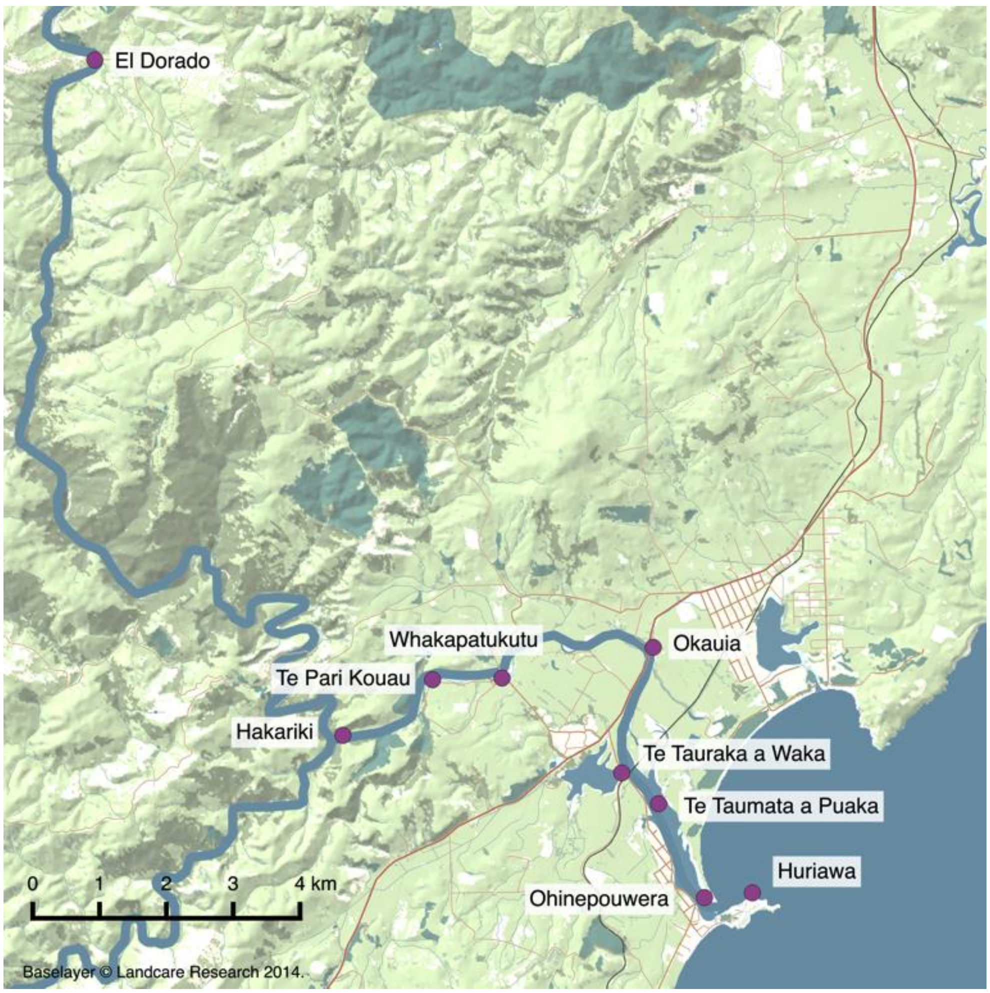

Figure 1: Map of the Waikouaiti River showing the 9 mahinga kai sites.

Site physical characterisation

Photos of the all the sites were taken and physical aspects such as substrate type, stream width, and stream depth were measured. Other characteristics were also recorded including fence value (0: No Fencing, 10: Fully fenced), fence distance (meters of riparian edge), stock access (0: No access, 10: Complete access), stock present (0: Currently present, 10: No evidence of access), 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 2). 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 mahinga 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 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 2: Ten metre transect line along the Waikouaiti River indicating the sampling area for site characteristics and the wider ecological survey.

Figure 3: 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 mahinga 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 25 mm 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 mahinga 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. The true right and true left banks were surveyed seperately.

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). 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. 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. All vegetation, bare ground or artifical structures that could be seen was 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: Riparian vegetation survey within a 10 m x 10 m area carried out along the Waikouaiti Estuary.

Figure 6: 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 % (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 (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 base layers (Landcare New Zealand Limited). Three separate summary tables were created for freshwater and estuarine mahinga 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 mahinga 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 in stream macrophytes was calculated. Average periphyton cover at each freshwater site was plotted along with the proportion of total cover in each periphyton category. The mean number 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

Site Descriptions

The following site descriptions describe physical characteristics of the sites.

El Dorado

Ecological Survey Date: 2016-01-10

Site ID: 1

Wadeable / Freshwater Site: Yes

Latitude: -45.52348

Longitude: 170.5478

Fencing: Site Value = 10 **|** No Fencing [0] [10] Fully Fenced

Stock Access: Site Value = 10 **|** Complete Access [10] [0] No Access

Stock Present: Site Value = 10 **|** Observed [10] [0] Not Present

Site notes (Man-made modifications): bridge below, farm buildings with 300m

Stream width / depth at El Dorado (wadeable freshwater sites only)

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

Hakariki

Ecological Survey Date: 2016-01-10

Site ID: 2

Wadeable / Freshwater Site: Yes

Latitude: -45.61539

Longitude: 170.5914

Fencing: Site Value = 0 | No Fencing [0] [10] Fully Fenced

Stock Access: Site Value = 10 | Complete Access [10] [0] No Access

Stock Present: Site Value = 10 | Observed [10] [0] Not Present

Site notes (Vegetation): true left is rocky gravelly open

Site notes (Man-made modifications): old fence

Stream width / depth at Hakariki (wadeable freshwater sites only)

	Stream Width (m)	Depth Centre (mm)	Average Depth (mm)
Downstream	7.3	120	52
Centre	6.5	170	76
Upstream	8.92	460	173

Te Pari Kouau

Ecological Survey Date: 2016-01-10

Site ID: 3

Wadeable / Freshwater Site: Yes

Latitude: -45.60827

Longitude: 170.609

Fencing: Site Value = 0 | No Fencing [0] [10] Fully Fenced

Stock Access: Site Value = 10 | Complete Access [10] [0] No Access

Stock Present: Site Value = 10 | Observed [10] [0] Not Present

Site notes (Man-made modifications): road and water intake

Stream width / depth at Te Pari Kouau (wadeable freshwater sites only)

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

Whakapatukutu

Ecological Survey Date: 2016-01-10

Site ID: 4

Wadeable / Freshwater Site: Yes

Latitude: -45.60832

Longitude: 170.6223

Fencing: Site Value = 0 | No Fencing [0] [10] Fully Fenced

Stock Access: Site Value = 0 | Complete Access [10] [0] No Access

Stock Present: Site Value = 0 | Observed [10] [0] Not Present

Site notes (Man-made modifications): bridge downstream

Stream width / depth at Whakapatukutu (wadeable freshwater sites only)

	Stream Width (m)	Depth Centre (mm)	Average Depth (mm)
Downstream	14.8	200	143
Centre	13.13	195	69
Upstream	14.31	184	75

Okauia

Ecological Survey Date: 2016-01-17

Site ID: 5

Wadeable / Freshwater Site: No

Latitude: -45.60479

Longitude: 170.6514

Fencing: Site Value = 10 | No Fencing [0] [10] Fully Fenced

Stock Access: Site Value = 5 | Complete Access [10] [0] No Access

Stock Present: Site Value = 5 | Observed [10] [0] Not Present

Site notes (Vegetation): park on True Right, no 10x10 survey done

Site notes (Man-made modifications): highway bridge 50m up stream, park/rest area on TR

Te Tauraka a Waka

Ecological Survey Date: 2016-01-17

Site ID: 6

Wadeable / Freshwater Site: No

Latitude: -45.62156

Longitude: 170.6447

Fencing: Site Value = 0 | No Fencing [0] [10] Fully Fenced

Stock Access: Site Value = 0 | Complete Access [10] [0] No Access

Stock Present: Site Value = 0 | Observed [10] [0] Not Present

Site notes (Man-made modifications): railway bridge and road within 50m

Te Taumata a Puaka

Ecological Survey Date: 2016-01-17

Site ID: 7

Wadeable / Freshwater Site: No

Latitude: -45.62586

Longitude: 170.6516

Fencing: Site Value = 10 | No Fencing [0] [10] Fully Fenced

Stock Access: Site Value = 5 | Complete Access [10] [0] No Access

Stock Present: Site Value = 10 | Observed [10] [0] Not Present

Site notes (Vegetation): car tracks on both sides on the saltmarsh, floodgate on True right going under the road

Site notes (Man-made modifications): road 100m away, burm running north/south

Ohinepouwera

Ecological Survey Date: 2016-01-17

Site ID: 8

Wadeable / Freshwater Site: No

Latitude: -45.63867

Longitude: 170.6599

Fencing: Site Value = 0 | No Fencing [0] [10] Fully Fenced

Stock Access: Site Value = 0 | Complete Access [10] [0] No Access

Stock Present: Site Value = 0 | Observed [10] [0] Not Present

Site notes (Vegetation): True Left is a sand dune, True right is a boat launching area and road

Substrate Type

Note that the next plot excludes the following categories because they did not appear at any sites:

- Bedrock
- Boulders (>25cm)
- Woody debris

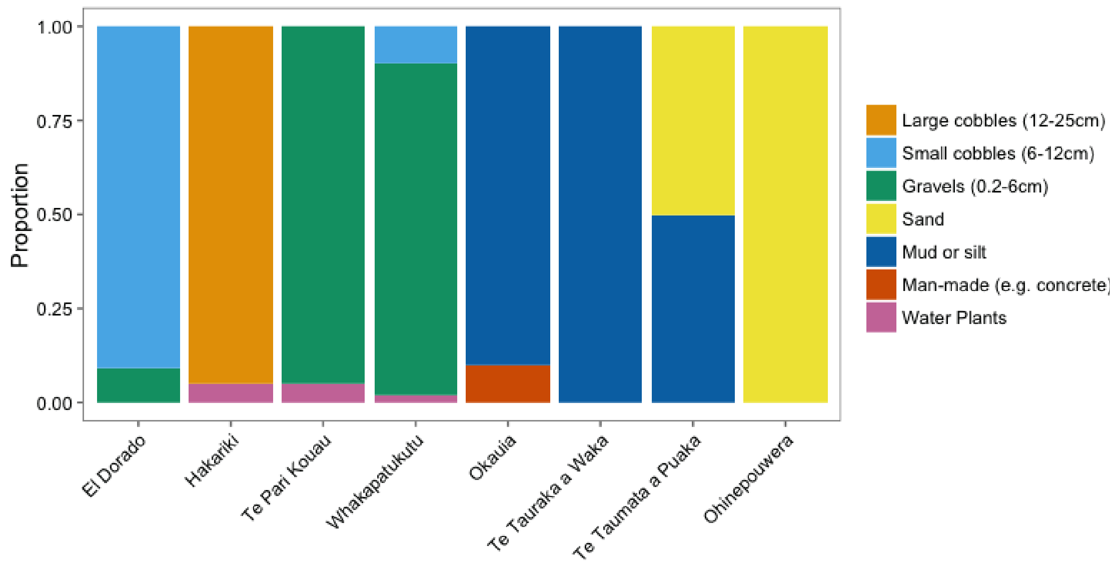

Figure 7: Proportion of substrate types making up the stream bed at each of the freshwater and estuarine mahinga kai sites. Categories from SHMAK (Biggs et al. 2002).

```
    # Underlying data for Substrate Type
    write.csv(substrate$data, file="./output/summary_substrate.csv", ro
w.names = F)
```

Water quality and nutrient concentrations

During the He Pataka Wai Ora Project, the nine mahinga kai sites were sampled 21 times between 3 June 2015 and 29 April 2016. Generally, all sites were visited and sampled in a single day.

Water quality

Water temperature showed seasonal variation with both the lowest temperature of 0.45ºC and the highest temperature of 24.58ºC recorded at El Dorado (Site 1) in July and February, respectively (Figure 8). There does not appear to be any variation in water temperature between the sites (Figure 9). Conductivity did not show any trends over time (Figure 8). However, on a spatial scale, conductivity increased downstream (Figure 9). Average conductivity was lowest at Hakariki (166.40 ± 12.55 μS/cm; Site 2), and highest at Huriawa (48901 ± 1646 μS/cm; Figure 9). pH values did not vary over time or between sites (Figure 8), and ranged from 6.89 ± 0.35 at Whakapatukutu to 7.81 ± 0.31 at Huriawa (Figure 9). Dissolved oxygen showed no clear temporal trends (Figure 8) but varied between sites, with higher values at the upstream sites and a decreasing trend downstream (Figure 9). Average dissolved oxygen values ranged from 10.78 ± 0.96 mg/L at Te Taumata a Puaka to 16.28 ± 1.54 mg/L at Hakariki.

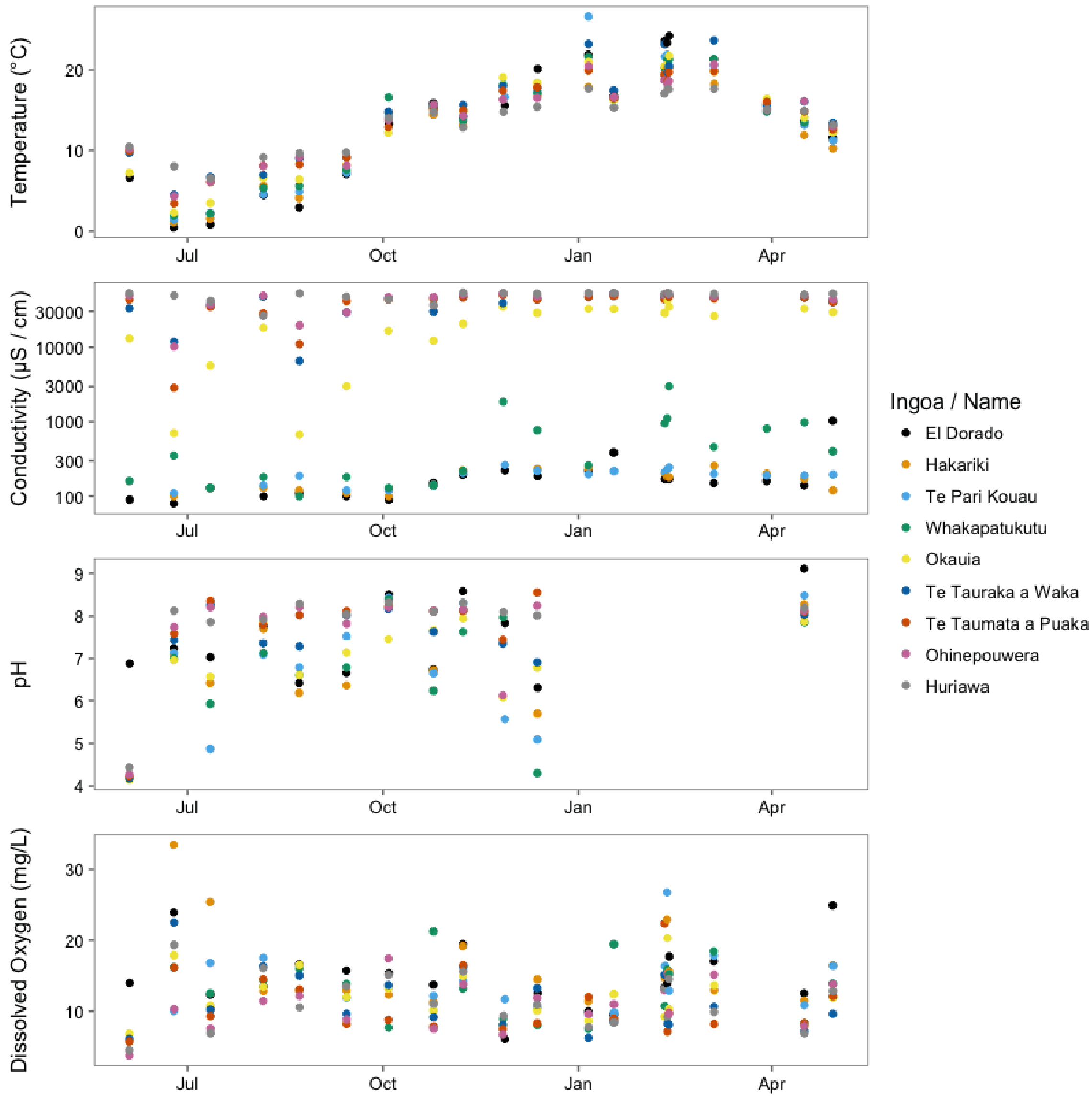

Figure 8: Water quality measurements for water temperature, conductivity, pH and dissolved oxygen over time at the nine mahinga kai sites.

```
    write.csv(wq$site$temp, file = "./output/summary_temp_site.csv", ro
w.names = F)
    write.csv(wq$site$cond, file = "./output/summary_cond_site.csv", ro
w.names = F)
    write.csv(wq$site$ph,   file = "./output/summary_ph_site.csv",   ro
w.names = F)
    write.csv(wq$site$do,   file = "./output/summary_do_site.csv",   ro
w.names = F)
```

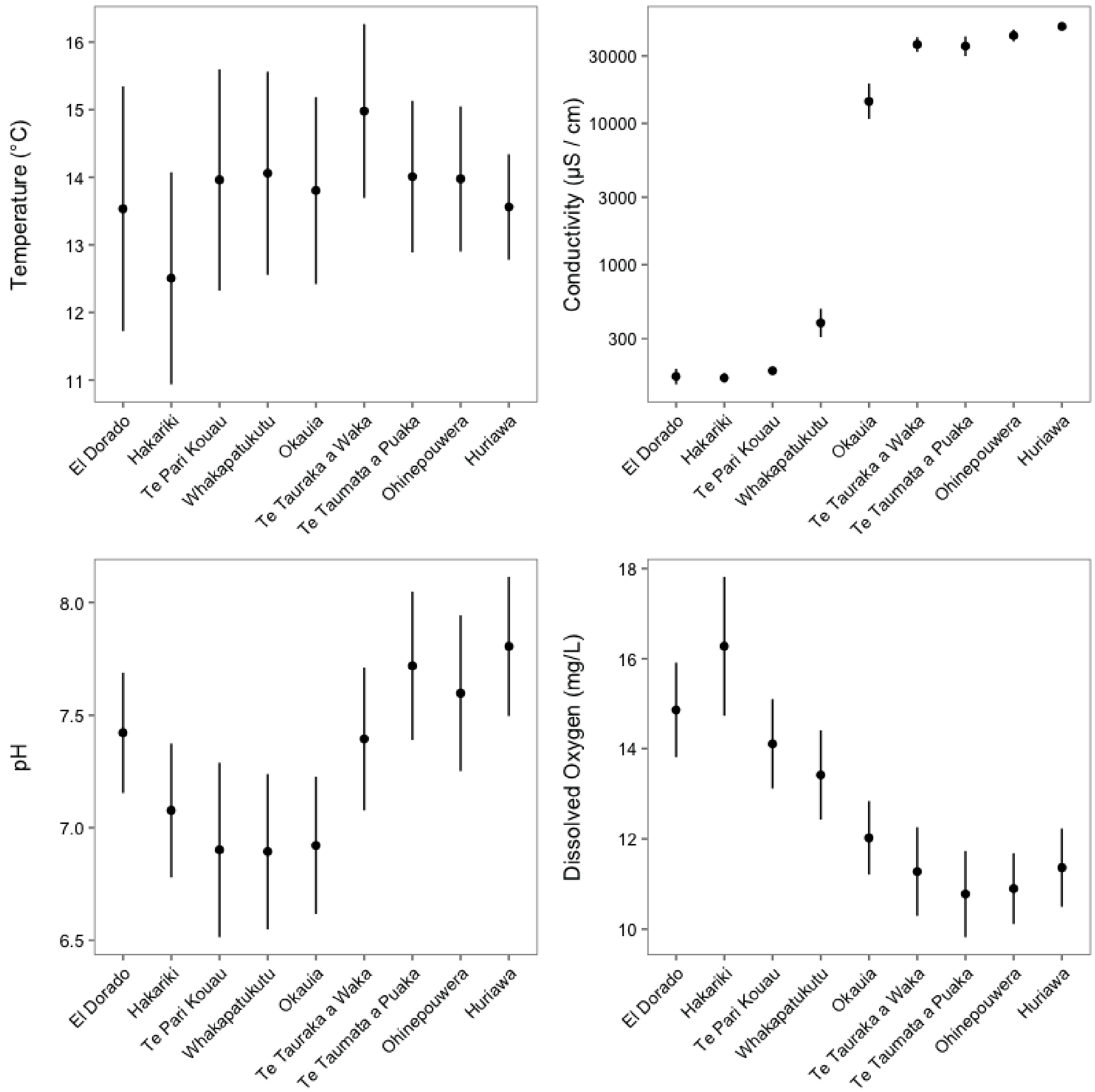

Figure 9: Average (± standard error) measurements of water temperature, conductivity, pH and dissolved oxygen for the nine mahinga kai sites.

Nutrients

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 10). Phosphate showed a weak temporal pattern, with values increasing over the winter months and decreasing during summer (Figure 10). 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 (0.0734 ± 0.0073 mg/L; Figure 11). Nitrate concentration did not show any clear trend between sites (Figure 11). 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 11).

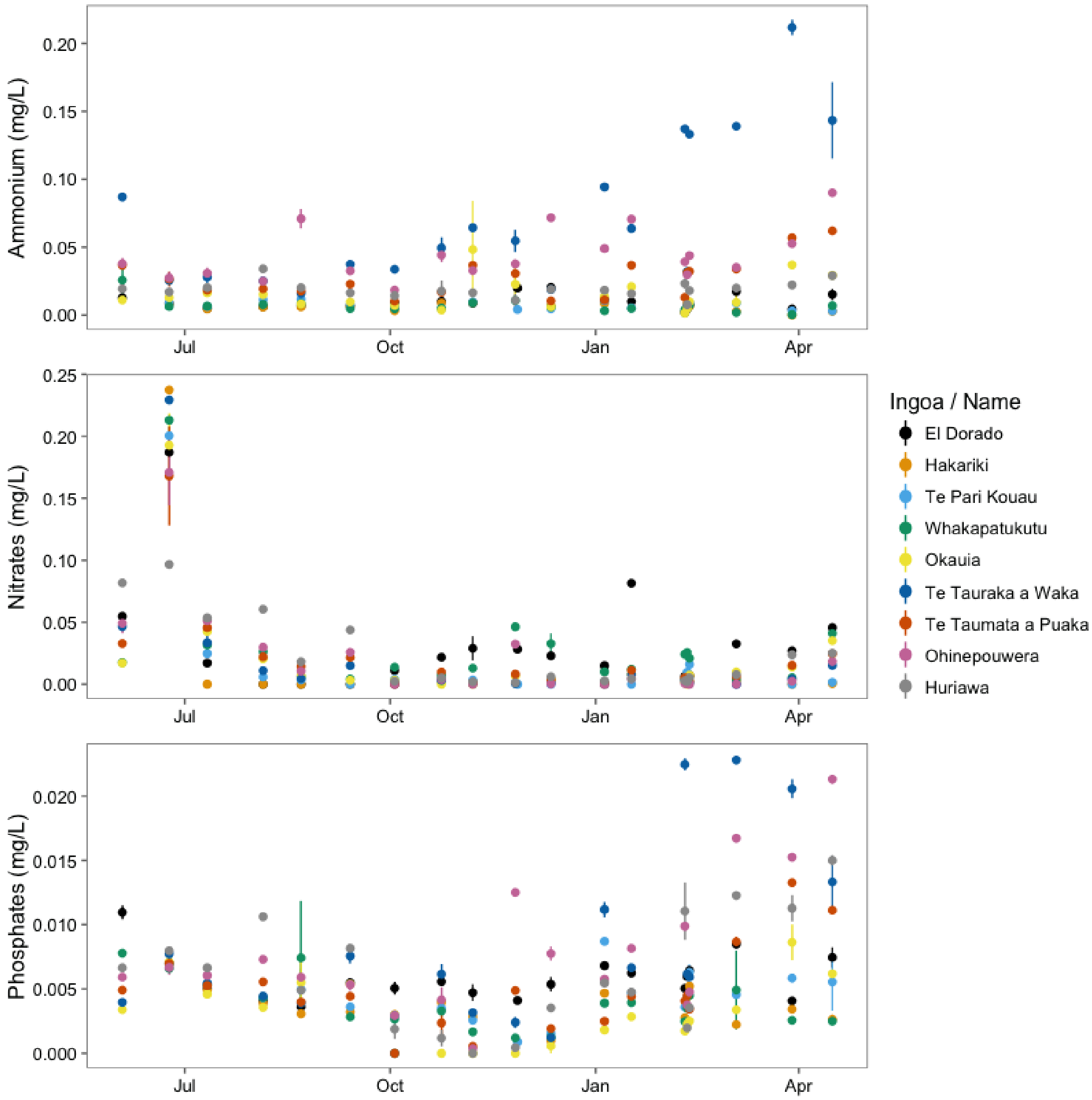

Figure 10: Average (± standard error) concentrations of ammonium, nitrates and phosphates over time at the nine mahinga kai sites.

```
    # Underlying data for Nutrient Timeseries.
    # Tables are too large for effective text respresentation. Write to CSV.
    write.csv(nuts$ts$NH4, file = "./output/summary_NH4_ts.csv", row.names = F)
    write.csv(nuts$ts$NOX, file = "./output/summary_NOX_ts.csv", row.names = F)
    write.csv(nuts$ts$PO4, file = "./output/summary_PO4_ts.csv", row.names = F)
```

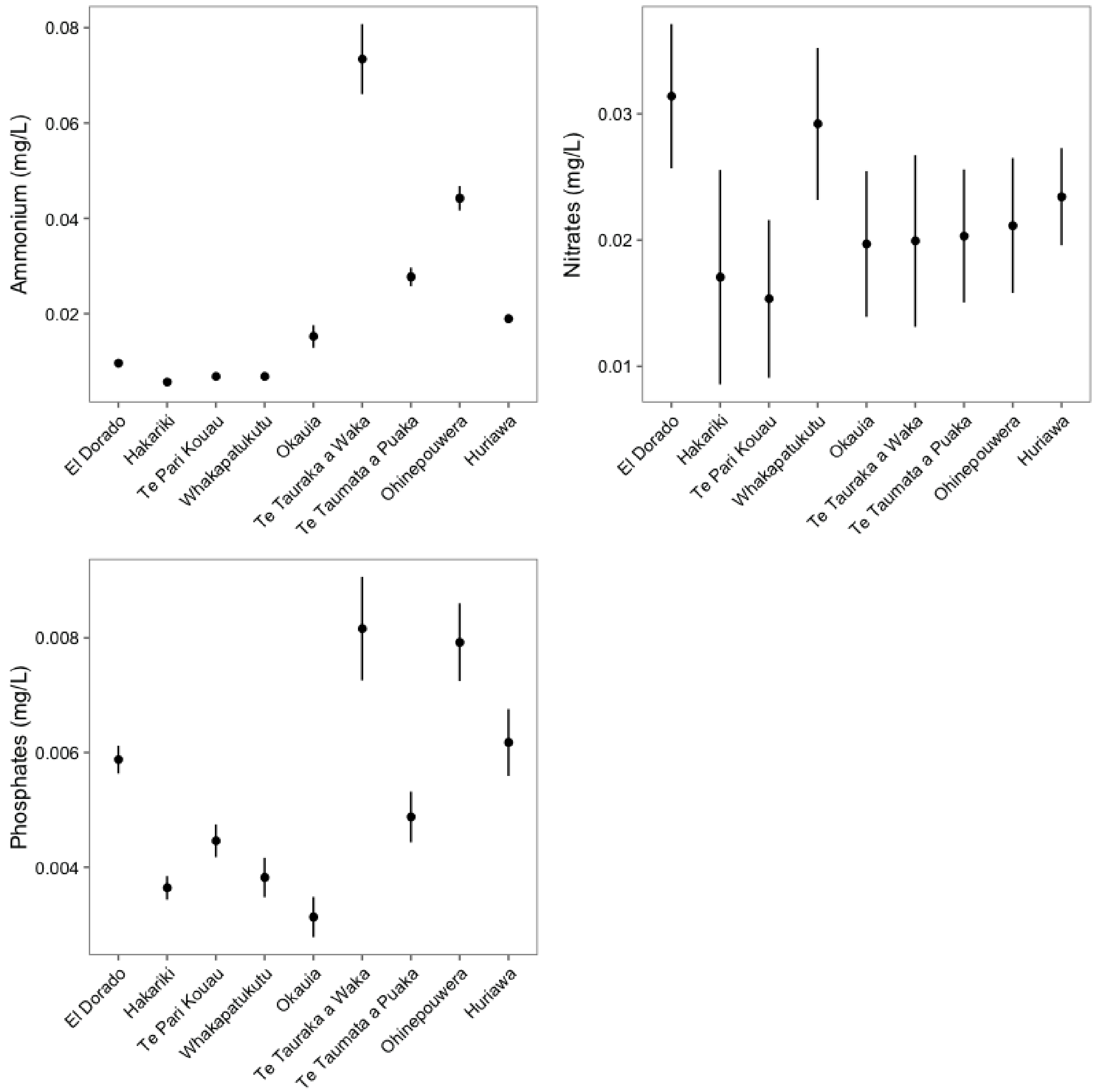

Figure 11: Average (± standard error) concentrations of ammonium, nitrates and phosphates for the nine mahinga kai sites.

```
    # Underlying data for Nutrient Site Summaries.
    write.csv(nuts$site$NH4, file = "./output/summary_NH4_site.csv", row.names = F)
    write.csv(nuts$site$NOX, file = "./output/summary_NOX_site.csv", row.names = F)
    write.csv(nuts$site$PO4, file = "./output/summary_PO4_site.csv", row.names = F)
```

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 12). Riparian vegetation percent cover was highest at Whakapatukutu (128%) and lowest at Hakariki (64%; Figure 12, top). The stream-margin vegetation cover was highest at Okauia (100%) and lowest at El Dorado (51%; Figure 12, bottom). 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 13). 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 13).

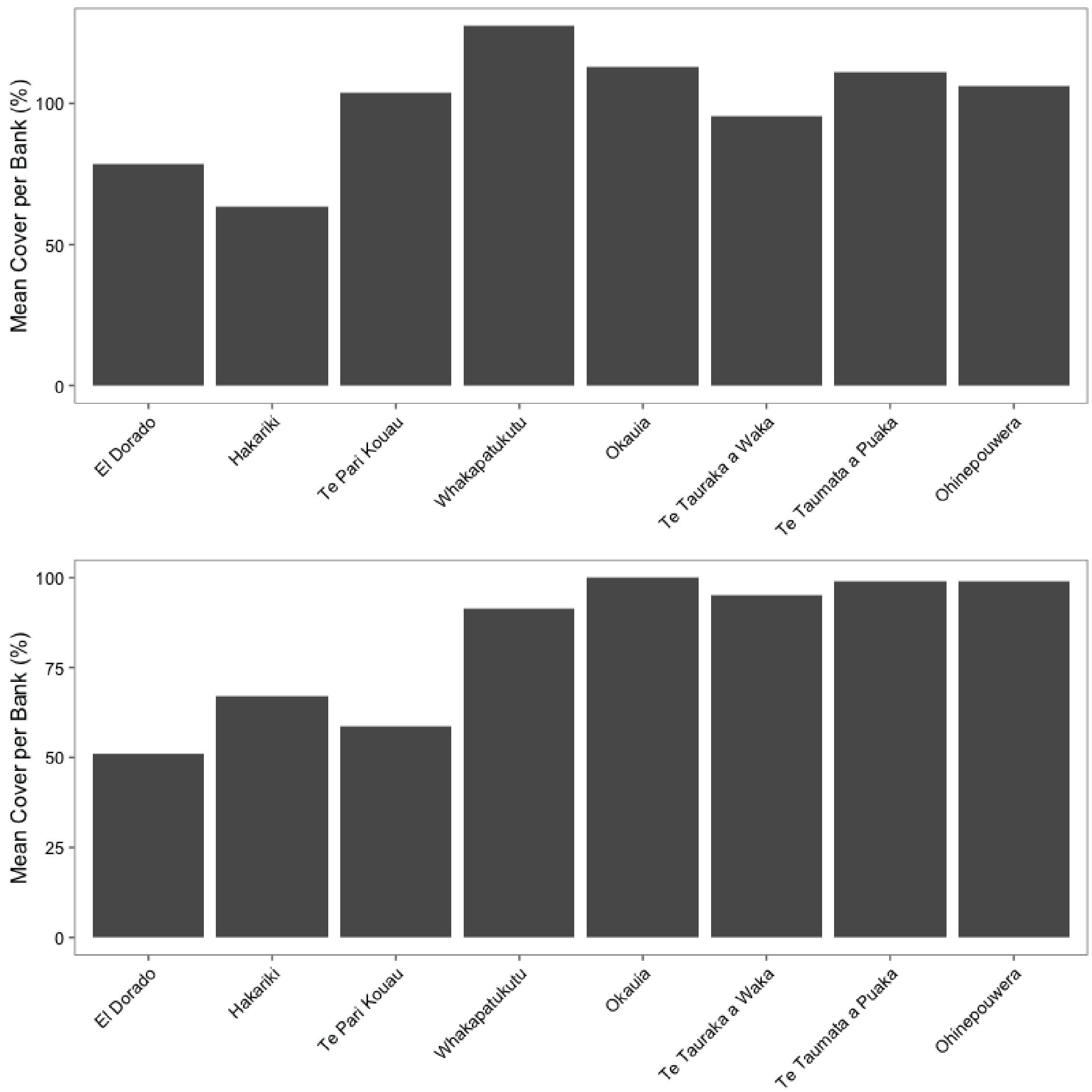

Figure 12: Total cover (mean of true left and true right).

```
    # Underlying data for Vegetation Cover
    write.csv(vege_mean_cover$dat, file="./output/summary_vege_cover.cs
v", row.names = F)
```

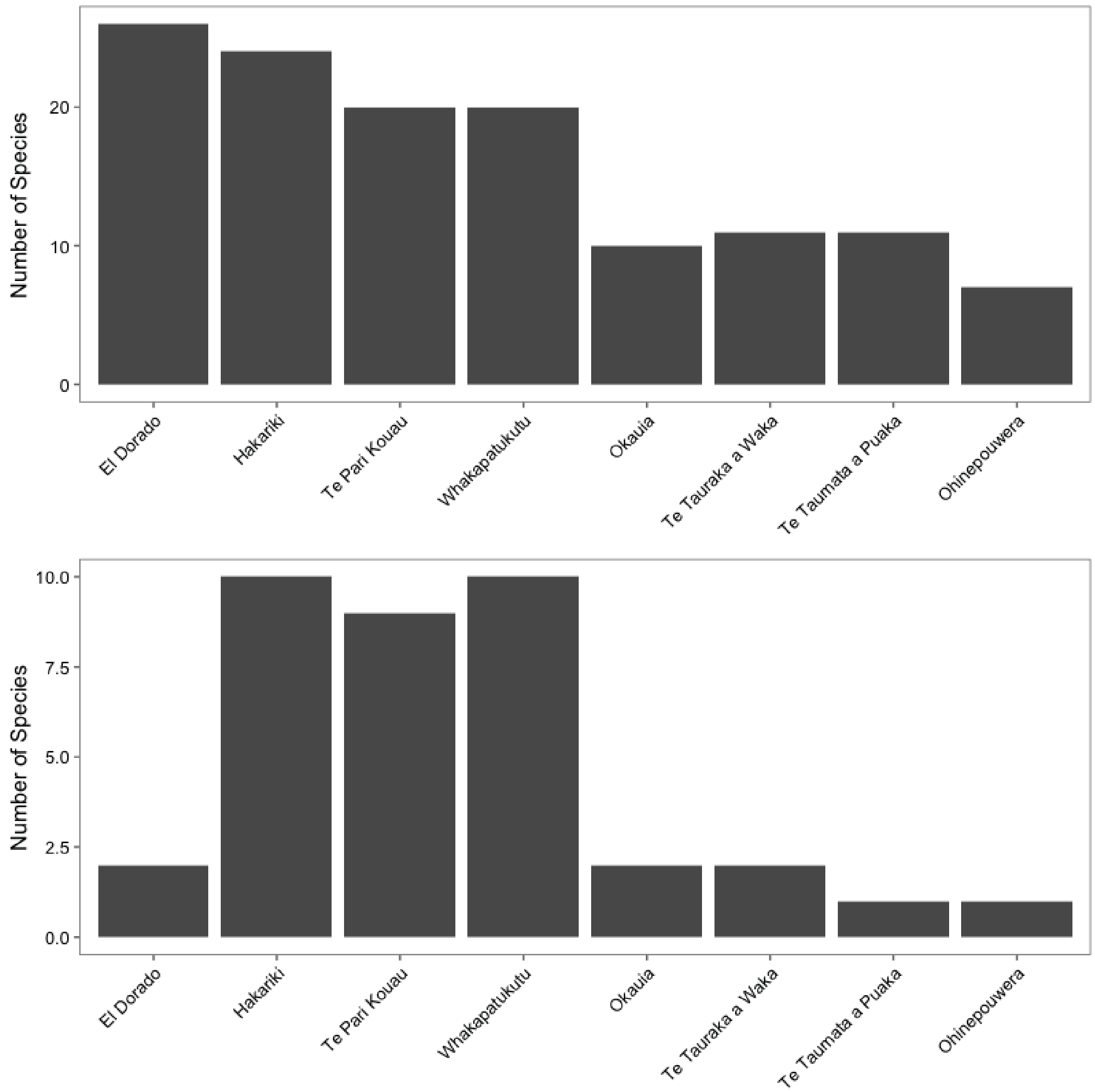

Figure 13: Number of riparian (top) and stream-margin (bottom) vegetation species found at each of the eight freshwater and estuarine mahinga kai sites.

```
# Underlying data for Number of Vegetation Species
write.csv(vege_n_spp$dat, file="./output/summary_vege_nspp.csv", row.names = F)
```

Life-form and native cover

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 14). 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 14). Overall, the majority of the riparian and stream-margin vegetation at each site was made up of non-native species (Figure 15). The exception was at Te Taumata a Puaka where the riparian vegetation cover was almost entirely made up of native species (Figure 15). 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 15).

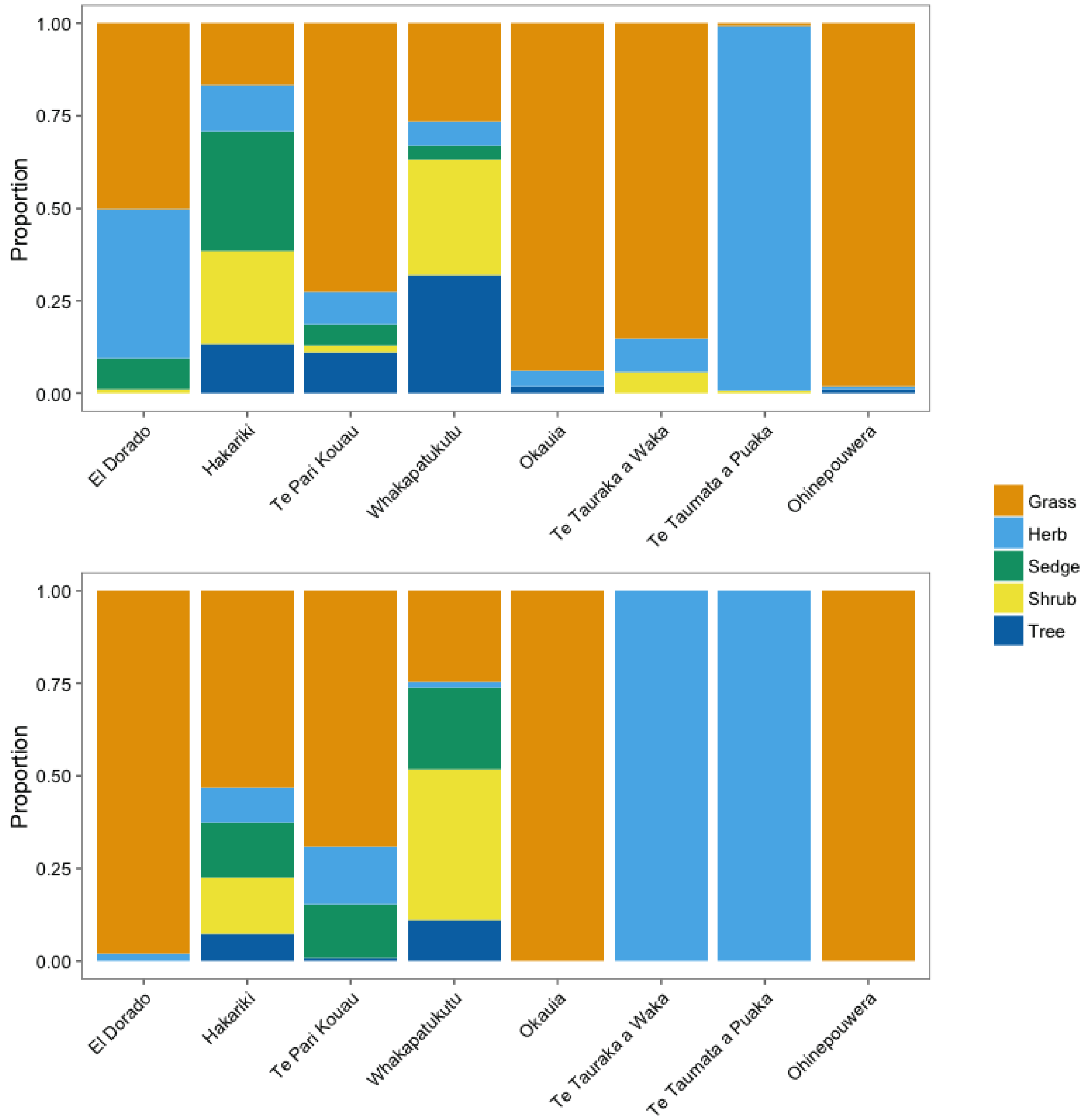

Figure 14: Life form cover in riparian (top) or stream-margin (bottom) transects.

```
    # Underlying data for Vegetation Lifeform
    write.csv(vege_life_form$dat[, , "Transect"], file="./output/summary_vege_lf_transect.csv", row.names = F)
    write.csv(vege_life_form$dat[, , "Margin"],   file="./output/summary_vege_lf_margin.csv",    row.names = F)
```

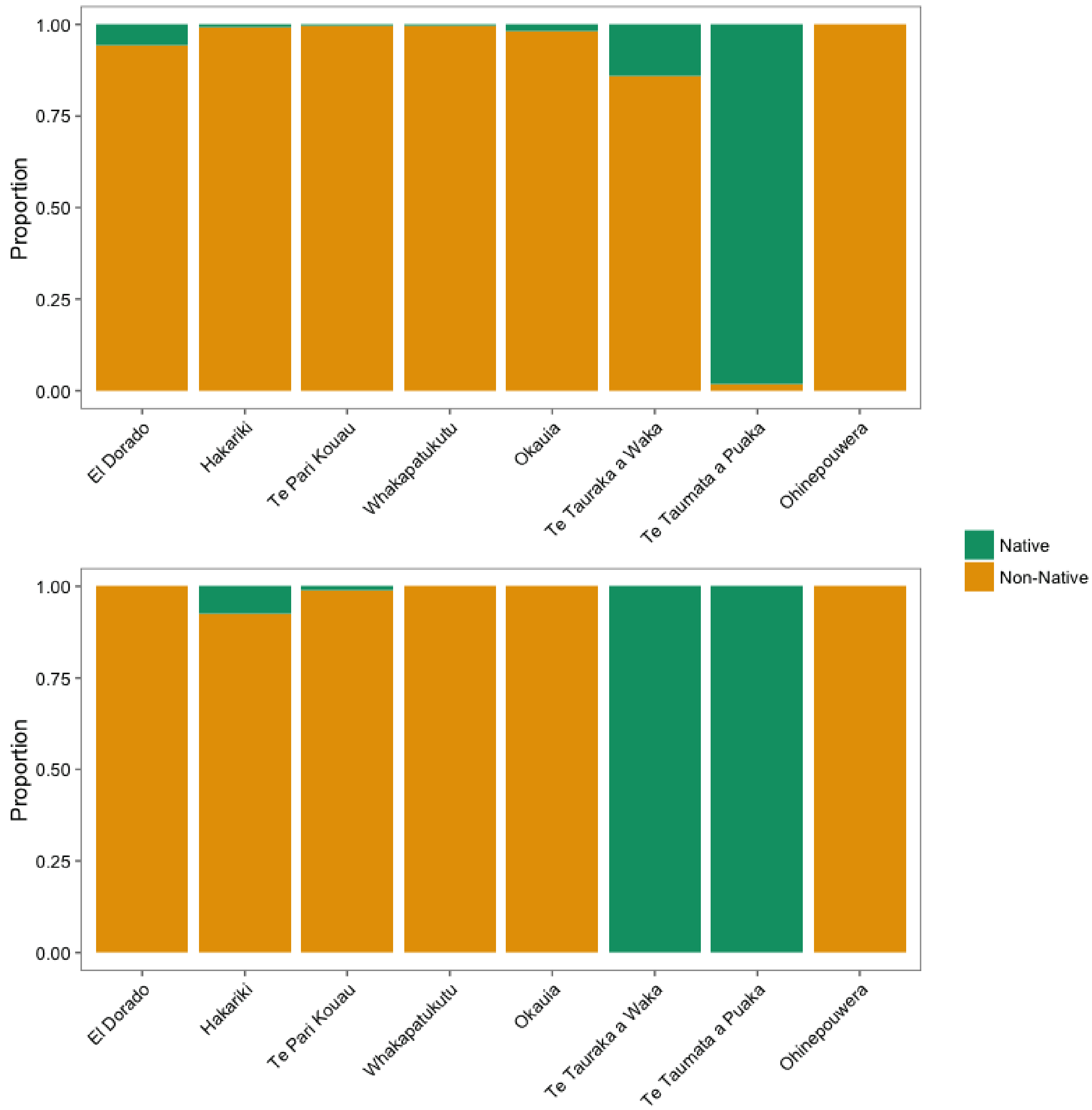

Figure 15: Proportion of native and non-native species that make up the total vegetation cover of the riparian (top) and stream-margin (bottom) vegetation at each of the eight freshwater and estuarine mahinga kai sites.

```
    # Underlying data for Native vs Non-native Vegetation
    write.csv(vege_native_cover$dat[, , "Transect"], file="./output/sum
mary_vege_nvsnn_transect.csv", row.names = F)
    write.csv(vege_native_cover$dat[, , "Margin"],   file="./output/sum
mary_vege_nvsnn_margin.csv",   row.names = F)
```

Vegetation classes

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 16). 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 16).

Note that the next plot excludes the following categories because they did not appear at any sites:

- Tall tussock grasslands, not improved
- Short tussock grassland, improved

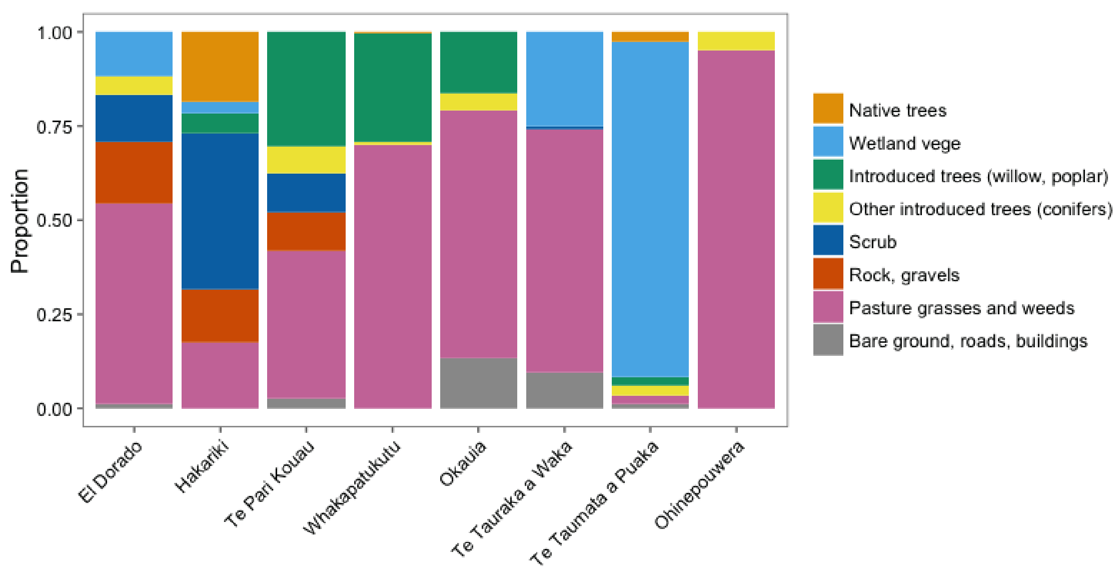

Figure 16: Proportion of life forms that make up the total cover of the riparian (top) and stream-margin (bottom) vegetation at each of the eight freshwater and estuarine mahinga kai sites.

Instream vegetation and periphyton

NB: Periphyton and instream vegetation data is only available at wadeable freshwater sites.

The percentage of macrophyte cover at the wadeable freshwater mahinga kai sites varied from 0 % cover at El Dorado to 5 % cover at both Hakariki and Te Pari Kouau (Table 1). Only two species of macrophyte were identified: *Ranunculus trichophylus* at Hakariki and Te Pari Kouau and *Limosella lineta* at Whakapatukutu (Table 1).

```
    # Instream macrophyte data does not warrant a figure. Display as a
table.
    tc <- paste("Table 1: Summary of percent cover and species of instr
eam",
                "macrophytes sampled at the four wadeable freshwater ma
hika",
                "kai sites.")
    dat <- t(instream_vege$dat[1:4, ])
    pandoc.table(dat, caption = tc, split.tables = 200)
```

Table 1: 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

Average periphyton cover (%) of the 10 sampling units ranged from 41 ± 4.6 % at Hakariki to 62 ± 8.9 % at Te Pari Kouau (Figure 17). 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 18).

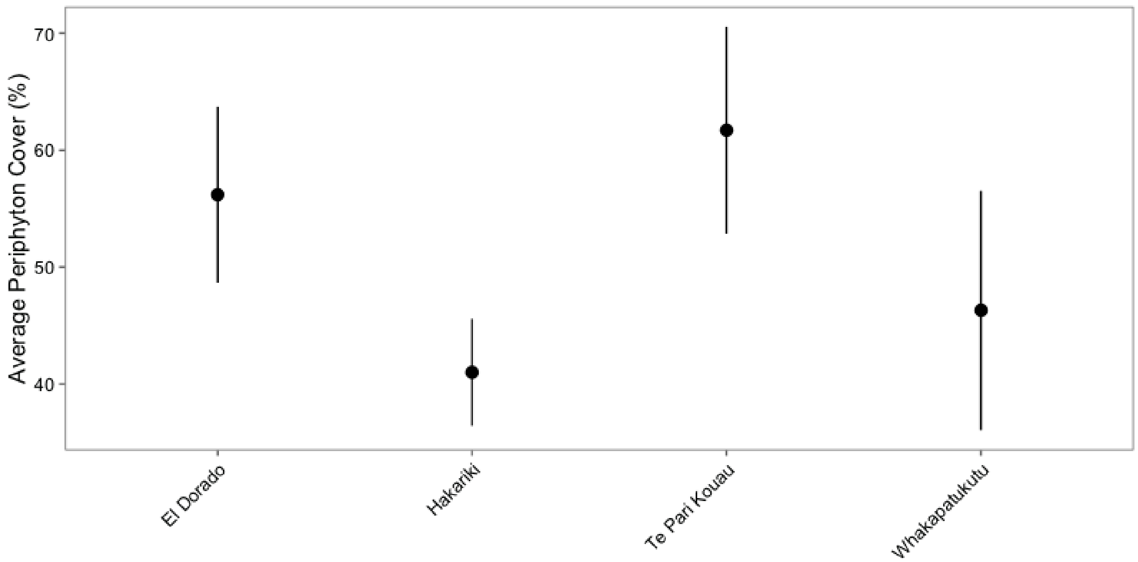

Figure 17: Average (± standard error) periphyton cover (%) of sampling units at the four wadeable freshwater mahinga kai sites on the Waikouaiti River (n = 10).

```
    # Underlying data for Periphyton Cover Plot
    write.csv(periphyton$dat_mean_cover, file="./output/summary_peripyt
on_cover.csv")
```

Note that the next plot excludes the following categories because they did not appear at any sites:

- Thin light brown
- Medium light brown
- Medium black/dark brown
- Thick green/light brown

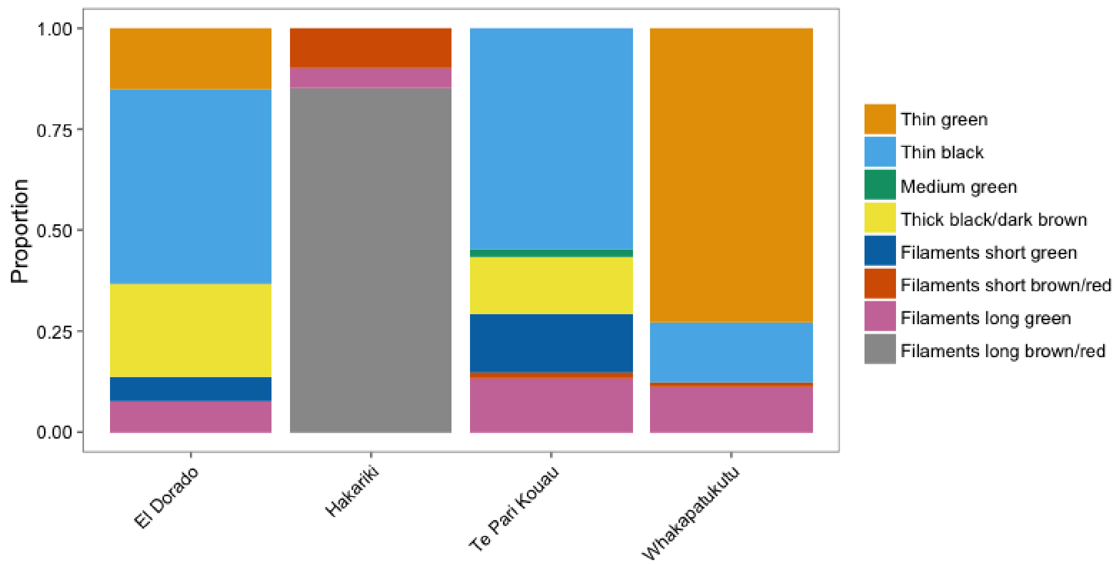

Figure 18: Proportion of periphyton categories making up the total periphyton cover for each wadeable freshwater mahinga kai site (n = 10). Categories from SHMAK (Biggs et al. 2002).

```
# Underlying data for Periphyton Categories Plot
write.csv(periphyton$dat_proportion, file="./output/summary_peripyt
on_category.csv")
```

Invertebrates

NB: Invertebrate data is only available at wadeable freshwater sites.

The average number of invertebrates was highest at El Dorado with 100 ±7.7 and lowest at Hakariki with 55 ± 9.8 (Figure 19). The proportion of invertebrate categories that made up the number of invertebrates varied between sites (Figure 20). The invertebrate categories that made up 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 20).

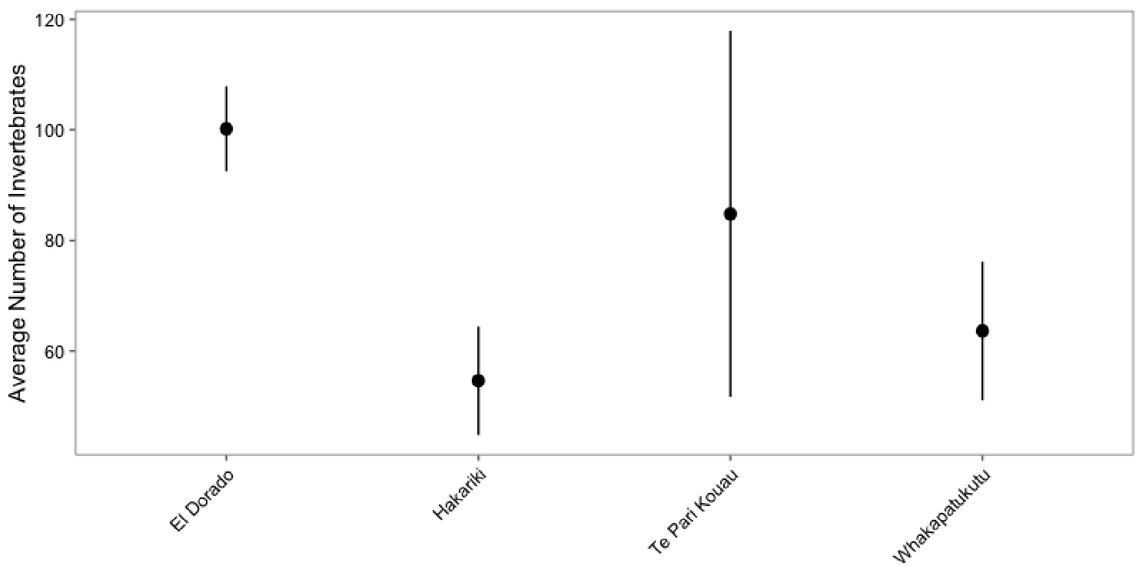

Figure 19: Average (± standard error) number of invertebrates found at each wadeable freshwater mahinga kai site on the Waikouaiti River (n = 10).

```
    # Underlying data for Invertebrate Numbers Plot
    write.csv(inverts$dat_mean_count, file = "./output/summary_invert_c
ount.csv")
```

Note that the next plot excludes the following categories because they did not appear at any sites:

- Small Bivalves (mussels and clams)
- Limpet-like molluscs
- Ostracods
- Cranefly larvae
- Spiral caddisfly
- Stonefly larvae

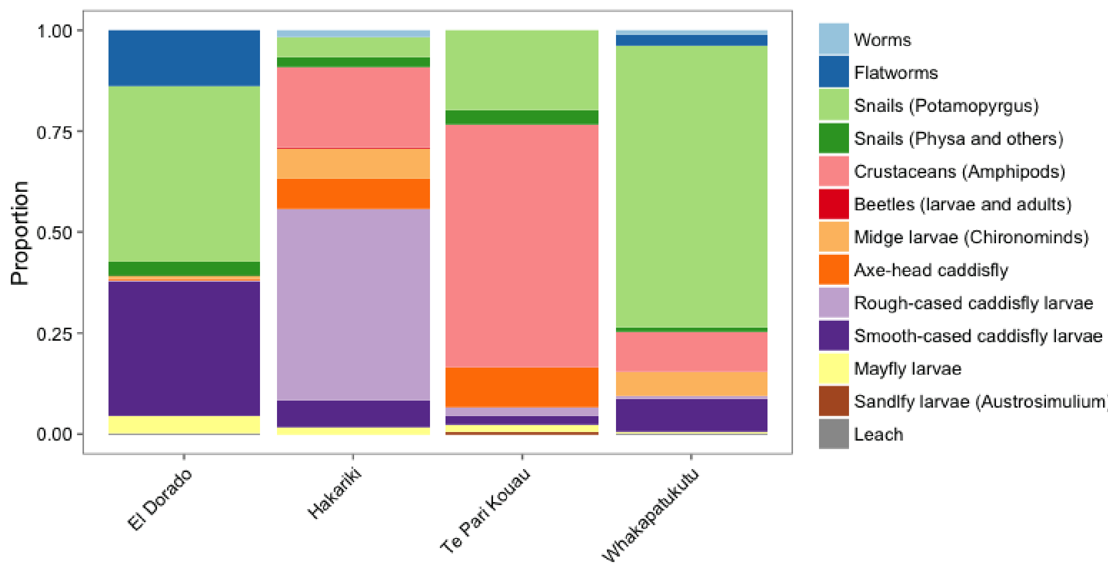

Figure 20: Proportion of invertebrate categories making up the total number of invertebrates at each wadeable freshwater mahinga kai site (n = 10). Categories from SHMAK (Biggs et al. 2002).

```
    # Underlying data for Invertebrate Categories Plot
    write.csv(inverts$dat_proportion, file = "./output/summary_invert_c
ategory.csv")
```

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 2). 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 21).

Table 2: Summary of stream category and SHMAK scores for habitat, invertebrates, and periphyton for each of the wadeable freshwater mahinga kai sites.

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

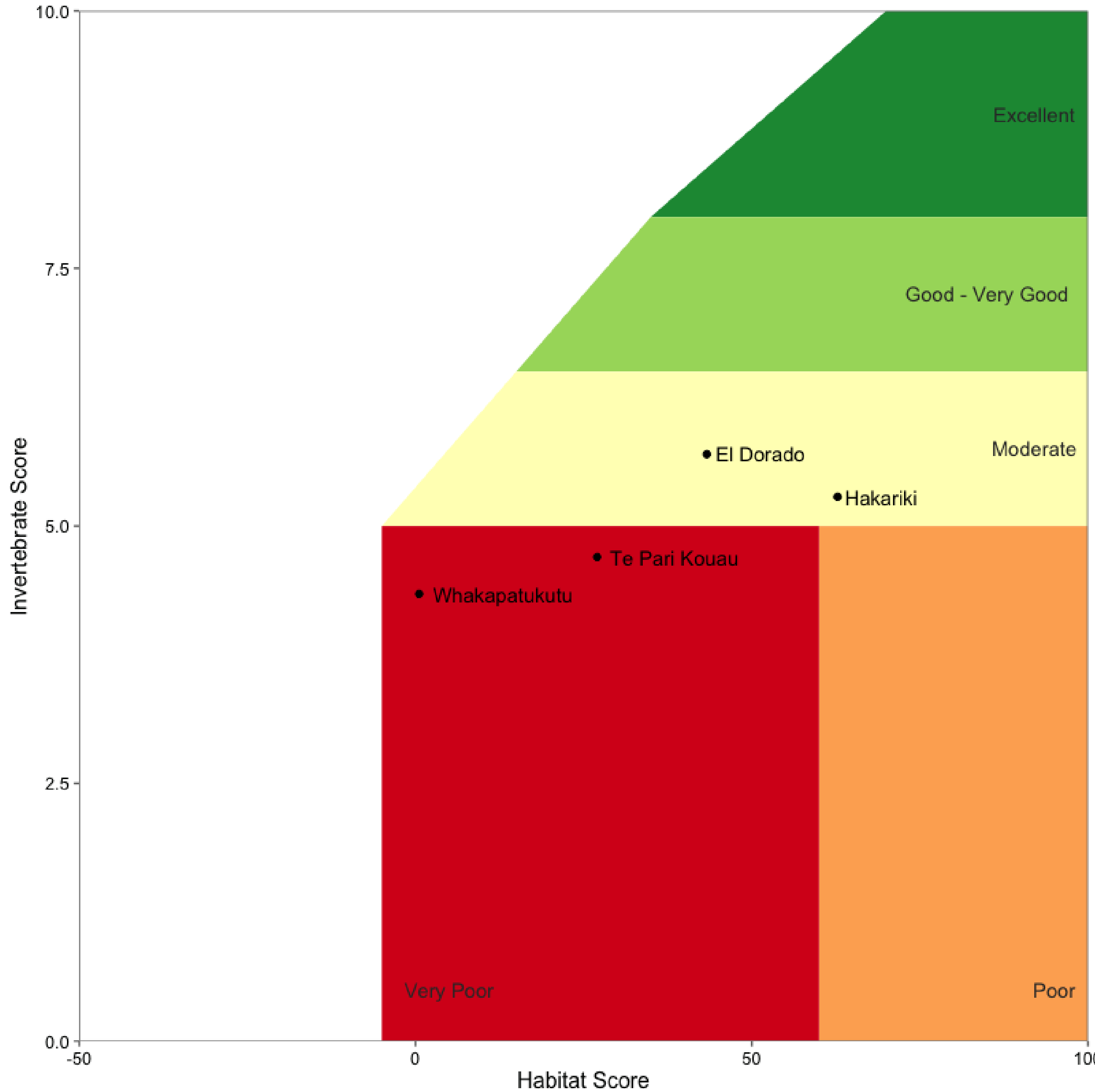

Figure 21: Overall health score for each wadeable freshwater mahinga kai site (black dots). Overall score is calculated using the invertebrate and habitat scores. Figure modified from SHMAK manual (Biggs et al. 2002).

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