Boffa Miskell

Pūharakekenui Styx River catchment

Five-yearly and annual aquatic ecology monitoring
Prepared for the Christchurch City Council

4 September 2023

Document Quality Assurance

Bibliographic reference for citation: Boffa Miskell Limited 2023. *Pūharakekenui Styx River catchment: Five-yearly and annual aquatic ecology monitoring*. Report prepared by Boffa Miskell Limited for the Christchurch City Council.		
Prepared by:	Kate Hornblow Ecologist Boffa Miskell Limited	K Hornblow
Reviewed by: Approved for release by:	Tanya Blakely Associate Partner Ecologist Boffa Miskell Limited	
Status: FINAL	Revision / version: 2	Issue date: 4 September 2023 Revised 26 September 2023

Template revision: 20230109 0000

File ref: BM211177B_002G_Styx_River_ecology_monitoring_20230925.docx

Executive Summary

This report summarises the current ecological condition of waterways monitored as a requirement of the Christchurch City Council's (CCC) Comprehensive Stormwater Network Discharge Consent (CSNDC). Aquatic ecological surveys were undertaken at 14 five-yearly monitoring sites in the Pūharakekenui / Styx River catchment, and two annual monitoring sites in each of the Ōtūkaikino River and Cashmere Stream catchments. Desktop analysis was undertaken on macroinvertebrate data provided by Environment Canterbury for one site in Balguerie Stream, Banks Peninsula.

Indigenous vegetation was relatively common in the Pūharakekenui / Styx River catchment compared to previous years and to other Christchurch City catchments. However, willow saplings were also common and large willows were encroaching into the stream across the catchment. Bank erosion was moderate (i.e., >30%) and had increased since 2018 at some sites. Total cover of fine sediment was high and had increased at most five-yearly sites compared to previous years. Only one site complied with the CSNDC attribute target level of maximum fine sediment cover (20%). Two (of the four) annual monitoring sites and one (of the 14) five-yearly monitoring site had a total macrophyte cover that exceeded the CSNDC maximum of 50%. All sites complied with the CSNDC maximum filamentous algae cover target level. Sediment quality was moderate, with 50% of sites complying with the CSNDC target level for zinc. Concentrations of other contaminants met target levels at all sites. Caddisfly richness had declined at some sites, and some notable pollution sensitive taxa that were found in previous surveys were absent in 2023. Only two (of 14) of the five-yearly sites complied with the CSNDC Quantitative Macroinvertebrate Community Index (QMCI) target of ≥5. All four annual monitoring sites failed to comply with the QMCI target. Notably, within the Pūharakekenui / Styx River catchment, one site supported juvenile kanakana (Threatened, Nationally Vulnerable), eight sites supported longfin eels (At Risk, Declining), and four sites supported īnanga (At Risk, Declining). The Balguerie Stream annual monitoring site met the QMCI target on all occasions over the last 10 years including 2023.

Overall, when considering all of the parameters measured, ecosystem health was variable across sites in the Pūharakekenui / Styx River catchment. There was no indication of overall improvements in ecosystem health, with most sites being assessed as overall similar to previous years. However, sites STYX16, STYX12, STYX11, and STYX10 indicated potential decline in multiple ecosystem heath measures (such as increased sediment depth and/or cover at STYX16, STYX12, STYX11, and STYX10 and QMCI scores declining from being indicative of 'fair' to 'poor' stream health at STYX16 and STYX11).

Key recommendations and future considerations specific to Pūharakekenui / Styx River catchment include targeted willow control, further stabilising banks to reduce localised sediment inputs to the river, investigating the sources of zinc in the catchment, careful planning for further land-use intensification in the catchment and utilising best practice stormwater treatment to reduce inputs of fine sediments and contaminants. Key opportunities include enhancing in-stream habitat to support kanakana spawning thought the catchment and considering the use of existing catchment-wide habitat mapping data (e.g., CREAS) or additional targeted surveys to specifically identify current or potential kanakana spawning habitat locations for management opportunities.

CONTENTS

Appendices

Appendix 1: Site Photographs from 2023

Appendix 2: Sediment quality results

Appendix 3: SIMPER results 2018-2023

Appendix 4: SIMPER results 2018-2023 condensed taxonomic list

1.0 Introduction

The Christchurch City Council (CCC) monitors sediment quality and aquatic ecology at sites throughout Christchurch and Banks Peninsula. This monitoring is a requirement of the Council's Comprehensive Stormwater Network Discharge Consent (CSNDC) (CRC231955) and in accordance with the CCC's Environmental Monitoring Programme (EMP).

As part of its long-term monitoring programme, the CCC monitors sediment quality and aquatic ecology at several sites within each of the city's main river catchments every five years. The Pūharakekenui / Styx River catchment was the focus of the 2023 survey. In addition to the five-yearly monitoring, each year the CCC monitors aquatic ecology at two sites in Wilsons Drain (Ōtūkaikino River catchment), two sites in Cashmere Stream (Ōpāwaho / Heathcote River catchment), and Balguerie Stream (Banks Peninsula).

1.1 Scope

The purpose of this report is to present the findings of these five-yearly and annual surveys, and:

- Describe the current ecological condition of these waterways, including riparian and in-stream habitat conditions, sediment quality, and the macroinvertebrate and fish communities.
- Compare current conditions against the CSNDC surface water quality objectives; Environment Canterbury's Land and Water Regional Plan (LWRP) water quality standards and freshwater outcome guidelines, and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000).
- Compare trends over time by assessing the current conditions against the results of previous surveys (Boffa Miskell Ltd, 2022; EOS Ecology, 2008, 2013; InStream Consulting Ltd, 2018, 2021a).
- Discuss overall ecological health of the sites and recommend how to improve the health, particularly where:
  - Water quality objectives have not been met; and
  - Any significant long-term trends have been observed.

2.0 Methods

2.1 Monitoring sites

The monitoring sites were within the Pūharakekenui / Styx River catchment (five-yearly ecology monitoring) and the Ōtūkaikino River catchment, Cashmere Stream and Balguerie Stream (annual ecology monitoring). There were a combination of sediment quality and aquatic ecology sites, plus a desktop review of macroinvertebrate data collected from Balguerie Stream by Environment Canterbury in November 2022.

The Pūharakekenui / Styx River catchment is a spring-fed system draining residential, industrial, and agricultural land to the north, north-eastern fringes of Christchurch. There were 14 five-yearly ecology and sediment quality sites within this catchment (Table 1). The co-ordinates (northing and easting) of each site was taken from the EMP, with the exception of STYX03 and STYX15. To match the locations of the 2018 monitoring sites, the co-ordinates for these two sites were taken from the 2018 Pūharakekenui/ Styx River monitoring report (InStream Consulting Ltd, 2018) rather than the EMP. Eleven sites were located in the wadeable reaches upstream of Marshland Road, and three sites were located downstream in the non-wadeable reaches. There were a total of five annual monitoring sites, two of which were located in the Ōtūkaikino River catchment, two in Cashmere Stream and one in Balguerie Stream (Table 1).

At each of the sites shown in Figure 1-Figure 3, assessments of riparian and in-stream habitat conditions, and the macroinvertebrate and fish communities were conducted during base-flow conditions (i.e., no less than 5-7 days after a flood peak) between 03 March and 18 April 2023. Monitoring methods were in line with the CCC Environmental Monitoring Programme Version 8 Methodology as detailed in Sections 2.2-2.6, below.

Table 1. Survey sites within the five-yearly monitoring sites of Pūharakekenui / Styx River, and the annual monitoring sites of Ōtūkaikino River and Cashmere Stream catchments and Balguerie Stream. Sites are grouped by waterway and are listed in order of their location in the catchment, from upstream to downstream; five-yearly monitoring sites are listed first, followed by annual monitoring sites. Soft bottomed (SB) or hard bottomed (HB) reflect the dominant substrate present at each site in 2023, and to indicate the tolerance scores used to calculate macroinvertebrate community metrics (Stark & Maxted, 2007). *Indicates sites with co-ordinates that differ from the EMP; co-ordinates for these sites were modified to align with sites surveyed by InStream Consulting Ltd (2018).

Site ID	Catchment	Waterway	Site name	Five-yearly instream sediment monitoring	Five-yearly aquatic ecology monitoring	Annual aquatic ecology monitoring	Easting	Northing
STYX16	Pūharakekenui/ Styx River	Pūharakekenui/ Styx River	Styx River at Claridges Road	-	✓	-	2476512	5748528
STYX14	Pūharakekenui/ Styx River	Pūharakekenui/ Styx River	Styx River upstream of Styx Mill Reserve	-	✓	-	2477610	5749003
STYX13	Pūharakekenui/ Styx River	Pūharakekenui/ Styx River	Styx River adjacent to Styx Mill Dog Area carpark	-	✓	-	2477927	5749206
STYX12	Pūharakekenui/ Styx River	Pūharakekenui/ Styx River	Styx River at Styx Mill Conservation Reserve	✓	✓	-	2478252	5749370
STYX03*	Pūharakekenui/ Styx River	Pūharakekenui/ Styx River	Styx River at Main North Road	✓	✓	-	2478980	5748892
STYX06	Pūharakekenui/ Styx River	Pūharakekenui/ Styx River	Styx River at Marshland Road Bridge	✓	✓	-	2482359	5749393

Site ID	Catchment	Waterway	Site name	Five-yearly instream sediment monitoring	Five-yearly aquatic ecology monitoring	Annual aquatic ecology monitoring	Easting	Northing
STYX07	Pūharakekenui/ Styx River	Pūharakekenui/ Styx River	Styx River at Richards Bridge / Teapes Road	✓	✓	-	2483977	5751255
STYX08	Pūharakekenui/ Styx River	Pūharakekenui/ Styx River	Styx River at Kainga Road / Harbour Road Bridge	✓	✓	-	2485000	5756366
STYX15*	Pūharakekenui/ Styx River	Smack Creek	Smacks Creek at Hussey Road	✓	✓	-	2477008	5749419
STYX04	Pūharakekenui/ Styx River	Kā Pūtahi Creek	Kā Pūtahi Creek at Blakes Road	✓	-	-	2480401	5749645
STYX10	Pūharakekenui/ Styx River	Kā Pūtahi Creek	Kā Pūtahi Creek between Blakes and Belfast Roads	-	✓	-	2480943	5749727
STYX09	Pūharakekenui/ Styx River	Kā Pūtahi Creek	Kā Pūtahi Creek at Ouruhia Reserve	-	✓	-	2481755	5751732
STYX05	Pūharakekenui/ Styx River	Kā Pūtahi Creek	Kā Pūtahi Creek at Belfast Road (lower)	✓	-	-	2482195	5749882
STYX11	Pūharakekenui/ Styx River	Horners Drain	Horners Drain at Hawkins Road	-	✓	-	2481293	5748401

Site ID	Catchment	Waterway	Site name	Five-yearly instream sediment monitoring	Five-yearly aquatic ecology monitoring	Annual aquatic ecology monitoring	Easting	Northing
OTUKAI02	Ōtūkaikino River	Wilsons Drain	Wilsons Drain at Main North Road	-	-	✓	2481242	5752409
OTUKAI06	Ōtūkaikino River	Wilsons Drain	Wilsons Drain at Tyrone Street	-	-	✓	2480720	5751544
HEATH27	Cashmere Stream	Cashmere Stream	Cashmere Stream behind 406 Cashmere Road (downstream of stormwater discharge)	-	-	✓	2477452	5736476
HEATH28	Cashmere Stream	Cashmere Stream	Cashmere Stream behind 420-426 Cashmere Road (upstream of stormwater discharge)	-	-	✓	2477361	5736392
BP03	Banks Peninsula	Balguerie Stream	Downstream of Settlers Hill (road)	-	-	✓	2507759	5711175

File Ref: BM211177B_004_A4L_Pūharakekenui_Site_Locations.mxd

Boffa Miskell

www.boffamiskell.co.nz

0 1 km

1:50,000 @ A4

Data Sources:
Topo base map sourced from LINZ Topo 50 map series

Projection: NZGD 2000 New Zealand Transverse Mercator

Monitoring Type

- Annual ecology monitoring site
- Annual ecology and sediment monitoring site
- Five-yearly ecology monitoring site
- Five-yearly ecology and sediment monitoring site
- Five-yearly sediment monitoring site

CCC FRESHWATER MONITORING

Pūharakekenui / Styx River 2023 site locations

Date: 15 May 2023 | Revision: 0

Plan prepared for CCC by Boffa Miskell Limited

Project Manager: tanya.blakely@boffamiskell.co.nz | Drawn: BMc | Checked: KHo

Figure 1

File Ref: BM211177B_004_A4L_Cashmerei_Site_Locations.mxd

This plan has been prepared by Boffa Miskell Limited on the specific instructions of our Client. It is solely for our Client's use in accordance with the agreed scope of work. Any use or reliance by a third party is at that party's own risk. Where information has been supplied by the Client or obtained from other external sources, it has been assumed that it is accurate. No liability or responsibility is accepted by Boffa Miskell Limited for any errors or omissions to the extent that they arise from inaccurate information provided by the Client or any external source.

Boffa Miskell

www.boffamiskell.co.nz

0 0.25 km

1:10,000 @ A4

Data Sources: Topo base map sourced from LINZ Topo 50 map series

Projection: NZGD 2000 New Zealand Transverse Mercator

Monitoring Type

- Annual ecology monitoring site

CCC FRESHWATER MONITORING

Cashmere Stream catchment 2023 site locations

Date: 15 May 2023 | Revision: 0

Plan prepared for CCC by Boffa Miskell Limited

Project Manager: tanya.blakely@boffamiskell.co.nz | Drawn: BMc | Checked: KHo

Figure 2

File Ref: BM211177B_004_A4L_Balgurie_Site_Locations.mxd

Boffa Miskell

www.boffamiskell.co.nz

0 0.25 km

1:10,000 @ A4

Data Sources:
Topo base map sourced from LINZ Topo 50 map series

Projection: NZGD 2000 New Zealand Transverse Mercator

Monitoring Type

- Annual ecology monitoring site

CCC FRESHWATER MONITORING

Banks Peninsula 2023 site locations

Date: 15 May 2023 | Revision: 0

Plan prepared for CCC by Boffa Miskell Limited

Project Manager: tanya.blakely@boffamiskell.co.nz | Drawn: BMc | Checked: KHo

Figure 3

2.2 Water quality

Spot measures of specific conductivity, pH, dissolved oxygen, and water temperature were taken at each site using a handheld YSI multi-parameter water quality meter.

2.3 Riparian and in-stream habitat

At each site, three transects, spaced at 10 m intervals, were established across the waterway, where the downstream most transect was located at the co-ordinates provided in Table 1. Canopy cover (%), bank erosion (%), extent of undercut bank (cm) and overhanging vegetation (cm) (if present), percent of bank with vegetation cover, bank slope (degrees), bank height (cm), type of bank material, types of riparian vegetation, and the surrounding land-use were recorded for the true left (TL) and true right (TR) banks, separately, at each of the three transects across each site.

The percent composition of different flow habitats (i.e., riffle, run or pool) was estimated for each site. Total wetted width (m) was recorded at each of the three transects. An average wetted width was calculated from these three measures for each site. Water velocity was measured at each of the three transects, using a Seba Current Meter c/w counter and wading rods, where:

Velocity[1] *= (S * r.p.s) + C,*

At each of five locations (TL bank, 25%, 50%, 75%, and TR bank) along each of the three transects (at each site) the following parameters were also measured:

- Water depth (cm)
- Soft sediment depth (cm)
- Embeddedness (%)
- Substrate composition (%)
- Macrophyte depth (cm), percent cover, type (submerged or emergent), and dominant species present
- Percent cover and type of organic material (leaves, moss, coarse woody debris)
- Percent cover and type of periphyton.

Where parameters were measured at five locations across each of the transects (i.e., water depth, sediment depth, embeddedness, and macrophyte and periphyton cover), these were averaged to give a mean value for each transect.

Embeddedness is a measure of the degree to which larger substrates are surrounded by fine particles, and therefore, an indication of the clogging of interstitial spaces.

Soft sediment depth was determined by gently pushing a metal wading rod (10 mm diameter) into the substrate until it hit the harder substrates underneath.

Substrate composition was measured within an approximately 20 x 20 cm quadrat at each of the five locations along the three transects. Within each quadrat, the percent composition of the following sized substrates was estimated: silt / sand (<2 mm); gravels (2-16 mm); pebbles (16-64

[1] *S* = slope specific to the propeller used; *r.p.s* = revolutions per second as determined by the count meter; and *C* = constant.

mm); small cobbles (64-128 mm), large cobbles (128-256 mm), boulders (256-4000 mm), and bedrock / concrete / artificial hard surfaces (>4000 mm) (modified from Harding et al., 2009).

A substrate index (SI) was calculated from the five replicate substrate composition measures taken along each transect. These values were then averaged, to give a mean SI for each transect. The SI was calculated using the formula (modified from Harding et al., 2009):

SI = (0.03 x %silt / sand) + (0.04 x %gravel) + (0.05 x %pebble) + (0.06 x (%small cobble + %large cobble)) + (0.07 x %boulder)

The calculated SI can range between 3 and 7, where an SI of 3 indicated 100% silt / sand and an SI of 7 indicated 100% boulders. That is, the larger the SI, the coarser the substrate and the better the habitat for macroinvertebrate and fish communities. Finer substrates generally provide poor, and often unstable, in-stream habitat, and smother food (algal) resources and macroinvertebrates inhabiting the waterway.

2.4 Sediment quality

Surface sediment at each of the sediment quality monitoring sites (Table 1) collected by scraping along the surface (top 3 cm) of the waterway bed with a sample container (prepared collection jar provided by Hills Laboratory) attached to a mighty gripper. Water was drained directly off the collected samples and transferred to a cooler bin before transporting to Hill Laboratories, an International Accreditation New Zealand (IANZ) laboratory. Hill Laboratories conducted the following analyses (Table 2), all of which are IANZ accredited, except for total organic carbon (TOC).

Total polycyclic aromatic hydrocarbons (PAHs) were calculated by summing the 18 PAHs analysed, which include the PAHs listed as priority pollutants by the USEPA (1982). Total PAHs were normalised to 1% TOC, as recommended in ANZECC (2000), before comparison to the guidelines. Where one or more PAH compound was below the detection limit, half the detection limit was used in the calculation. This method is consistent with the approach used in many reports of sediment quality in Christchurch’s waterways (e.g., NIWA, 2015).

Table 2. Analysis conducted by Hill Laboratories on sediment samples collected from the eight survey sites in 2023.

Test	Method description	Reference
7 grain sizes profile	Wet sieving, gravimetric analysis	N/A
Total recoverable copper, lead, and zinc	Air dried at 35°C and sieved, <2 mm fraction. Nitric / hydrochloric acid digestion, ICP-MS, screen level.	US EPA 200.2
Total organic carbon (TOC)	Air dried at 35°C and sieved, <2 mm fraction. Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	N/A
Total recoverable phosphorus (TP)	Air dried at 35°C and sieved, <2 mm fraction. Nitric / hydrochloric acid digestion, ICP-MS, screen level.	US EPA 200.2
Polycyclic aromatic hydrocarbons (PAHs)	Air dried at 35°C and sieved, <2 mm fraction. Dried at 103°C for 4-22 hr, sonication extraction, SPE cleanup, GC-MS SIM analysis.	US EPA 3540, 3550 & 3630.
Semi-volatile organic compounds (SVOCs)	Air dried at 35°C and sieved, <2 mm fraction. Sonication extraction, SPE cleanup, GC-MS full scan analysis.	US EPA 3540, 3550, 3640 & 8270

2.5 Macroinvertebrate community

The macroinvertebrate community was assessed at each site within the same 20 m reach where riparian and in-stream habitat was surveyed. The macroinvertebrate community was sampled at each site on the same day that the habitat assessment was conducted (i.e., prior to habitat assessments, but after basic water chemistry and temperature parameters were measured).

A single and extensive composite kick-net (500 µm mesh) sample was collected from each site in accordance with protocols C1 and C2 of Stark et al. (2001). That is, each kick net sampled approximately 0.3 m x 2.0 m of stream bed, including sampling the variety of microhabitats present (e.g., stream margin, mid channel, undercut banks, macrophytes) so as to maximise the likelihood of collecting all macroinvertebrate taxa present at a site, including rare and habitat-specific taxa.

Macroinvertebrate samples were preserved separately in 70% ethanol prior to sending to Boffa Miskell's independent taxonomy lab, in Tauranga, for identification and counting in accordance with Protocol P2 (200 Individual Fixed Count with scan for rare taxa) of Stark et al (2001), identifying to species level where practical, as per the EMP.

2.5.1 Biotic indices and stream health metrics

The following macroinvertebrate metrics were calculated from each kick-net sample, to provide an indication of stream health. MCI and QMCI scores were calculated using the tolerance scores for soft-bottomed streams for STYX16, STYX06, STYX07, and STYX08, and for hard-bottomed streams at all other sites to reflect the dominant substrate present (Stark & Maxted, 2007). The use of soft or hard bottomed tolerance scores for each sites aligned with those used in the relevant previous survey (Boffa Miskell Ltd, 2022; InStream Consulting Ltd, 2018).

- **Total abundance** – the total number of individuals collected at each site. Macroinvertebrate abundance can be a good indicator of stream health, or ecological condition, because abundance tends to increase in the presence of organic enrichment, particularly for pollution-tolerant taxa (e.g., chironomid midge larvae and oligochaete worms).
- **Taxonomic richness** – the total number of macroinvertebrate taxa collected at each site. Streams supporting high numbers of taxa generally indicate healthy communities, however, the pollution sensitivity / tolerance of each taxon needs to also be considered.
- **EPT taxonomic richness** – the total number of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) collected at each site. These three insect orders (EPT) are generally sensitive to pollution and habitat degradation and therefore diversity of these insects provides a useful indicator of degradation. High EPT richness suggests high water quality, while low richness indicates low water or habitat quality.
- **EPT taxonomic richness (excl. hydroptilids)** – the total number of EPT taxa excluding the family Hydroptilidae. The algal piercing caddisflies belonging to the family Hydroptilidae are generally considered more tolerant of degraded conditions than other EPT taxa. Excluding hydroptilid caddis from the EPT metric is a more conservative approach and more accurately represents the 'clean-water' EPT taxa.
- **%EPT abundance** – the total abundance of macroinvertebrates that belong to the pollution-sensitive EPT orders, relative to the total abundance of all macroinvertebrates, collected at each site. High %EPT richness suggests high water quality.
- **%EPT abundance (excl. hydroptilids)** – the percentage abundance of EPT taxa, excluding the more pollution-tolerant hydroptilid caddisflies, collected at each site.

- **Macroinvertebrate Community Index (MCI)** – this index is based on tolerance scores for individual macroinvertebrate taxa found in hard- or soft-bottomed streams, as appropriate (Stark and Maxted 2007). These tolerance scores, which indicate a taxon's sensitivity to in-stream environmental conditions, are summed for the taxa present in a sample, and multiplied by 20 to give MCI values ranging from 0-200. Table 3 provides a summary of how MCI scores were used to evaluate stream health.
- **Quantitative Macroinvertebrate Community Index (QMCI)** – this is a variant of the MCI, which instead uses abundance data. The QMCI provides information about the dominance of pollution-sensitive species in hard- or soft-bottomed streams, as appropriate. Table 3 provides a summary of how QMCI scores were used to evaluate stream health.
- **Average Score Per Metric (ASPM)** – this combines: %EPT, EPT taxa richness, and MCI indices into a single metric (Collier 2008). Following recommendations of the National Policy Statement for Freshwater Management (NPS-FM), the ASPM was calculated as the average of the following: %EPT / 100, EPT taxa richness / 29, and MCI / 200.

Table 3. Interpretation of MCI and QMCI scores for hard- and soft-bottomed stream (Stark & Maxted, 2007).

Stream health	Water quality descriptions	MCI	QMCI
Excellent	Clean water	≥120	≥6.00
Good	Doubtful quality or possible mild enrichment	100-119	5.00-5.99
Fair	Probable moderate enrichment	80-99	4.00-4.99
Poor	Probable severe enrichment	≤79	≤3.99

Note, the MCI and QMCI were developed primarily to assess the health of streams impacted by agricultural activities (e.g., organic enrichment) and should be interpreted with caution in relation to urban systems.

2.6 Fish community

The fish community was surveyed in a (minimum) 30 m reach or 30 m^2 area that overlapped with the 20 m reach where the macroinvertebrate community and habitat assessments were made. Several factors, including soft sediment depth, macrophyte cover, water velocity and water depth were taken into consideration when determining the most appropriate fish surveying technique (i.e., electric fishing or trapping and netting) to use at each site.

Electric fishing: the fish community at Sites STYX03, STYX09, STYX11, STYX12, STYX14, STYX15, STYX16, OTUKAI06, HEATH27 and HEATH28 was assessed using a single pass with a Kainga EFM 300 backpack mounted electric-fishing machine (NIWA Instrument Systems, Christchurch). Fish were captured in a downstream push net or in a hand (dip) net and temporarily held in buckets. All fish were then identified, counted, and measured (length, mm) before being returned alive to the stream.

Trapping and netting: Electric fishing techniques were not a safe, or an appropriate method for sampling at the following sites: STYX06, STYX07, STYX08, and OTUKAI02[2] (sites were too deep), STYX10 (was too restricted by macrophytes), and STYX13 (was too restricted by low hanging vegetation). In previous surveys, the fish communities at STYX06, STYX07, and STYX08 were surveyed using trapping and netting, rather than electric fishing; trapping and netting was used in OTUKAI02 in 2022 but had been surveyed used electric fishing in all other surveys. STYX10 and STYX13 had been surveyed using electric fishing in all previous surveys; 2023 was the first occasion where traps and nets were used. At each site, two fyke nets[3] (baited

[2] Results presented for OTUKAI02 are from three Gee minnow traps only, as two Gee minnow and two fyke nets were stolen.

[3] Fyke net mesh size: 4 mm; net dimensions were in line with recommendations of Joy et al. (2013).

with tinned cat food) and five Gee minnow traps (1/8 inch mesh size and baited with marmite) were set late in the afternoon and left overnight. The following morning, all fish captured were identified and measured to the nearest 5 mm before being returned alive to the stream.

Assessments of the fish community were conducted in accordance with Boffa Miskell's research and collection permit from the Department of Conservation (pursuant to section 26ZR of the Conservation Act 1987) and a Special Permit from the Ministry for Primary Industry (pursuant to section 97(1) of the Fisheries Act 1996.

2.6.1 Catch per unit effort

In order to account for the inevitable differences in areas sampled at each site, fish catches were converted into catch per unit effort (CPUE). Electric fishing data were converted to number of fish captured per 100 m^2 of stream surveyed; trapping data were presented as number of fish captured per trap, per night.

2.7 Consent target levels and guidelines

Water quality, sediment quality, habitat, and macroinvertebrate data were compared against the relevant CSNDC attribute target levels, the 'Freshwater Outcomes for Canterbury Rivers' set out in LWRP (Environment Canterbury 2015); and the ANZG guideline value (GV-high) (Table 4). The monitoring sites in the Pūharakekenui / Styx River catchment and the Ōtūkaikino River catchment are classified as "Spring-fed – plains" under the LWRP, while the Cashmere Stream and Balguerie Stream monitoring sites are classified as "Banks Peninsula".

Table 4. Consent attributes target levels and guidelines for relevant stream attributes in the Pūharakekenui / Styx River catchment, Ōtūkaikino River catchment, Cashmere Stream catchment, and Banks Peninsula in 2023. SP = "Spring-fed – plains", BP = "Banks Peninsula" under the LWRP.

Parameter	Consent Attribute Target Level	LWRP[1]	NPS-FM 2020[2]	ANZG (2018)[3]
Water quality				
Dissolved oxygen		≥70%	4 mg/L	
Temperature (°C)		<20		
pH		6.5–8.5		
Fine sediment cover (%)	SP: 20 BP: 20		21-29	
Sediment quality				
Copper (mg/kg)	65			270
Lead (mg/kg)	50			220
Zinc (mg/kg)	200			410
Total PAHs (mg/kg)	10			50
Emergent macrophyte cover (%)		SP: 30		
Total macrophyte cover (%)	SP: 50 BP: 30			
Long filamentous algae (≥2 cm long) cover (%)	SP: 30 BP: 20			
Macroinvertebrates				
QMCI	SP: 5 BP: 5		4.5	
MCI			90	
ASPM[4]			0.3	

[1]Land and Water Regional Plan Freshwater Outcomes for Canterbury Rivers for dissolved oxygen and water temperature, and for pH. [2]National Policy Statement for Freshwater Management 2020 National Bottom-Line values. [3]Australia New Zealand Water Quality Guidelines (2018) for sediment quality are GV-high. [4]Average Score per Metric.

2.8 Changes over time

Habitat conditions

Comparisons in habitat conditions were made of variables measured over previous studies (Boffa Miskell Ltd, 2022; InStream Consulting Ltd, 2018, 2021a) and this study. For those parameters where field methods were generally comparable across the two surveys, two-way analyses of variance (ANOVA) were used to test for differences over time. Where necessary, response variables were log transformed to meet assumptions of normality and homogeneity of variances. ANOVAs were performed in R version 4.1.2 (RStudio Team, 2020).

Macroinvertebrate community

Visual comparisons were made between biotic metrics calculated at the monitoring sites over various studies (Boffa Miskell Ltd, 2022; InStream Consulting Ltd, 2018, 2021a) and this study; a two-way (ANOVA) was not conducted due to a lack of replication. Comparisons between macroinvertebrate abundances between 2023 and 2018 were not possible due to differences in sample laboratory processing. In 2023, samples were processed using Protocol P2 (200 Individual Fixed Count with scan for rare taxa) of Stark et al (2001), while in 2018 samples were processed using Protocol P3 (Full count with subsampling option) of Stark et al (2001) (InStream Consulting Ltd, 2018).

Separate non-metric multidimensional scaling (or NMDS) ordinations[4] of macroinvertebrate presence absence and abundance data with 999 random permutations were used to determine if the macroinvertebrate communities found in 2018 and 2023 at sites were similar. Presence absence data were used to account for differences in laboratory processing methods between 2018 (full count) and 2023 (fixed count). For the abundance ordination, fixed counts were scaled up in accordance with the percentage of sample processed to reach 200 fixed count. This gave approximately similar abundances between years for comparisons. NMDS ordinations rank sites such that distance in ordination space represents community dissimilarity (using the Bray-Curtis dissimilarity metric). Therefore, an ordination score (an *x* and a *y* value) for the entire macroinvertebrate community found at a ‘site’ can be presented on an *x*-*y* scatterplot to graphically show how similar the community was among upstream control, farm track, and downstream control sites. Ordination scores that are closest together are more similar in macroinvertebrate community composition than those further apart (Quinn & Keough, 2002). A permutational multivariate analysis of variance (PERMANOVA), with 100 permutations was then used to test for significant differences in macroinvertebrate community composition at sites between years. An NMDS ordination may show that communities appear to be quite distinct (i.e., when shown graphically, sites could be quite distinct from one another in ordination space), but PERMANOVA results show whether these differences are in fact statistically significantly different. Similarity percentages (SIMPER) were calculated[5] to show which macroinvertebrate taxa were driving these differences. NMDS, PERMANOVA and SIMPER analyses were performed in PRIMER version 7.0.13 (Clarke & Warwick, 2001).

Fish community

Qualitative comparisons were made between the fish communities found: comparing this study (2023) with the findings from previous surveys (Boffa Miskell Ltd, 2022; InStream Consulting Ltd,

---

[4] Goodness-of-fit of the NMDS ordination was assessed by the magnitude of the associated ‘stress’ value. A stress value of 0 indicates perfect fit (i.e., the configuration of points on the ordination diagram is a good representation of actual community dissimilarities). It is acceptable to have a stress value of up to 0.2, indicating an ordination with a stress value of <0.2 corresponds to a good ordination with no real prospect of misleading interpretation (Quinn & Keough 2002).

[5] The SIMPER routine computes the percentage contribution of each macroinvertebrate taxon to the dissimilarities between all pairs of sites among groups.

2018, 2021a). Comparisons in the fish community at STYX10 and STYX13 between years was not possible due to different sampling methods used – the sites were electro-fished in 2018 (InStream Consulting Ltd, 2018), but trapped in this survey. See Section 2.6 for explanation on methods used.

3.0 Results

3.1 Water quality

Five-yearly monitoring

Dissolved oxygen (DO) was variable across sites, ranging from 45.7% at STYX16: Styx River at Claridges Road, to 88.2% at STYX09: Kā Pūtahi Creek at Ouruhia Reserve. Three sites (STYX08, STYX15, and STYX16) did not meet the LWRP guideline of ≥70% saturation for 'spring-fed – plains' waterways (Table 5). Water temperature was variable across sites, but was generally low (i.e., cool) with all sites below the LWRP guideline of ≤20°C for Canterbury Rivers. The coolest water temperature of 13.6°C was recorded in STYX16: Styx River at Claridges Road, while STYX11: Horners Drain at Hawkins Road had the highest water temperature (17.7°C). pH was circum-neutral at all sites and fell within the LWRP guideline range of 6.5 to 8.5 pH. Conductivity was also similar across all sites, ranging from 116 µS / cm to 159 µS / cm (Table 5). It is important to note that water quality parameters were measured only once during the daytime, and at different times of the day across sites; pH, water temperature and dissolved oxygen can vary diurnally and seasonally.

In the previous monitoring round in 2018, DO was below the LWRP guideline of ≥70% saturation at STYX06 (61.5%), STYX07 (55.1%), STYX15 (55.0%) and STYX16 (56.0%) (InStream Consulting Ltd, 2018). Otherwise, field-measured water quality results for temperature, pH, and conductivity were similar to measurements in 2018.

Annual monitoring

DO was high at most annual monitoring sites (i.e., >90%, meeting the LWRP ecological health indicator) except at OTUKAI06: Wilsons Drain at Tyrone Street, which had a low DO concentration of 27.1% (Table 5). Water temperature at all sites complied with the LWRP guideline (≤20°C) ranging from 15.3°C at OTUKAI02: Wilsons Drain at Main North Road, to 17.0°C at HEATH28: Cashmere Stream behind 420-426 Cashmere Road. pH was circum-neutral at all sites and fell within the LWRP guideline range of 6.5 to 8.5 pH. Conductivity was generally similar across all sites, ranging from 112 µS / cm to 229 µS / cm (Table 5). It is worth noting water depth at OTUKAI06 was very shallow (see Section 3.3), the site had relatively high water temperature and high macrophyte cover (>60%), which may have affected the DO spot measurement. Warm water holds less oxygen than cool water and DO can fluctuate diurnally as macrophytes shift from respiration (oxygen taken up, carbon dioxide released) in hours of darkness to photosynthesis during daylight hours. In 2022, DO was above the LWRP guideline of ≥70% saturation at OTUKAI06 (134.4%).

Table 5. Field-measured water quality at five-yearly and annual monitoring sites surveyed in 2023. Values in red do not comply with the relevant LWRP Freshwater Outcomes for Canterbury Rivers: dissolved oxygen ≥70%; water temperature ≤20°C.

Site ID	Site name	Dissolved oxygen (%)	Temperature (°C)	pH	Conductivity (µS / cm)
Five-yearly monitoring					
STYX16	Styx River at Claridges Road	46.8	13.6	6.51	143
STYX14	Styx River Upstream of Styx Mill Reserve	74.1	15.5	6.92	120
STYX13	Styx River Adjacent to Styx Mill Dog Area Carpark	72.4	14.5	6.88	147
STYX12	Styx River at Styx Mill Conservation Reserve	77.6	15.0	6.98	146
STYX03	Styx River at Main North Road	73.5	13.4	7.14	143
STYX06	Styx River at Marshland Road Bridge	74.2	14.2	7.31	139
STYX07	Styx River at Richards Bridge/ Teapes Road	81.9	15.9	7.38	118
STYX08	Styx River at Kainga Road/ Harbour Road Bridge	67.7	16.3	7.21	131
STYX15	Smacks Creek at Hussey Road	59.8	13.6	6.68	148
STYX10	Kā Pūtahi Creek Between Blakes and Belfast Roads	82.9	15.6	7.24	159
STYX09	Kā Pūtahi Creek at Ouruhia Reserve	88.2	15.4	7.24	148
STYX11	Horners Drain at Hawkins Road	77.4	17.7	7.54	157
Annual monitoring					
OTUKAI02	Wilsons Drain at Main North Road	90.3	15.3	7.97	133
OTUKAI06	Wilsons Drain at Tyrone Street	27.1	17.3	6.77	112
HEATH27	Cashmere Stream behind 406 Cashmere Road	93.7	16.6	7.37	217
HEATH28	Cashmere Stream behind 420-426 Cashmere Road	99.6	17.9	7.34	229

3.2 Riparian and in-stream habitat

A brief summary of the general habitat conditions encountered at each site is given in Table *6*. Photographs depicting riparian and in-stream habitat in 2023 at all aquatic ecology sites monitored in this survey are in Appendix 1.

Five-yearly monitoring

Riparian habitat: There was no notable change in riparian vegetation between 2018 and 2023 at STYX07, STYX08, STYX09, STYX11, STYX14 and STYX15. With the exception of STYX15, which was dominated by native ferns and trees, these sites remained dominated by exotic grass and trees, with little native vegetation. Conversely, riparian conditions at STYX03 (Photo 1), STYX06 (Photo 2), and STYX10 (Photo 3) had improved since 2018. At STYX03 and STYX06 in 2018 the banks were dominated by exotic grass and deciduous exotic trees (primarily willows). In 2023, willow control was apparent, and the banks were dominated by plantings of native Carex sedges, shrubs, and trees, which may in time provide shading and improved in-stream habitat for fish and macroinvertebrates. At STYX10, new natives plantings had grown considerably since 2018, however, willow saplings were noted on both banks and in high abundance. Riparian conditions had declined at STYX12 (Photo 4), and STYX13 (Photo 5) since the previous survey. At STYX12 and STYX13 in 2018 the riparian margin was dominated by willow and native plantings; in 2023 while native vegetation was still present, the riparian margins were dominated by large willow encroaching in the stream. The riparian margin at STYX16 was dominated by native vegetation, similar to 2018, which provided canopy cover to the waterway, however the understory vegetation (e.g., Carex shrubs and harakeke flax) was less abundant in this survey than in 2018, reducing the amount of overhanging vegetation at the site (Photo 6, Table 6).The riparian margins at sites generally had high ground vegetation cover, with low areas of exposed earth (Table 6). However, at the sites in the upper and upper mid catchment, STYX16, STYX13 and STYX12, bank erosion was moderate (i.e., >30%) on at least one bank and had increased compared to 2018. Bank erosion at STYX14 has also increased compared to 2018, but remained low (i.e., <10%) (Table 6).

In-stream habitat: All sites were dominated by run habitat, with riffle and pool flow habitats uncommon. Comparatively, flow habitat conditions in 2018 at most sites were similarly dominated by run habitat. The exception to this was STYX11, where in 2018 the site was 100% riffle habitat but 100% run habitat in 2023. At all sites, except STYX13 and STYX15, fine sediments (e.g., silt, sand) dominated the stream bed substrates. Substrate at STYX13 and STYX15 was dominated by pebbles and cobbles. Larger substrates were present at most sites but were often covered by fine sediment. In 2018, STYX09, STYX14, and STYX16 were dominated by fine sediments; all other sites were dominated by pebbles and small cobbles.


Photo 1. Site STYX03: Styx River at Main North Road, upstream looking downstream in 2018 (left) and 2023 (right)


Photo 2. Site STYX06: Styx River at Marshland Road, upstream looking downstream in 2018 (left) and 2023 (right)


Photo 3. Site STYX10: Kā Pūtahi Creek between Blakes and Belfast roads, downstream looking upstream in 2018 (left) and 2023 (right)


Photo 4. Site STYX12: Styx River at Styx Mill Conservation Reserve, downstream looking upstream in 2018 (left) and 2023 (right)

Photo 5. Site STYX13: Styx River adjacent to Styx Mill Dog Area carpark, downstream looking upstream in 2018 (left) and 2023 (right)

Photo 6. Site STYX16: Styx River at Claridges Road, upstream looking downstream in 2018 (left) and 2023 (right)

Table 6. Summary of the riparian and in-stream habitat conditions at each of the monitoring sites surveyed between March and April 2023. Arrows indicate if there has been an observed increase, decrease or no detectable change compared to the relevant previous five-yearly survey (InStream Consulting Ltd, 2018) and annual survey (Boffa Miskell Ltd, 2022), noting that only one bank was surveyed at the non-wadeable sites (STYX06, STYX07, and STYX08) in 2018.

Site ID	Surrounding land use	Bank material	Canopy cover	Horizontal bank undercut	Overhanging vegetation	Ground cover vegetation (%)	Bank erosion (%)	Flow habitat type (%still: backwater: pool: run: riffle)
Five-yearly monitoring								
STYX16: Styx River at Claridges Road	TLB: Residential/ garden TRB: Residential/ garden	TLB: Earth TRB: Earth	TLB: 100% ↑ TRB: 70% →	TLB: 21 cm ↓ TRB: 5 cm →	TLB: 13 cm ↓ TRB: 16 cm ↓	TLB: 22% ↓ TRB: 15% ↓	TLB: 36% ↑ TRB: 73% ↑	0: 5: 0: 95: 0
STYX14: Styx River Upstream of Styx Mill Reserve	TLB: Reserve TRB: Reserve	TLB: Earth TRB: Earth	TLB: 45% ↓ TRB: 21% →	TLB: 0 cm ↓ TRB: 0 cm ↓	TLB: 110 cm → TRB: 0 cm ↓	TLB: 71% ↓ TRB: 95% →	TLB: 8% ↑ TRB: 6% ↑	0: 1: 0: 98: 1
STYX13: Styx River Adjacent to Styx Mill Dog Area Carpark	TLB: Reserve TRB: Reserve	TLB: Earth TRB: Earth	TLB: 75% ↑ TRB: 55% ↑	TLB: 0 cm → TRB: 18 cm ↑	TLB: 166 cm ↑ TRB: 67 cm ↑	TLB: 12% ↓ TRB: 62% ↓	TLB: 38% ↑ TRB: 9% ↑	0: 0: 0: 100: 0
STYX12: Styx River at Styx Mill Conservation Reserve	TLB: Reserve TRB: Reserve	TLB: Earth TRB: Earth	TLB: 61% ↑ TRB: 68% ↑	TLB: 0 cm ↓ TRB: 10 cm →	TLB: 60 cm → TRB: 140 cm ↑	TLB: 53% ↓ TRB: 15% ↓	TLB: 12% ↑ TRB: 38% ↑	0: 2: 0: 98: 0
STYX03: Styx River at Main North Road	TLB: Reserve TRB: Reserve	TLB: Earth TRB: Earth	TLB: 63% → TRB: 55% →	TLB: 8 cm → TRB: 10 cm →	TLB: 48 cm → TRB: 0 cm ↓	TLB: 100% → TRB: 100% ↑	TLB: 0% → TRB: 0% →	0: 0: 0: 95: 5
STYX06: Styx River at Marshland Road Bridge	TLB: Semi rural/ residential TRB: Reserve/ road	TLB: Earth TRB: Earth, concrete	TLB: 0% → TRB: 0%	TLB: 0 cm ↓ TRB: 0 cm	TLB: 0 cm ↓ TRB: 0 cm	TLB: 100% → TRB: 100%	TLB: 0% ↓ TRB: 0%	0: 0: 0: 100: 0
STYX07: Styx River at Richards	TLB: Rural, farming TRB: Rural, farming	TLB: Earth TRB: Earth	TLB: 0% TRB: 0% →	TLB: 0 cm TRB: 0 cm →	TLB: 0 cm TRB: 0 cm ↓	TLB: 100% TRB: 100% →	TLB: 0% TRB: 0% →	0: 10: 0: 90: 0

Site ID	Surrounding land use	Bank material	Canopy cover	Horizontal bank undercut	Overhanging vegetation	Ground cover vegetation (%)	Bank erosion (%)	Flow habitat type (%still: backwater: pool: run: riffle)
Bridge/ Teapes Road								
STYX08: Styx River at Kainga/ Harbour Road Bridge	TLB: Rural, farming TRB: Rural, farming	TLB: Earth TRB: Earth	TLB: 0% → TRB: 56%	TLB: 0 cm → TRB: 0 cm	TLB: 30 cm → TRB: 0 cm	TLB: 95% → TRB: 98%	TLB: 41% → TRB: 0%	0: 5: 0: 95: 0
STYX15: Smacks Creek at Hussey Road	TLB: Native bush TRB: Native bush	TLB: Earth TRB: Earth	TLB: 83% ↑ TRB: 80% ↑	TLB: 7 cm ↑ TRB: 18 cm ↑	TLB: 0 cm ↓ TRB: 0 cm ↓	TLB: 40% → TRB: 45% →	TLB: 5% → TRB: 0% →	0: 2: 0: 95: 3
STYX10: Kā Pūtahi Creek Blakes	TLB: Road/ native plantings TRB: Reserve/ native plantings	TLB: Earth TRB: Earth	TLB: 0% ↓ TRB: 0% ↓	TLB: 0 cm → TRB: 0 cm →	TLB: 46 cm → TRB: 50 cm ↑	TLB: 100% ↑ TRB: 100% ↑	TLB: 0% → TRB: 0% →	0: 0: 0: 100: 0
STYX11: Horners Drain at Hawkins Road	TLB: Semi-urban, road TRB: Rural, farming	TLB: Wood TRB: Wood	TLB: 30% → TRB: 64% ↑	TLB: 0 cm → TRB: 0 cm →	TLB: 0 cm → TRB: 0 cm →	TLB: 76% ↓ TRB: 53% ↓	TLB: 0% → TRB: 0% →	0: 0: 0: 100: 0
STYX09: Kā Pūtahi Creek at Ouruhia Reserve	TLB: Reserve TRB: Residential/ garden	TLB: Earth TRB: Earth	TLB: 11% ↓ TRB: 0% ↓	TLB: 0 cm ↓ TRB: 0 cm ↓	TLB: 5 cm ↓ TRB: 2 cm ↓	TLB: 100% → TRB: 73% ↓	TLB: 0% → TRB: 8% →	0: 2: 0: 98: 0
Annual monitoring								
OTUKAI02: Wilsons Drain at Main North Road	TLB: Rural, farming TRB: Reserve/ park	TLB: Earth TRB: Earth	TLB: 65% → TRB: 100% ↑	TLB: 3 cm → TRB: 0 cm ↓	TLB: 56 cm → TRB: 96 cm ↑	TLB: 76% ↓ TRB: 51% →	TLB: 11% ↓ TRB: 26% ↓	0: 0: 0: 100: 0 →
OTUKAI06 Wilsons Drain Tyrone Street	TLB: Semi-urban, road TRB: Residential/ garden	TLB: Wood TRB: Wood	TLB: 0% ↓ TRB: 0% ↓	TLB: 0 cm → TRB: 0 cm →	TLB: 0 cm → TRB: 0 cm →	TLB: 62% ↑ TRB: 34% ↓	TLB: 0% → TRB: 0% →	0: 0: 0: 100: 0 →
HEATH27: Cashmere Stream	TLB: Rural, farming	TLB: Earth	TLB: 0% → TRB: 0% →	TLB: 0 cm → TRB: 0 cm ↓	TLB: 0 cm → TRB: 0 cm ↓	TLB: 31% ↓ TRB: 55% →	TLB: 2% → TRB: 35% ↑	0: 0: 0: 100: 0 →

Site ID	Surrounding land use	Bank material	Canopy cover	Horizontal bank undercut	Overhanging vegetation	Ground cover vegetation (%)	Bank erosion (%)	Flow habitat type (%still: backwater: pool: run: riffle)
behind 406 Cashmere Road	TRB: Residential/ garden	TRB: Earth, concrete						
HEATH28: Cashmere Stream behind 420-426 Cashmere Road	TLB: Rural, farming TRB: Residential/ garden	TLB: Earth TRB: Earth, wood	TLB: 24% → TRB: 34% →	TLB: 0 cm → TRB: 13 cm →	TLB: 0 cm → TRB: 10 cm →	TLB: 62% ↓ TRB: 80% →	TLB: 14% ↓ TRB: 30% ↑	0: 2: 0: 98: 0 →

Annual monitoring

Riparian habitat: There was no notable change in riparian conditions between 2022 and 2023 at the 4 annual monitoring sites: OTUKAI02, OTUKAI06, HEATH27, and HEATH28. At OTUKAI02 the riparian margins remained dominated by native vegetation (e.g., *Carex* sedges, lemonwoods, cabbage trees), which provided shading to the waterway and additional habitat for in-stream fauna from overhanging vegetation. OTUKAI06 remained dominated by exotic grass and bare gravel, with some shading provided to the water by a shelterbelt hedge immediately downstream. Notably, at OTUKAI06, works were being completed to upgrade a bridge crossing and a port-a-loo was located in the immediate riparian margin. The riparian margins at HEATH27 and HEATH28 remained dominated by maintained[6] exotic grass on the true left bank, and residential garden on the true right bank.

In-stream habitat: All annual monitoring sites were dominated by run habitat, as observed in previous years. There was no change in stream bed substrate between 2022 and 2023, where all sites were dominated by fine sediments.

3.3 Wetted width and water depth

Five-yearly monitoring

Average wetted width was variable between the mainstem and tributaries, ranging from 1.9 m in Horners Drain at Hawkins Road (STYX11) to 6.8 m in Styx River at Styx Mill Conservation Reserve (STYX12). There was a significant difference in width between sites (ANOVA: $F_{1,90} = 21.07$; $P < 0.001$), and a significant site by time interaction (ANOVA: $F_{8,90} = 4.24$; $P < 0.001$). This interaction was most notable at STYX12 and STYX10, which were a magnitude wider in 2023 compared to previous years, while width at all other sites in 2023 was generally similar to 2008, 2013, and 2018 (Figure 4).

Water depth was significantly different between sites (ANOVA: $F_{1,90} = 94.22$; $P < 0.001$), ranging from 0.19 m in Kā Pūtahi Creek at Ouruhia Reserve (STYX09) to 0.56 m in Styx River at Claridges Road (STYX16). Generally, water depth was greater at sites in the mainstem compared to sites in tributary waterways. There was a significant site by time interaction (ANOVA: $F_{8,90} = 2.04$; $P = 0.04$), where the difference in water depth compared to previous years was a magnitude greater at STYX12 and STYX10 compared to other sites (Figure 4). Differences in wetted width and water depth between years could reflect differences in river flows across monitoring years. While surveys were undertaken in baseflow conditions, there had been 3 consecutive days of rain in the week prior to our 2023 survey. Differences in channel morphology at STYX12 and STYX10 (e.g., shallow bank slope combined with restricted channel capacity due to in-stream vegetation) compared to other sites likely made variations in flow conditions in response to this rainfall more noticeable at these two sites.

[6] Bank maintenance works (i.e., mowing) had occurred on the true left banks between January and February 2023.

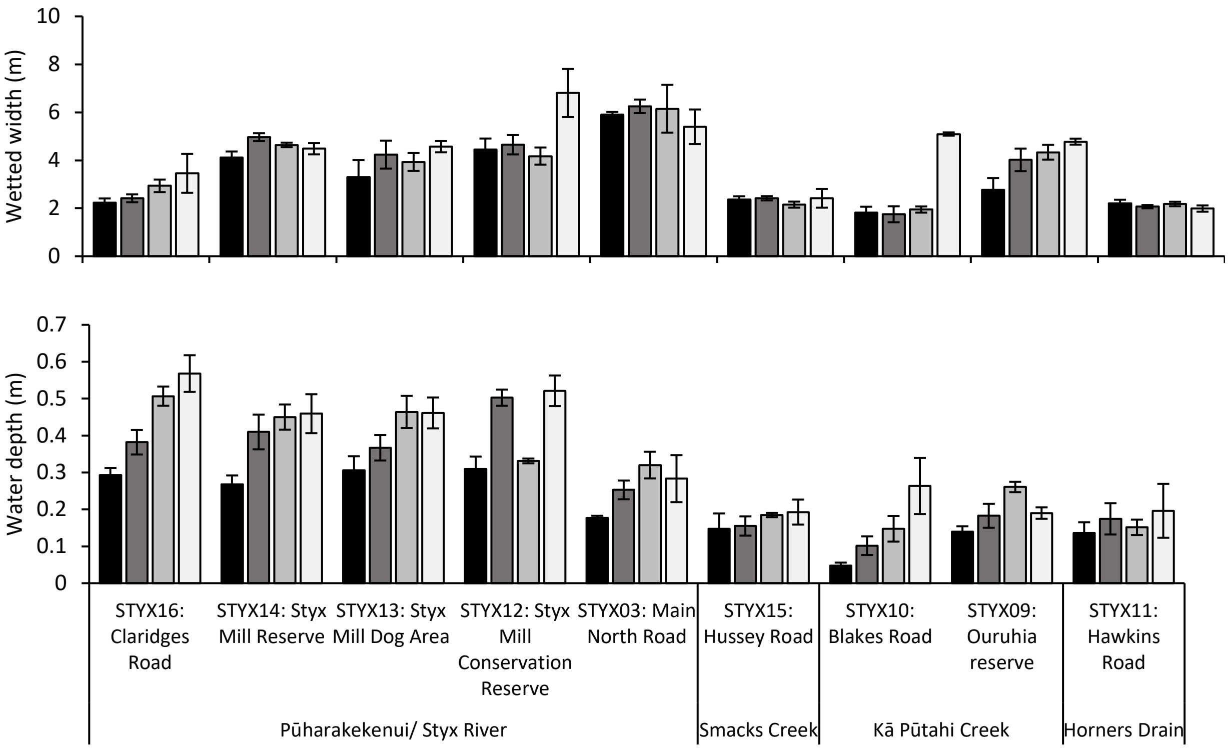


Figure 4. Mean (±1SE) wetted width (top) and water depth (bottom) at nine of the wadable sites in the Pūharakekenui / Styx River catchment in 2008 (black bars; EOS Ecology, 2008), 2013 (dark grey bars; EOS Ecology, 2013), 2018 (light grey bars; InStream Consulting Ltd, 2018), and 2023 (white bars; this survey). Sites are grouped by waterway and then in order of upstream to downstream.

<u>Annual monitoring</u>

Wetted width was generally similar at annual monitoring sites between years (Figure 5). Trend analysis showed no significant increasing or decreasing trend (Mann-Kendall P = 1) in stream width at HEATH28. There was insufficient data available for trend analysis at all other annual monitoring sites. Water depth was also generally similar between years (Figure 5). Trend analysis showed no significant increasing or decreasing trend (Mann-Kendall P = 0.11) in water depth at HEATH28.

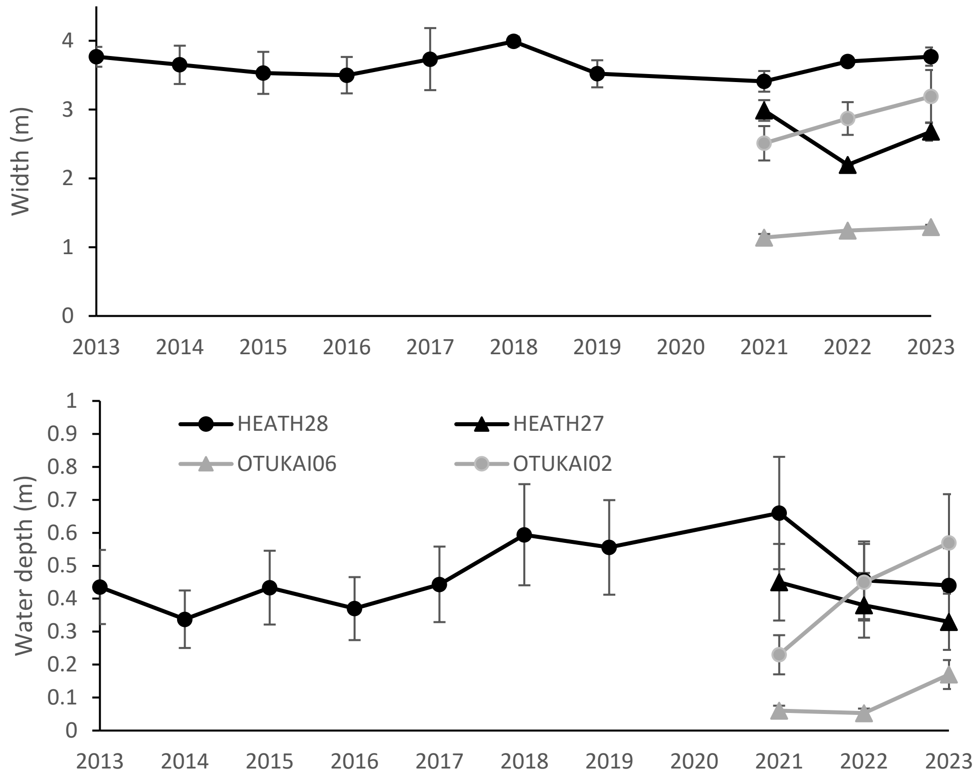


Figure 5. Changes in mean (±SE) wetted width (top) and mean (±SE) water depth (bottom) over time at the annual monitoring sites in Cashmere Stream (HEATH27 and HEATH28) and Wilsons Drain (OTUKAI02 and OTUKAI06).

3.4 Velocity

Five-yearly monitoring

Velocity ranged from 0.07 m / s in Kā Pūtahi Creek at Blakes Road (STYX10) to 0.59 m / s in Kā Pūtahi at Ouruhia Reserve (STYX09). Velocity was not significantly different among sites (ANOVA: $F_{1,90} = 0.26$; P = 0.61) but was between years (ANOVA: $F_{8,90} = 5.57$; P <0.001). The magnitude of change between years appeared to vary across sites (Figure 6), however, likely due to high variation within sites, there was no significant site by time interaction (ANOVA: $F_{8,90}$ = 0.71; P = 0.67).

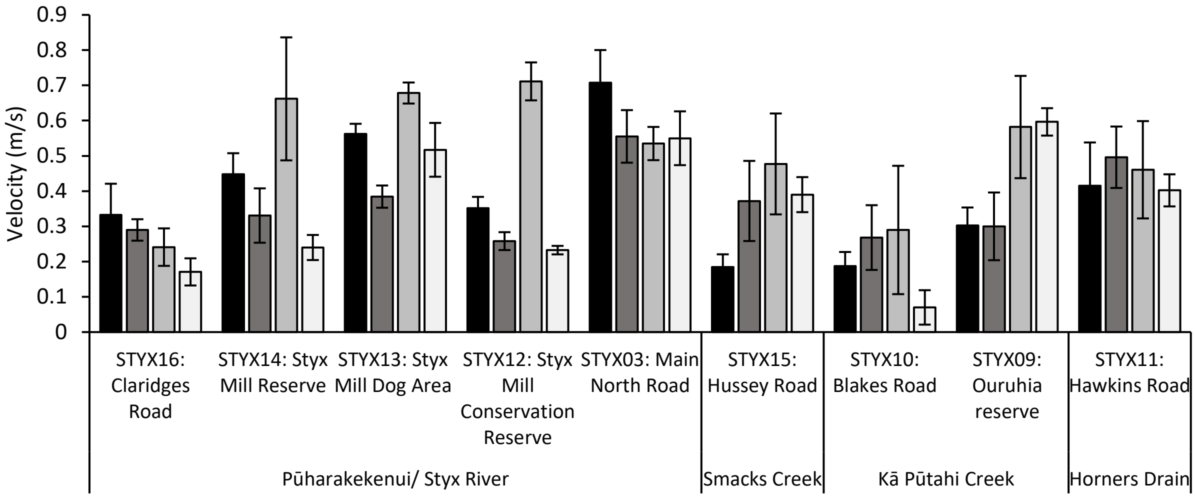


Figure 6. Mean (±1SE) velocity at nine of the wadable sites in the Pūharakekenui / Styx River catchment in 2008 (black bars, EOS Ecology, 2008), 2013 (dark grey bars, EOS Ecology, 2013), 2018 (light grey bars, InStream Consulting Ltd, 2018), and 2023 (white bars, this survey). Sites are grouped by waterway and then in order of upstream to downstream.

Annual monitoring

Velocity has varied over monitoring occasions but was similar at all annual monitoring sites in 2023 compared to 2022 (Figure 7). Trend analyses showed no significant increasing or decreasing trend (Mann-Kendall P = 0.72) in velocity at HEATH28.

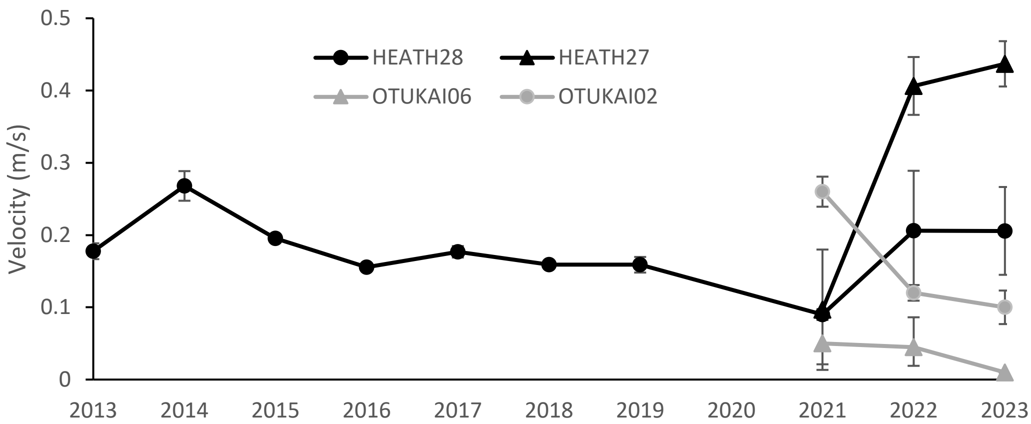


Figure 7. Changes in mean (±SE) velocity over time at the two annual monitoring sites in Cashmere Stream (HEATH27 and HEATH28) and two annual monitoring sites in Wilsons Drain (OTUKAI02 and OTUKAI06).

3.5 Substrate index

Five-yearly monitoring

The substrate index (SI) was not significantly different between sites (ANOVA: $F_{1,90}$ = 1.44; P =0.23). Horners Drain at Hawkins Road (STYX11) had the highest SI (5.3), indicating coarser substrates dominated by large cobbles, rather than smaller substrates (gravels, pebbles, and silt) that were found at other sites. Styx River at Claridges Road (STYX16) had the lowest SI of 3.3, indicating the substrate was dominated by silt and sand. SI was significantly different at sites between years (ANOVA: $F_{8,90}$ = 5.14; P <0.001). At some sites, (i.e., STYX12, STYX14) SI appeared to be increasing over time, at STYX11 SI appeared to be decreasing over time, and SI at other sites showed no apparent increase or decrease over time (Figure 8).

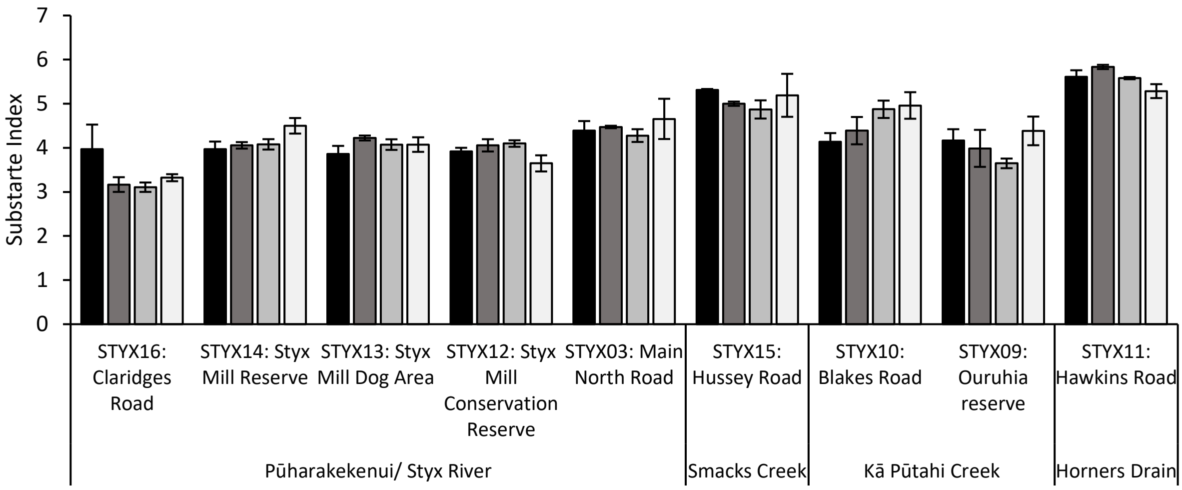


Figure 8. Mean (±1SE) Substrate Index at nine of the wadable sites in the Pūharakekenui / Styx River catchment in 2008 (black bars, EOS Ecology, 2008), 2013 (dark grey bars, EOS Ecology, 2013), 2018 (light grey bars, InStream Consulting Ltd, 2018), and 2023 (white bars, this survey). Sites are grouped by waterway and then in order of upstream to downstream.

Annual monitoring

SI was similar between years at OTUKAI02 and HEATH28 (Figure 9). At OTUKAI06 and HEATH27, SI was higher in 2023 compared to 2022, which may suggest that fine sediment cover may have decreased over time. However, there was insufficient data to perform a time trend analysis, as there was no substrate index data prior to 2021.

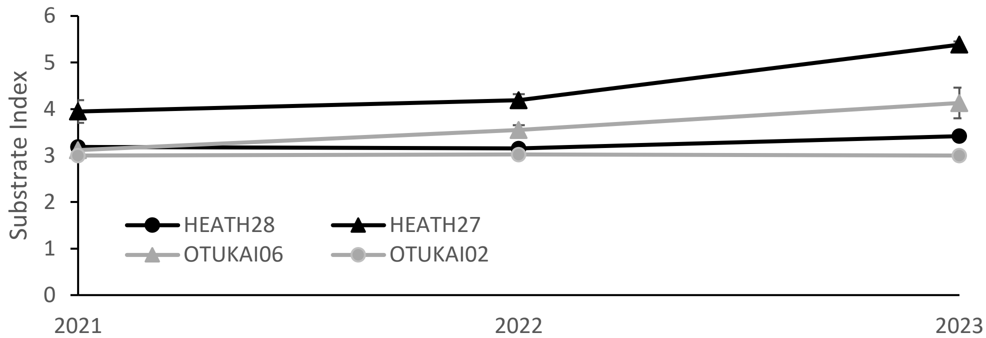


Figure 9. Changes in mean (±SE) Substrate Index over time at the two annual monitoring sites in Cashmere Stream (HEATH27 and HEATH28) and two annual monitoring sites in Wilsons Drain (OTUKAI02 and OTUKAI06).

3.6 Embeddedness

Five-yearly monitoring

Embeddedness in the Pūharakekenui / Styx River catchment was variable, ranging from 19% in Smacks Creek at Hussey Road (STYX15) to 94% in Kā Pūtahi Creek at Blakes Road

(STYX10). Although variable among sites, embeddedness was relatively similar in 2023 and 2018 at most sites. However, it was notably higher at STYX12, STYX10, and STYX11 in 2023 compared to 2018, which may indicate an increased cover of fine substrates like sand and silt over time.

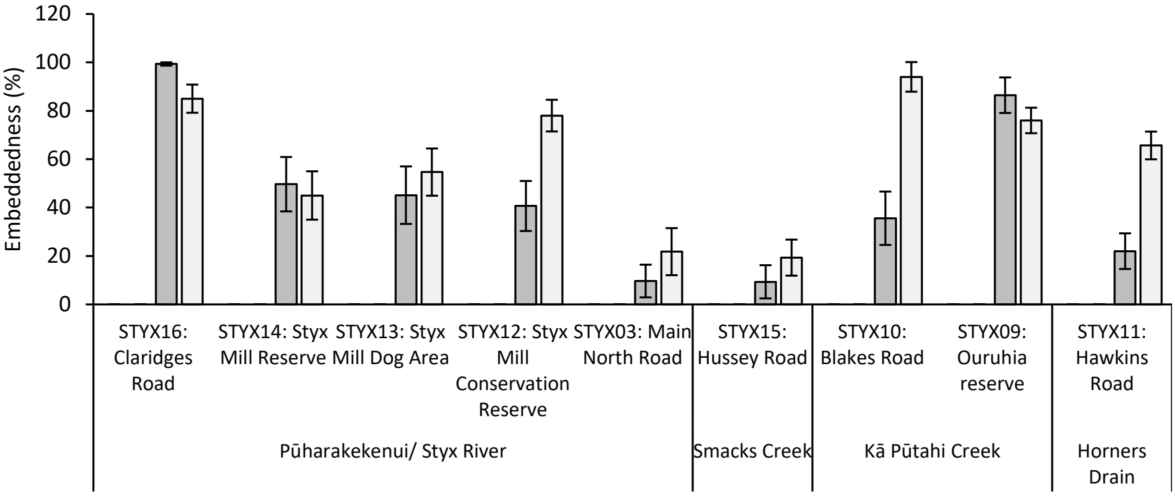


Figure 10. Mean (±1SE) embeddedness at nine of the wadable sites in the Pūharakekenui / Styx River catchment in 2018 (light grey bars, InStream Consulting Ltd, 2018), and 2023 (white bars, this survey). Sites are grouped by waterway and then in order of upstream to downstream. Embeddedness was not measured in the 2008 or 2013 surveys.

<u>Annual monitoring</u>

Embeddedness was consistently high (i.e., >90%) at OTUKAI02 and HEATH28, and consistently moderate (i.e., 40-50 %) at HEATH27 between years (Figure 11). At OTUKAI06, embeddedness was lower in 2023 compared to 2022; again, this may indicate a decreased cover of fine substrates like sand and silt at this site. There was insufficient data to perform a time trend analysis, as no embeddedness data were available prior to 2021.

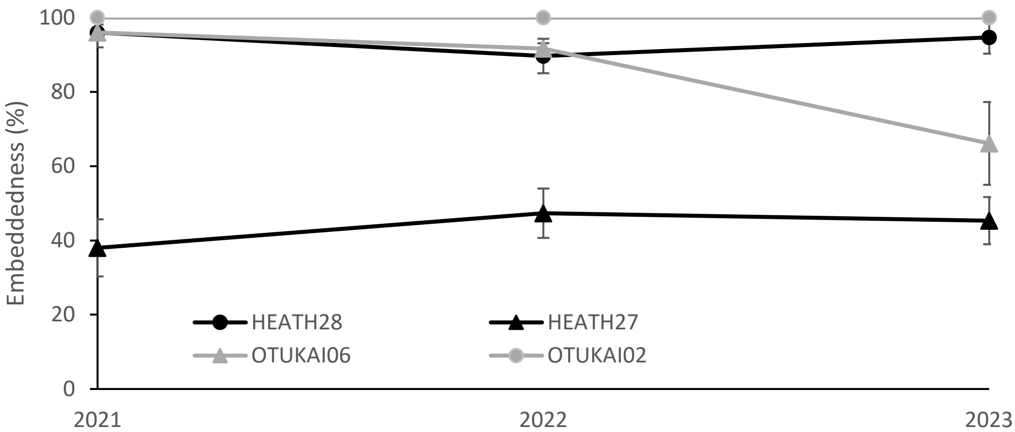


Figure 11. Changes in mean (±SE) embeddedness over time at the two annual monitoring sites in Cashmere Stream (HEATH27 and HEATH28) and two annual monitoring sites in Wilsons Drain (OTUKAI02 and OTUKAI06).

3.7 Sediment depth and cover

Five-yearly monitoring

Average sediment depth was variable between the mainstem and tributaries, ranging from 0.04 m deep in Styx River at Main North Road (STYX03) to 0.45 m deep in Styx River at Claridges Road (STYX16). There was a significant difference in sediment depth between sites (ANOVA: $F_{8,18} = 6.01$; P <0.001), and a significant site by time interaction (ANOVA: $F_{8,90} = 4.24$; P <0.001). Generally, sediment depth was higher in 2023 compared to previous years (at 6 of the 9 sites surveyed). Notably, sediment depth at STYX16 had increased by approximately 0.20 m (Figure 12). Sediment cover exceeded the consent target level (i.e., was greater than 20%) at all sites, except STYX15. The sites in the upper mainstem, STYX16, STYX14, STYX13 and STYX12, have exceeded the CSNDC trigger of maximum 20% cover on all sampling occasions. Generally, sediment cover was greater in 2023 compared to previous years. While the sample size is too small for time trend analyses, sediment cover at six sites (STYX14, STYX13, STYX12, STYX102, STYX09, and STYX11) appears to be increasing over time (Figure 12). STYX03 and STYX15, which had the lowest sediment cover also had the lowest embeddedness, and high SI scores. Conversely, most of the sites with the highest sediment cover (STYX16, STYX12, STYX10, STYX09, and STYX11) similarly had the highest embeddedness.

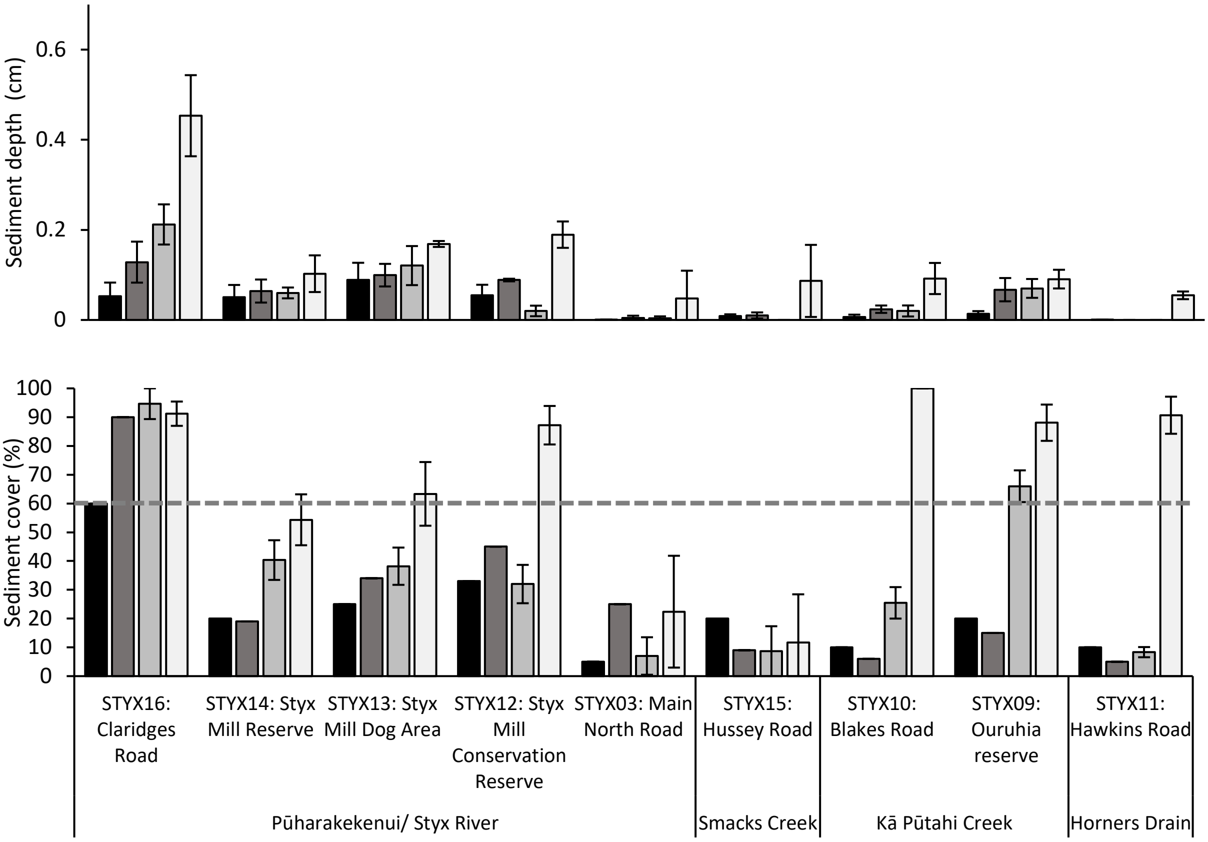


Figure 12. Mean (±1SE) sediment depth (top) and sediment cover (bottom) at nine of the wadable sites in the Pūharakekenui / Styx River catchment in 2008 (black bars, EOS Ecology, 2008), 2013 (dark grey bars, EOS Ecology, 2013), 2018 (light grey bars, InStream Consulting Ltd, 2018), and 2023 (white bars, this survey). Sediment cover was recorded as a site-wide estimate in 2008 and 2013. The dashed grey line indicates the CSNDC value for total fine sediment cover (maximum cover of 20%). Sites are grouped by waterway and then in order of upstream to downstream.

Annual monitoring

Sediment depth was similar at all annual monitoring sites in 2023 compared to 2022 (Figure 13). Mean sediment depth was greatest at OTUKAI02 (0.45 m) and shallowest at HEATH27 (0.06 m). From 2013 to 2023 there was no significant increasing or decreasing trend (Mann-Kendall P = 0.65) in sediment depth at HEATH28.

Sediment cover was high (i.e., >90%) at all annual monitoring sites in 2023. Sediment cover at OTUKAI02 and HEATH28 has been consistently high across years. Cover had increased by c.20% at OTUKAI06 and c.28% at HEATH27 in 2023 compared to 2022 (Figure 13). From 2013 to 2023 there was no significant increasing or decreasing trend (Mann-Kendall P = 0.06) in sediment cover at HEATH28.

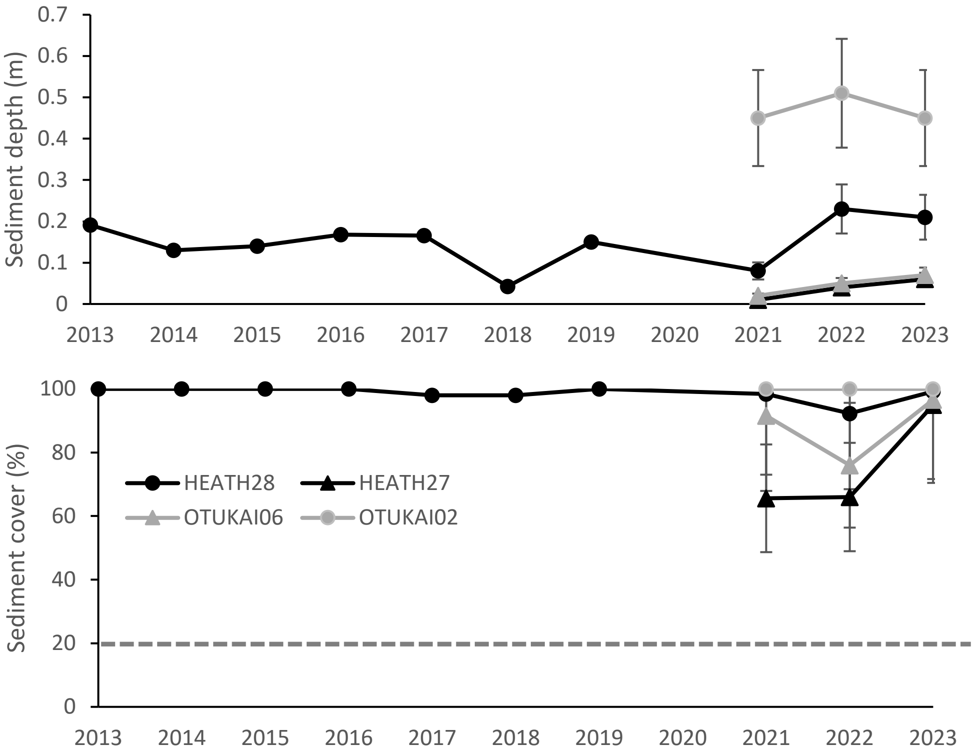


Figure 13. Changes in mean (±SE) sediment depth (top) and mean (±SE) sediment cover (bottom) over time at the two annual monitoring sites in Cashmere Stream (HEATH27 and HEATH28) and two annual monitoring sites in Wilsons Drain (OTUKAI01 and OTUKAI06), noting sediment cover was measured once per site at HEATH28 from 2013-2019. The dashed grey line indicates the CSNDC value for total fine sediment cover (maximum cover of 20%).

3.8 Sediment quality

Table 7 provides a summary of the grain size (%) composition and contaminant concentrations found in the sediment samples collected from each site. Full sediment analysis results are provided in Appendix 2. Metal contaminants are usually found in higher concentrations in sediment samples with the higher silt and clay contents (i.e., substrata <0.063 mm in size), as the greater surface area of smaller particles increases the adsorption. This is particularly relevant as higher metal concentrations at a site may primarily be driven by a higher proportion of small particles (i.e., better attachment of the metals). STYX04, STYX05, STYX07, and STYX08 were dominated by silt / clay, while STYX03, STYX06, STYX12, and STYX15 were dominated by fine sand (0.063-0.250 mm).

Total recoverable copper, lead, and total PAHs were below both the CSNDC guidelines and the ISQG-high and ISQG-low of the ANZECC (2000) sediment quality guidelines at all sites (Table 7). The concentrations of zinc in the stream bed material at STYX04, STYX05, and STYX07 were above the CSNDC guideline, but below the ISQG-low ANZECC (2000) sediment quality guideline. Where the sediment concentration is below the ISQG-low, it is considered that there is low risk of adverse effects to aquatic life. Zinc concentrations were similarly high in 2018 and exceeded the CSNDC guideline at STYX04and STYX05, however, zinc concentrations were markedly greater in 2023 at STYX07 (approx. at least 7 times greater) than that recorded in 2018. While zinc concentrations were markedly higher at STYX07 in 2023 than 2018, the levels were comparable to sites upstream (STYX05 and STYX04), and concentrations in 2014 and 2009 (Christchurch City Council, 2014; Golder Associates, 2009). Total PAHs and zinc concentrations exceeded the CSNDC guideline at STYX06 and STYX08 respectively, in 2018 but not in 2023 (Table 7).

There are no listed ANZECC (2000) guidelines for total phosphorus (TP) or TOC. However, the levels measured at all sites surveyed were similar in range to levels detected in other catchments within the Christchurch City limits (e.g., Boffa Miskell Ltd, 2022). TP and TOC concentrations ranged from 333 mg / kg to 1303 mg / kg TP, and 0.6 g / 100 g to 12.5 g / 100 g TOC. The highest concentration TP was recorded at STYX07, indicating this site (and possibly others) may be impacted by fertilisers. TOC was highest at STYX05; contaminants such as fertilisers, pesticides, and industrial chemicals can cause elevated TOC concentrations. Canopy cover of deciduous trees was also high at this site, which could have influenced the TOC concentration.

Table 7. Particle size distribution (grain size, %), and copper, lead, zinc, total organic carbon (TOC), total phosphorus (TP), total polycyclic aromatic hydrocarbons (PAHs), and semi-volatile organic compounds (SVOCs) in the sediment samples, collected between March and April 2023. Values from the 2018 survey are shown in brackets, where applicable. Total PAHs were normalised to 1% of TOC, as recommended by ANZECC (2000). Values in red exceed guideline values. LWRP = Canterbury's Land and Water Regional Plan; CSNDC = CCC's Comprehensive Stormwater Network Discharge Consent.

	STYX03: Styx River at Main North Road	STYX04: Kā Pūtahi Creek at Blakes Road	STYX05: Kā Pūtahi Creek at Belfast Road (lower)	STYX06: Styx River at Marshland Road Bridge	STYX07: Styx River at Richards Bridge/ Teapes Road	STYX08: Styx River at Kainga Road/ Harbour Road Bridge	STYX12: Styx River at Styx Mill Conservation Reserve	STYX15: Smacks Creek at Hussey Road	LWRP and CSNDC	ANZECC (2000) guideline GV-high
Grain size										
Silt / clay: <0.063 mm	11.6 (5.9)	34.8 (18.3)	38.0 (21.5)	25.1 (14.8)	56.8 (18.5)	38.0 (28.7)	31.2	12.8 (8.8)	-	-
Fine sand: 0.063-0.250 mm	64.0 (43.4)	27.5 (54.5)	36.7 (34)	57.1 (48.3)	35.5 (75.4)	36.7 (49.7)	42.7	49.3 (33.5)	-	-
Medium sand: 0.250-0.500 mm	20.7 (16.3)	22.0 (13)	12.9 (14.4)	15.4 (3.7)	4.9 (5.1)	12.9 (10)	11.7	14.0 (12)	-	-
Coarse sand: 0.500-2.00 mm	3.3 (3.4)	14.7 (7.5)	11.7 (15.1)	2.3 (7)	2.2 (0.7)	11.7 (11.1)	12.7	21.1 (21.2)	-	-
Gravel and cobbles: >2.00 mm	0.4 (31.1)	0.9 (6.7)	0.7 (15)	0.0 (26.2)	0.6 (0.3)	0.7 (0.5)	1.7	2.7 (24.5)	-	-
Contaminants										
Copper (mg / kg)	4.8 (4.4)	23 (6.3)	22.3 (23)	6.1 (6.2)	24.6 (5.9)	4.6 (24)	6.6	11.6 (44)	65	270
Lead (mg / kg)	14.3 (11.9)	49.7 (17.3)	50.0 (47)	12.3 (17.1)	38.3 (9.1)	12.5 (29)	9.8	6.4 (28)	50	220
Zinc (mg / kg)	93.3 (61)	330.3 (230)	383.3 (280)	117.7 (61)	346.7 (50)	62.0 (210)	64	74 (161)	200	410
Total organic carbon (g / 100 g)	0.9 (1.5)	7.9 (1.7)	12.5 (10.5)	1.6 (0.9)	8.3 (0.5)	1.2 (4)	2.29	3.6 (15.8)	-	-

	STYX03: Styx River at Main North Road	STYX04: Kā Pūtahi Creek at Blakes Road	STYX05: Kā Pūtahi Creek at Belfast Road (lower)	STYX06: Styx River at Marshland Road Bridge	STYX07: Styx River at Richards Bridge/ Teapes Road	STYX08: Styx River at Kainga Road/ Harbour Road Bridge	STYX12: Styx River at Styx Mill Conservatio n Reserve	STYX15: Smacks Creek at Hussey Road	LWRP and CSNDC	ANZECC (2000) guideline GV-high
Total phosphorus (mg / kg)	386.6	923.3	1236.7	323.3	1303.3	390.0	373.3	333.3	-	-
Total PAHs (mg / kg)	0.7 (0.6)	0.6 (0.9)	1.3 (0.04)	0.7 (19.4)	1.1 (not detected)	4.3 (not detected)	0.2	0.3 (0.03)	10	50

3.9 Macrophytes

Five-yearly monitoring

Total macrophyte cover was low at all sites, except STYX10, which had a total of 89% dominated by curly pondweed (*Potamogeton crispus*). STYX10 was the only five-yearly monitoring site where total macrophyte cover exceeded the consent target level (maximum 50% cover) (Figure 14). Macrophyte cover has fluctuated at all sites over time but has only exceeded the consent target level at two sites, STYX10 and STYX09, across all sampling occasions (Figure 14). Notably, macrophytes are actively managed in the Pūharakekenui / Styx River catchment, and our surveys took place prior to routine clearance.

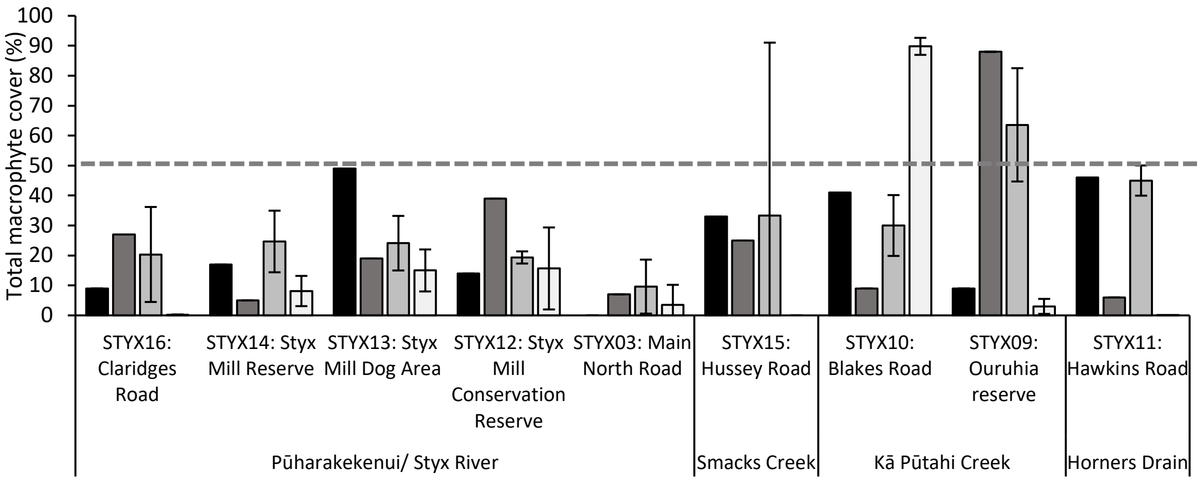


Figure 14. Mean (±1SE) macrophyte cover at nine of the wadable sites in the Pūharakekenui / Styx River catchment in 2008 (black bars, EOS Ecology, 2008), 2013 (dark grey bars, EOS Ecology, 2013), 2018 (light grey bars, InStream Consulting Ltd, 2018), and 2023 (white bars). Dashed line indicates the LWRP and CSNDC guidelines for 'spring-fed plains' waterways of 50% maximum total cover of macrophytes. Sites are grouped by waterway and then in order of upstream to downstream.

Annual monitoring

Total macrophyte cover met (i.e., was below) the LWRP guideline value at OTUKAI02 and HEATH27 but exceeded the consent target level at OTUKAI06 and HEATH28 (Figure 15). Where cover exceeded target level, macrophytes beds were dominated by emergent watercress (*Nasturtium officinale*) at OTUKAI06 and curly pondweed at HEATH28. Notably, macrophyte maintenance had occurred along Cashmere Stream, including HEATH27 and HEATH28 in late January 2023. From 2013 to 2023, there no significant increasing or decreasing trend (Mann-Kendall P = 0.58) in total macrophyte cover at HEATH28.

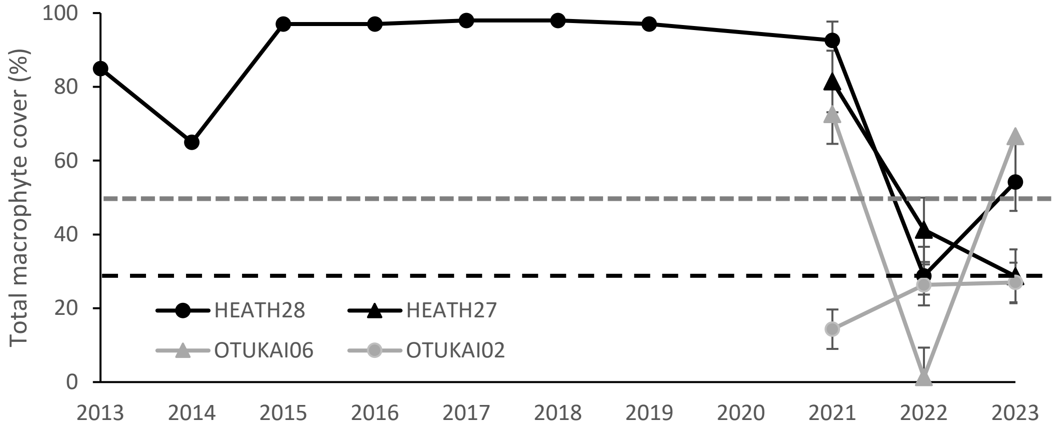


Figure 15. Changes in mean (±SE) total macrophyte cover over time at the two annual monitoring sites in Cashmere Stream (HEATH27 and HEATH28) and two annual monitoring sites in Wilsons Drain (OTUKAI02 and OTUKAI06), noting macrophyte cover was measured once per site at HEATH28 from 2013-2019. The dashed grey line indicates the LWRP and CSNDC guidelines for 'spring-fed – plains' waterways of 50% maximum total cover of macrophytes. The dashed black line indicates the LWRP and CSNDC guidelines for 'Banks Peninsula' waterways of 30% maximum total cover of macrophytes.

3.10 Filamentous algae

Five-yearly monitoring

Filamentous algae (>20 mm in length) was absent (or in very low abundances so not detectable) from most sites (Figure 16). Where present, at STYX10 and STYX09, cover was low and met the consent target level (maximum 30% cover). With the exception of STYX03 in 2013, total cover of filamentous algae has been low or absent from sites across all survey occasions.

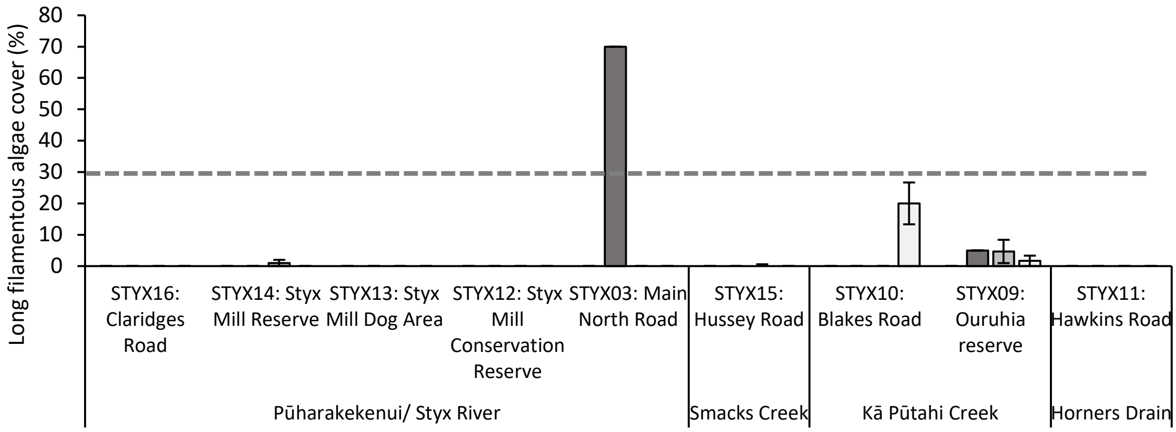


Figure 16. Mean (±1SE) filamentous algae cover at nine of the wadable sites in the Pūharakekenui / Styx River catchment in 2008 (black bars, EOS Ecology, 2008), 2013 (dark grey bars, EOS Ecology, 2013), 2018 (light grey bars, InStream Consulting Ltd, 2018), and 2023 (white bars, this survey). The dashed grey line indicates the LWRP and CSNDC guidelines for 'spring-fed – plains' waterways of 30% maximum cover of filamentous algae. Sites are grouped by waterway and then in order of upstream to downstream.

Annual monitoring

Filamentous algae (>20 mm in length) was absent at annual monitoring sites, except at OTUKAI02 where cover was 11.6%. Similarly, filamentous algae was absent from annual monitoring sites in 2021, except at OTUKAI02 where cover was 0.6%, which was well below the LWRP and CSNDC guideline of ≤30% for ‘spring-fed – plains’ waterways. There was insufficient data to perform a time trend analysis, as no filamentous algae data were available prior to 2021.

3.11 Macroinvertebrate community

Five-yearly monitoring

Macroinvertebrate taxonomic richness was variable across sites in 2023, ranging from 14 at STYX16 to 25 at STYX06 (Figure 17). Taxonomic richness was lower in 2023 (this study) compared to previous years, especially in the upper catchment mainstem (STYX16, STYX14 and STYX13) and the lower catchment tributaries (STYX09 and STYX11). The differences in taxonomic richness at sites between years were largely driven by more caddisflies, and ‘other’ taxa (flatworms, Nemertea worms, oligochaete worms, aquatic mites) being found in 2018 compared to 2023 (Table 8). Notably, at STYX10 and STYX16 there were 9 and 6, respectively less caddisfly taxa found in 2023 compared to 2013.

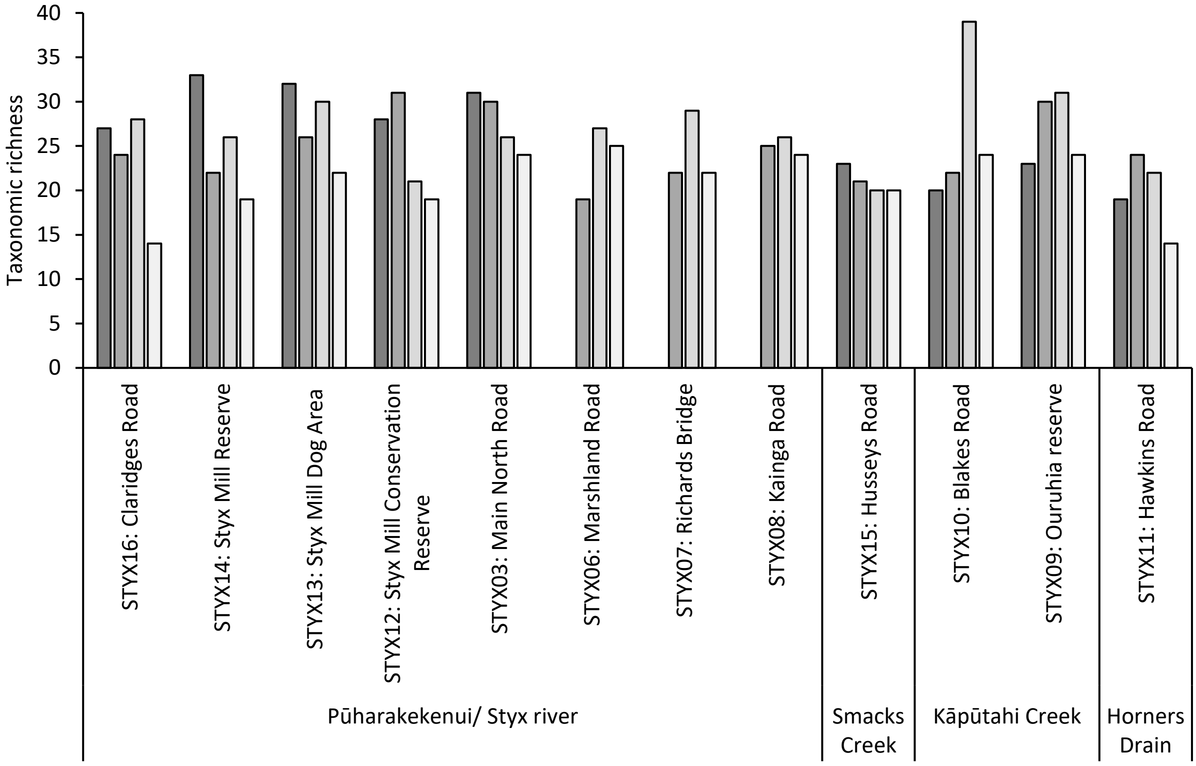


Figure 17. Number of macroinvertebrate taxa found at sites surveyed within the Pūharakekenui / Styx River catchment in 2008 (black bars, EOS Ecology, 2008), 2013 (dark grey bars, EOS Ecology, 2013), 2018 (light grey bars, InStream Consulting Ltd, 2018), and 2023 (white bars, this study). Sites are grouped by waterway and then in order of upstream to downstream.

Table 8. Taxonomic richness of macroinvertebrate taxonomic groups collected from monitoring sites surveyed in this survey 2023 and 2018 (InStream Consulting Ltd, 2018). Trichoptera (caddisflies), Ephemeroptera (mayflies), Mollusca (snails and bivalves), Diptera (true flies), Crustacea, and Other (flatworms, Nemertea worms, oligochaete worms, aquatic mites). There was some variation in the taxonomic resolution used in the 2018 and 2023 surveys, for example, the Caddisfly *Hudsonema* was only identified to genus level in 2023, while in 2018 it was recorded to species level, either *H. amabile*, or *H. clavigera*. Sites are grouped in order of upstream to downstream and grouped by waterway. Sites have been grouped by waterway and then upstream to downstream.

	Trichoptera		Ephemeroptera		Mollusca		Diptera		Crustacea		Other	
	2018	2023	2018	2023	2018	2023	2018	2023	2018	2023	2018	2023
STYX16: Styx River at Claridges Road	8	2	0	0	4	3	8	3	4	2	5	4
STYX14: Styx River at Styx Mill Reserve	12	7	0	1	4	3	6	3	2	2	3	3
STYX13: Styx River at Styx Mill Dog Area	13	8	1	1	4	4	6	5	3	2	5	2
STYX12: Styx River at Styx Mill Conservation Reserve	10	5	1	1	4	4	3	2	2	2	3	5
STYX03: Styx River at Main North Road	8	8	1	2	5	4	5	4	3	2	5	4
STYX06: Styx River at Marshland Road	4	4	1	0	4	4	6	7	4	4	10	6
STYX07: Styx River at Richards Bridge / Teapes Road	4	3	0	0	4	4	7	4	5	4	10	7
STYX08: Styx River at Kainga Road/Harbour Road Bridge	6	3	0	0	5	5	3	4	5	6	8	6
STYX15: Smacks Creek at Husseys Road	7	6	0	1	4	3	3	4	3	2	4	4
STYX10: Kā Pūtahi Creek between Blakes and Belfast Roads	12	3	1	0	5	4	9	6	2	4	10	7
STYX09: Kā Pūtahi Ouruhia reserve	10	6	1	0	4	3	6	5	5	2	9	8
STYX11: Horners Drain at Hawkins Road	7	2	0	0	3	3	5	3	2	3	5	3

The macroinvertebrate community at most five-yearly monitoring sites was dominated by pollution-tolerant taxa, such as oligochaete worms, ostracods, and the freshwater snail (*Potamopyrgus*). A single kēkēwai (freshwater crayfish) was caught at STYX14 via electric fishing methods. Kākahi (freshwater mussels) were not observed at any site, but populations are present in the lower mainstem of the Pūharakekenui / Styx River (InStream Consulting Ltd, 2021b). Both kēkēwai and kākahi are listed as listed as At Risk, Declining species (Grainger et al., 2018). Community composition was similar at STYX14, STYX13, STYX06, STYX07, STYX08, and STYX11 in 2023 compared to 2018, where sites remained dominated by pollution-tolerant taxa (Figure 18). The contribution of sensitive macroinvertebrate taxa, Trichoptera, caddisflies and Ephemeroptera, mayflies to community composition had decreased at STYX16, STYX12, and STYX10 in 2023 compared to 2018. STYX16, STYX10, and STYX12 were sites where caddisfly taxonomic richness had declined, meaning caddisflies were less abundant and less diverse at these sites compared to 2018 (Table 8). Notably, at three sites, STYX03, STYX15, and STYX09 the contribution of sensitive macroinvertebrate taxa increased in 2023 compared to 2018. At STYX03 mayfly abundance from 2% to 7%, and caddisfly abundance increased at STYX15 and STYX09 from 0.2% to 20% and from 2% to 9%, respectively (Figure 18).

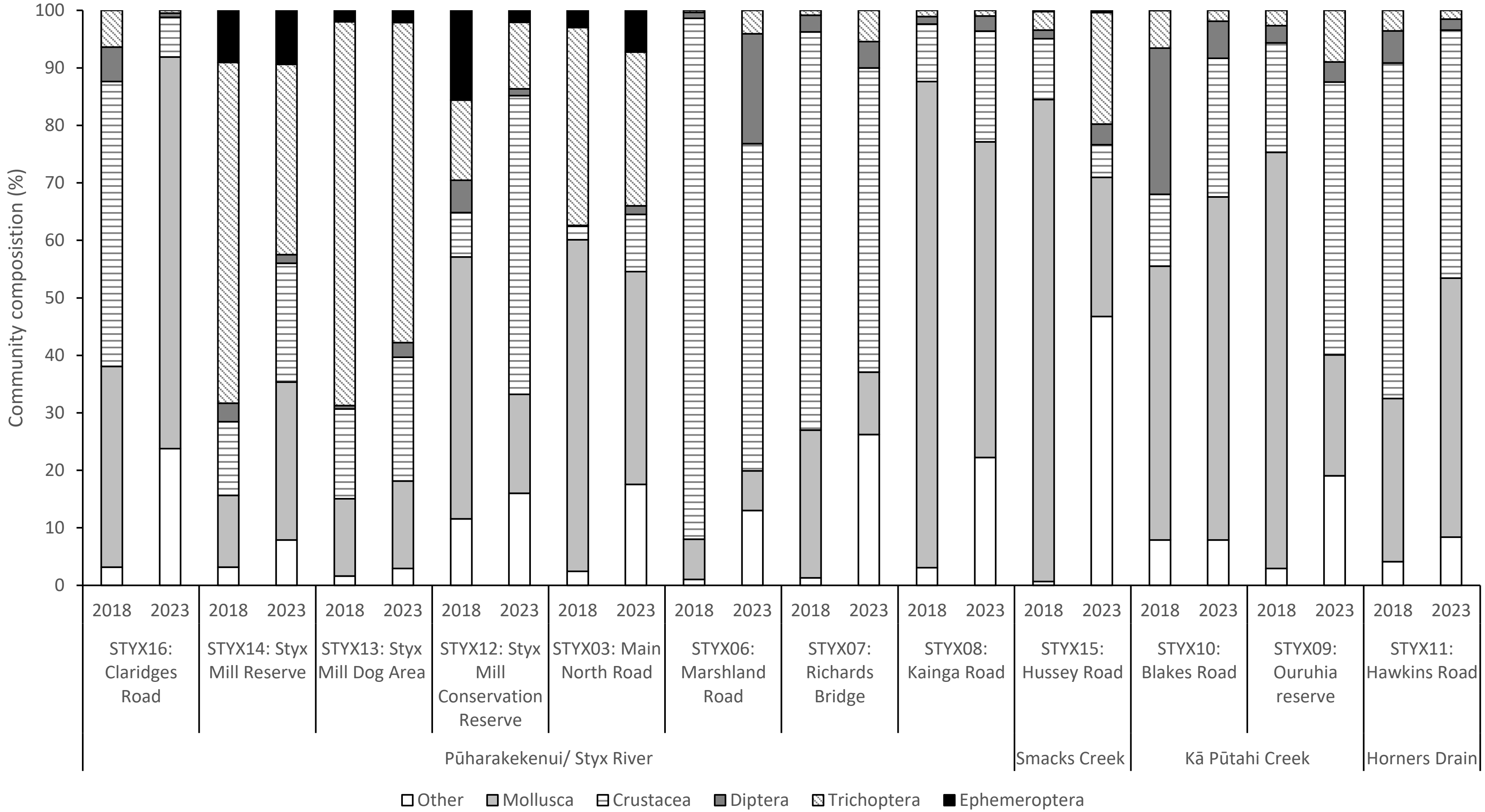


Figure 18. Average relative abundances of macroinvertebrate taxonomic groups collected from monitoring sites surveyed in this survey 2023 (top) and 2018 (bottom, InStream Consulting Ltd, 2018). Other = flatworms, Nemertea worms, oligochaete worms, aquatic mites. Sites are grouped by waterway and then in order of upstream to downstream.

The EPT insect orders (Ephemeroptera, mayflies; Plecoptera, stoneflies; and Trichoptera, caddisflies), which are generally sensitive to pollution and habitat degradation, are useful indicators of stream health. EPT taxa were represented by caddisflies and mayflies; no stoneflies were recorded. The following taxa that are considered most pollution-sensitive (i.e., those that have an MCI score ≥7, out of a maximum of 10) were present in 2023: the mayfly *Deleatidium* (MCI = 8), and caddisflies of the Oeconesidae family (MCI = 9), as well as *Polyplectropus* (MCI = 8), *Psilochorema* (MCI = 8) and *Pycnocentria* (MCI = 7). These notable taxa were present at more sites in 2018 compared to 2023 (Table 9). Three notable taxa were present at STYX16 and STYX10 in 2018, *Polyplectropus*, *Psilochorema*, and *Pycnocentria*, and *Deleatidium*, *Psilochorema*, and *Pycnocentria*, respectively, but were not found in 2023.

Table 9. Pollution-sensitive macroinvertebrate taxa (MCI scores of ≥7) found at sites in the Pūharakekenui / Styx River catchment in 2023 (this survey) and in 2018 (InStream Consulting Ltd, 2018).

Site ID	2008	2013	2018	2023
STYX16: Styx River at Claridges Road	*Deleatidium* *Oeconesus* *Olinga feredayi* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Olinga feredayi* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Polyplectropus* *Psilochorema bidens* *Pycnocentria*	*No taxa with MCI ≥7*
STYX14: Styx River at Styx Mill Reserve	*Deleatidium* *Oeconesus* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Deleatidium* *Oeconesus* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Deleatidium* *Oeconesus* *Polyplectropus* *P. bidens* *Pycnocentria*	*Deleatidium* *Psilochorema* *Pycnocentria*
STYX13: Styx River at Styx Mill Dog Area	*Deleatidium* *Oeconesus* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Deleatidium* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Deleatidium* *Oeconesus* *P. bidens* *Pycnocentria tautoru* *Pycnocentria*	*Deleatidium* *Oeconesus* *Psilochorema* *Pycnocentria*
STYX12: Styx River at Styx Mill Conservation Reserve	*Deleatidium* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Deleatidium* *Oeconesus* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Deleatidium* *P. bidens* *Pycnocentria*	*Deleatidium* *Psilochorema* *Pycnocentria*
STYX03: Styx River at Main North Road	*Deleatidium* *Psilochorema* *Pycnocentria*	*Deleatidium* *Oeconesus* *Psilochorema* *Pycnocentria*	*Deleatidium* *P. bidens* *Pycnocentria*	*Deleatidium* *Oeconesus* *Psilochorema* *Pycnocentria*
STYX06: Styx River at Marshland Road	*Deleatidium* *Psilochorema* *Pycnocentria*	*No taxa with MCI ≥7*	*No taxa with MCI ≥7*	*Pycnocentria*
STYX07: Styx River at Richards Bridge / Teapes Road	*No data*	*No taxa with MCI ≥7*	*No taxa with MCI ≥7*	*No taxa with MCI ≥7*

STYX08: Styx River at Kainga Road/Harbour Road Bridge	*No data*	*No taxa with MCI ≥7*	*Polyplectropus*	*Pycnocentria*
STYX15: Smacks Creek at Husseys Road	*Psilochorema*	*Psilochorema*	*Deleatidium* *Polyplectropus* *Psilochorema bidens*	*Deleatidium* *Polyplectropus* *Pycnocentria*
STYX10: Kā Pūtahi Creek between Blakes and Belfast Roads	*Deleatidium* *Psilochorema* *Pycnocentria*	*Psilochorema*	*Deleatidium* *P. bidens* *Pycnocentria*	*No taxa with MCI ≥7*
STYX09: Kā Pūtahi Ouruhia reserve	*Polyplectropus* *Pycnocentria*	*Polyplectropus* *Pycnocentria*	*Polyplectropus* *P. bidens*	*Psilochorema*
STYX11: Horners Drain at Hawkins Road	*No taxa with MCI ≥7*	*No taxa with MCI ≥7*	*Pycnocentria*	*No taxa with MCI ≥7*

The first NMDS ordination (using presence absence data), confirmed by the PERMANOVA results, showed a significant shift in macroinvertebrate community composition among sites (F = 24.78; P <0.01) and between years (F = 3.82; P <0.01). SIMPER analysis (Appendix 3) showed differences in community composition were due to differences in the presence and absence of particular taxa. For example, the caddisfly order, Hudsonema, was present in 2023, but absent in 2018, explaining 2.28% of dissimilarities in community composition. However, Hudsonema amabile was recorded in 2018 but not 2023. This suggests there may have been taxonomic differences that drove community dissimilarity.

To control for these differences that were due to taxonomic resolution rather than actual differences in community composition, a common taxonomic list was compiled, and the ordinations were rerun, to see if this reduced community dissimilarity between years. That is, where taxa had been identified to species level in one year but only to genus the other, genus level was used for both years. Using this condensed dataset, macroinvertebrate community composition (presence absence) at sites significantly differed between years (PERMANOVA F = 6.83; P <0.01). Similarly, using abundance data, macroinvertebrate community composition also significantly differed between years (PERMANOVA F = 6.48; P <0.01; Figure 19). SIMPER analysis (Appendix 4) showed, in order from contributing the most to the dissimilarity, Potamopyrgus, Amphipoda, Paracalliope, and Pycnocentria contributed to 59.44% of the differences between the macroinvertebrate communities in 2018 and 2023.

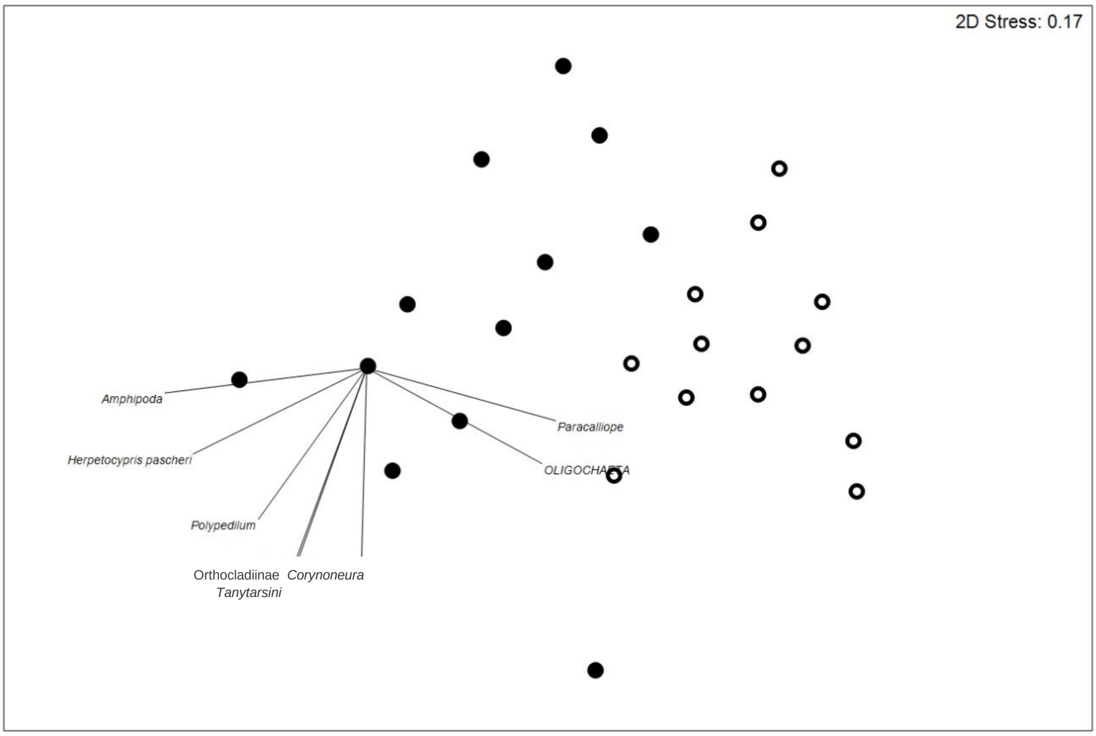


Figure 19. Non-metric multidimensional scaling (NMDS) ordination based on a Bray-Curtis matrix of dissimilarities calculated from abundance macroinvertebrate data from a condensed taxonomic list collected in single kicknet samples taken at each site in 2023 (white circles) and 2018 (black circles; InStream Consulting Ltd, 2018). Axes are identically scaled so that sites closest together are more similar in macroinvertebrate composition, than those further apart. The significance of differences in community dissimilarity was confirmed using permutational multivariate analysis of variance (PERMANOVA).

The percentage of the community made up by EPT taxa (excl. hydroptilids) was low (i.e., <10%) but variable across sites in 2023, ranging from 1% at STYX10 and STYX07, to 10% at STYX03. The EPT taxa contributed a relatively greater proportion of the macroinvertebrate community (6-10%) in the upper-mid mainstem of Pūharakekenui / Styx River sites compared to the wider catchment and tributaries. With the exception of STYX16 in the upper catchment, which had lower %EPT abundance compared to previous years. Prior monitoring occasions also showed greater %EPT abundance concentrated in the upper mainstem compared to the wider catchment (Figure 20). Sites that saw a decline in five or more caddisfly taxa (STYX16, STYX14, STYX13, STYX12, STXY10, and STYX11) had increased embeddedness, sediment cover and / or sediment depth. Conversely, sites with the lowest sediment cover and embeddedness (STYX15 and STYX03) saw no or little change in mayfly and caddisfly taxonomic richness and supported at least three of the notable pollution-sensitive taxa (Table 8). The reduction in %EPT and the loss of notable pollution-sensitive taxa from the upper catchment (STYX16) in 2023 may be of concern for the long-term persistence of these taxa in the catchment (if source populations are lost).

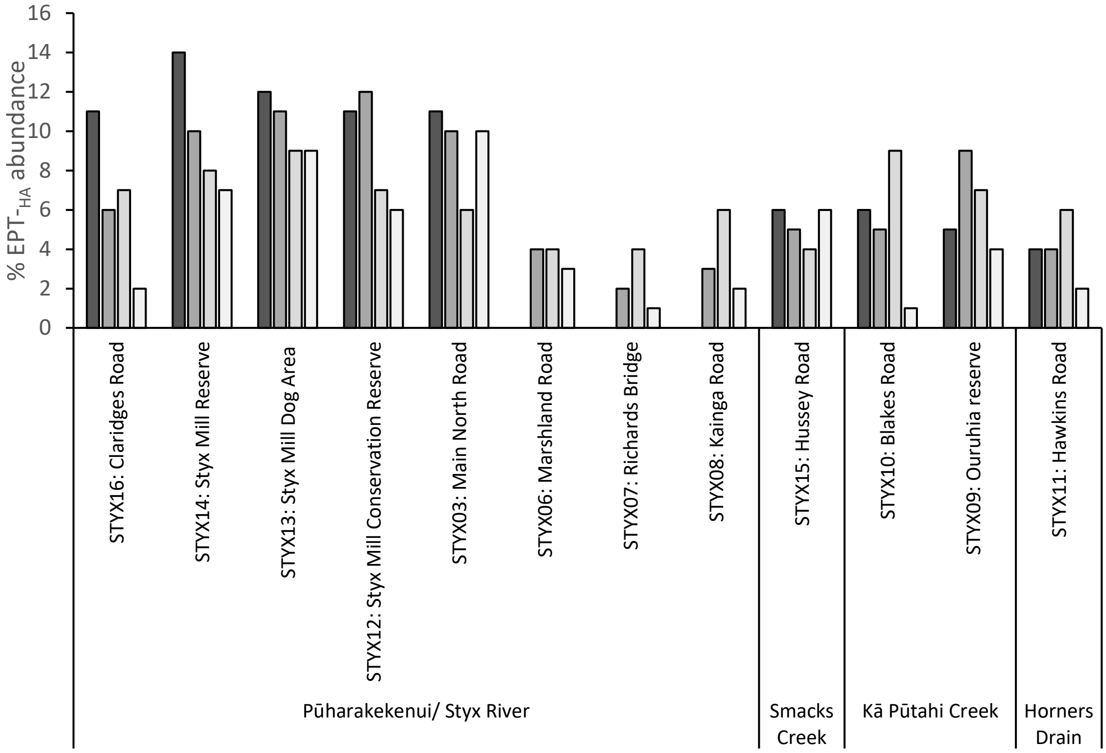


Figure 20. %EPT abundance (excl. hydroptilids) at sites within the Pūharakekenui / Styx River catchment in 2008 (black bars, EOS Ecology, 2008), 2013 (dark grey bars, EOS Ecology, 2013), 2018 (light grey bars, InStream Consulting Ltd, 2018), and 2023 (white bars, this survey). Sites are grouped by waterway and then in order of upstream to downstream.

The MCI scores were variable but low across sites. Site STYX07 in the lower mainstem of Pūharakekenui / Styx River had the lowest MCI score of 49, while STYX03, in the mid-upper mainstem had the highest MCI of 89.2 (Figure 21). Overall, MCI scores in 2023 at sites in the upper Pūharakekenui / Styx River were indicative of fair quality (MCI scores of 80 to 100), with the exception of Horners Drain, Smacks Creek and the three non-wadeable sites, which all had MCI scores indicative of poor quality (MCI scores below 80). However, it should be noted that MCI scores are typically lower at non-wadeable with substrates dominated by fine sediments, and a lower MCI score in soft-bottomed systems does not necessarily mean water quality or stream health is degraded.

All sites failed to meet the NPS-FM National Bottom-Line value of MCI score of 90. Noting, some sites in the mid-upper mainstem of the Pūharakekenui / Styx River (STYX14, STYX13, and STYX03) almost met the NPS-FM Bottom-Line value. In 2018, all sites, except STYX16 and STYX13, also failed to meet the National Bottom-Line (Figure 21).

The QMCI is considered a better indicator of “health” than MCI, as it considers both presence and abundance of macroinvertebrate taxa. The QMCI showed slightly different results to the MCI. In this survey, two sites in the upper-mid mainstem of the Pūharakekenui / Styx River (STYX14 and STYX13) complied with the consent target of a QMCI of 5 or greater, while all other sites had a QMCI value lower than 5 and did not comply with the consent target (Figure 21). Over time, STYX14 and STYX13 are the only sites where QMCI has complied with the consent target, but only more recently (i.e., in 2018 and 2023). These two sites have improved from ‘fair’ stream health in 2008 and 2013, to ‘good’ in 2018 and 2023. All other sites have fluctuated between ‘poor’ and ‘fair’ from 2008 to 2023. Notably, while QMCI scores at STYX14, STYX15 have increased over time, QMCI scores at STYX16, STYX15, and STYX07 show a marked decrease in 2023 compared to 2018 (Figure 21).

Average Score Per Metric (ASPM) scores were variable between sites. Three sites (STYX14, STYX13, and STYX03), all in the mid-upper mainstem, were above the NPS-FM National Bottom-Line of 0.3, STYX12 was just below the Bottom-Line, and all other sites were well below. Over time, ASPM scores STYX14, STYX13, STYX03 have consistently met the Bottom-Line, this was the first monitoring round where STX12 did not meet the Bottom-Line, STYX16 only met the Bottom-Line in 2008, while all other sites have never met the Bottom-Line (Figure 21). The ASPM is a composite of %EPT, EPT taxa richness, and MCI scores, so a very low ASPM score is indicative of a lack of sensitive taxa and strong dominance of pollution-tolerant taxa.

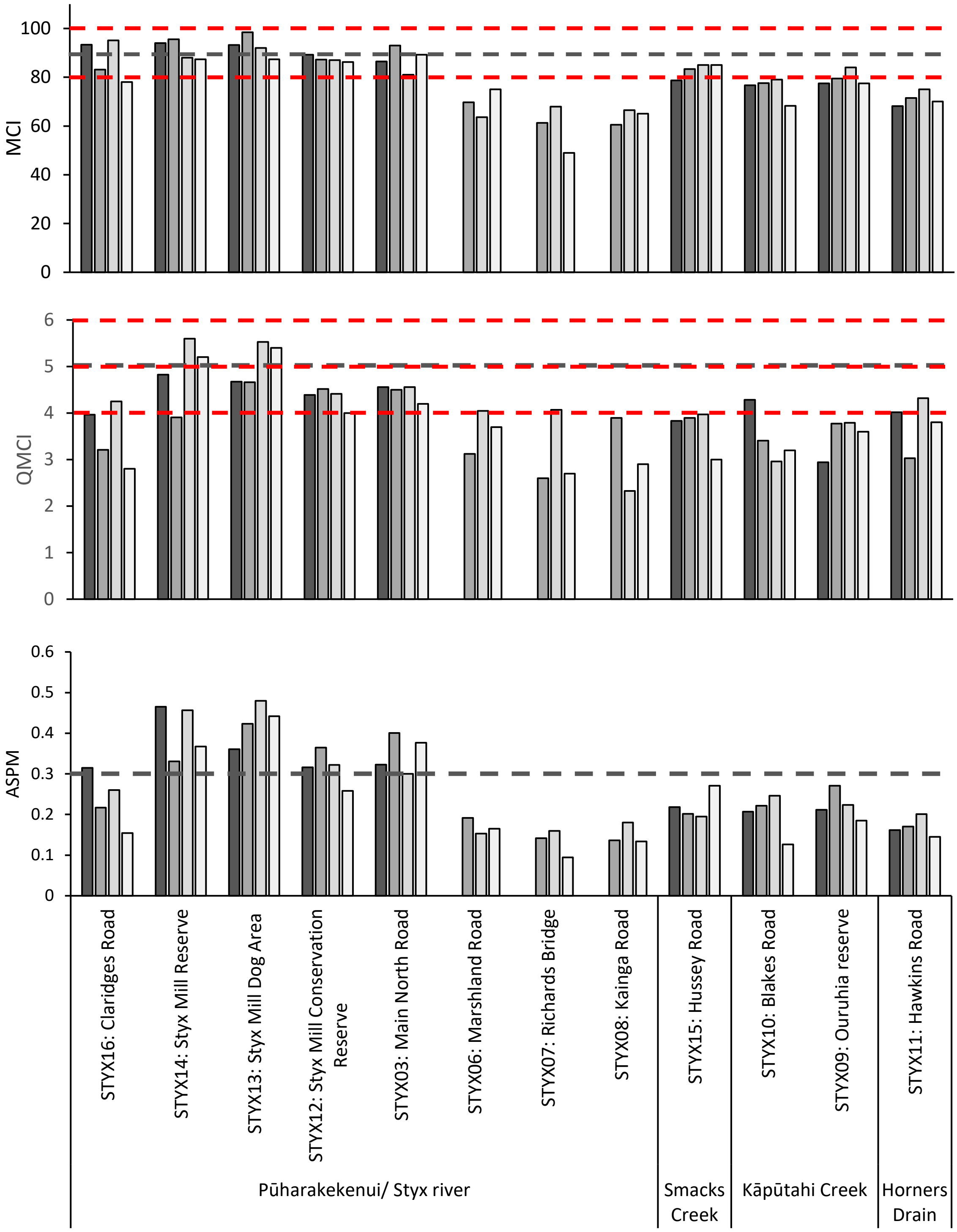


Figure 21. MCI (top), QMCI (middle) and ASPM (bottom) scores at sites within the Pūharakekenui / Styx River catchment in 2008 (black bars, EOS Ecology, 2008), 2013 (dark grey bars, EOS Ecology, 2013), 2018 (light grey bars, InStream Consulting Ltd, 2018), and 2023 (white bars, this study). The dashed grey line indicates consent attribute target levels (QMCI ≥5) and NPS-FM 2020 guidelines (MCI ≥90, ASPM ≥0.3). The red dashed lines indicate 'poor' (≤79), 'fair' (80-99), and 'good' (100-119) MCI stream health attribute bands, and 'poor' (≤3.9), 'fair' (4.0-4.9), and 'good' (5.0-5.9) QMCI stream health attribute bands. Sites are grouped by waterway and then in order of upstream to downstream.

Annual monitoring

The macroinvertebrate community at all annual monitoring sites was dominated by pollution-tolerant taxa, particularly oligochaete worms, ostracods, and the freshwater clam (Sphaeriidae). EPT taxa richness was low overall, consisting only of caddisflies with no mayflies or stoneflies recorded. Only one pollution-sensitive taxon, the caddisfly *Psilochorema* (MCI=8) was found at OTUKAI02, one of the Wilsons Drain sites. Two pollution-sensitive taxa *Psilochorema* and *Polyplectropus* (MCI=8) were recorded in Cashmere Stream, both at HEATH27. A single kēkēwai was caught at HEATH27, and two were caught at HEATH28 via electric fishing methods.

The dominance of pollution-tolerant taxa translated into low index scores for all annual monitoring sites, with QMCI, MCI, and ASPM scores below guidelines (Figure 22). Across all sampling occasions, MCI and QMCI scores at OTUKAI02 and OTUKA06 have indicated 'poor' stream health. Over time, MCI and QMCI scores at HEATH27 and HEATH28 have fluctuated between indicating "poor" and "good" stream health, both sites were in the "poor" stream health attribute band in 2023. Mann-Kendall trend analyses showed no significant increasing or decreasing trend in EPT richness (P = 0.64), MCI (P = 0.47), QMCI (P =0.72), or ASPM (P = 0.21) at HEATH28 over time. This means that there has been no change in the relative abundance of pollution-sensitive taxa over time, or in the total number of pollution-sensitive taxa at the site.

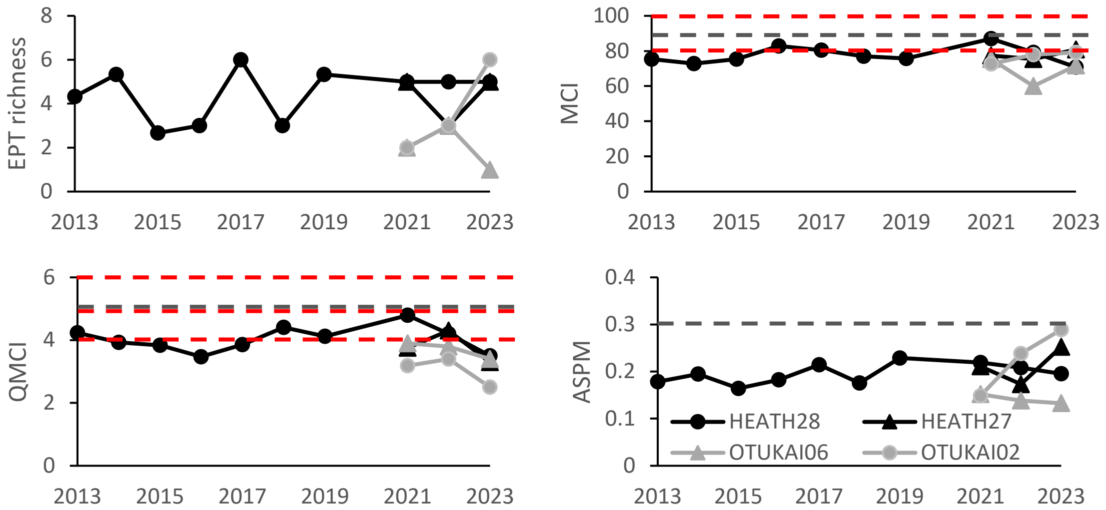


Figure 22. Changes in macroinverbrate indices over time at the two annual monitoring sites in Cashmere Stream and two annual monitoring sites in Wilsons Drain. The dashed lines indicate consent attribute target levels (QMCI ≥5) and NPS-FM 2020 guidelines (MCI ≥90, ASPM ≥0.3). The red dashed lines indicate 'poor' (≤79), 'fair' (80-99), and 'good' (100-119) MCI stream health attribute bands, and 'poor' (≤3.9), 'fair' (4.0-4.9), and 'good' (5.0-5.9) QMCI stream health attribute bands.

Balguerie Stream annual monitoring

EPT taxa, including mayflies, caddisflies, and low numbers of stoneflies dominated the macroinvertebrate fauna of Balguerie Stream. EPT richness varied over years but ranged from seven EPT taxa found in 2007 to 18 in 2012; 16 EPT taxa were collected in 2023. MCI values consistently complied with the NPS-FM National Bottom-Line values (of MCI ≥90). MCI values at Balguerie Stream have fluctuated from 110 to 129 since monitoring began in 2005, indicating "good" to "excellent" stream health. QMCI values consistently complied with the NPS-FM National Bottom-Line value of ≥4.5. QMCI generally complied with the CSNDC attribute target level of ≥5, except in 2007 and 2010 where QMCI was 4.9. With the exception of 2007 and

2010, QMCI scores have indicated “excellent” stream health. The National Bottom-Line ASPM value of 0.3 was complied with across all years (Figure 23). Mann-Kendall time trend analysis revealed a significant increase in EPT taxa richness (P = 0.007) and QMCI (P = 0.03) over time. There was no significant increasing or decreasing trend in MCI (P = 0.08) or ASPM (P = 0.22) at the Balguerie Stream monitoring site (Figure 23).

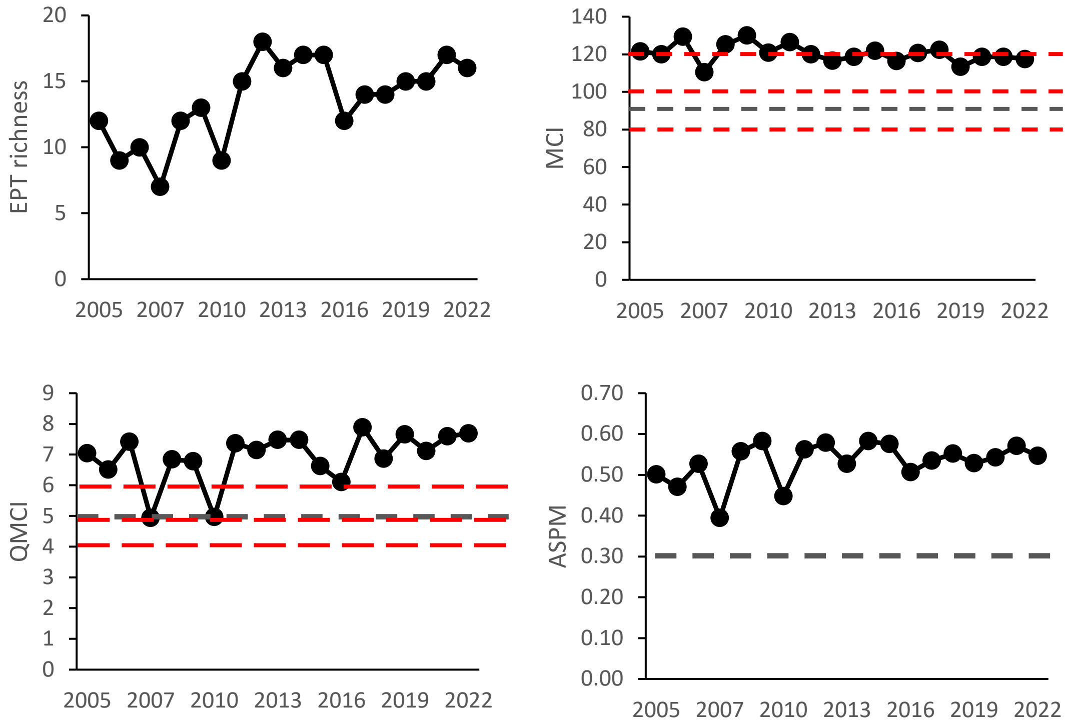


Figure 23. Changes in Macroinverbrate indices over time at Balguerie Stream. The dashed lines indicate consent attribute target levels (QMCI ≥5) and NPS-FM 2020 guidelines (MCI ≥90, ASPM ≥0.3). The red dashed lines indicate ‘poor’ (≤79), ‘fair’ (80-99), ‘good’ (100-119), and ‘excellent’ (≥120) MCI stream health attribute bands, and ‘poor’ (≤3.9), ‘fair’ (4.0-4.9), ‘good’ (5.0-5.9), and ‘excellent’ (≥6.0) QMCI stream health attribute bands.

3.12 Fish community

Five-yearly monitoring

A total of 214 fish, belonging to 8 species, were captured in the twelve sites surveyed within the Pūharakekenui / Styx River catchment in 2023. The species captured were, in descending order of total abundance (i.e., across all sites): common bully (*Gobiomorphus cotidianus*), shortfin eel (*Anguilla australis*), upland bully (*G. breviceps*), longfin eel (*A. dieffenbachii*), kanakana / lamprey (*Geotria australis*), īnanga (*Galaxias maculatus*), giant bully (*G. gobioides*), and brown trout (*Salmo trutta*). Kanakana has a conservation status of “Threatened, Nationally Vulnerable”, longfin eel and īnanga are currently listed “At Risk, Declining”, giant bully are listed as “At Risk, Naturally Uncommon”, upland bully, common bully, and shortfin eel as “Not Threatened”, and brown trout is an Introduced and Naturalised species (Dunn et al., 2018).

The fish communities were depauperate, with species richness generally around two to six fish species present at a site. STYX03 had the most diverse freshwater fish community with six species found, whereas STYX10 and STYX16 had the fewest species, with only two found at these sites. No fish were caught at STYX13. Shortfin eel was the most commonly encountered species, found at all sites except for STYX13 and STYX16. Kanakana was the least commonly encountered species in 2023; larvae (ammocoetes) fished from within sediment beds and one juvenile (macrophthalmia) were found at STYX16. In previous years, kanakana were not found at STYX16, but were present at STYX13, STYX12, and STYX03 (Table 10).

Larger eels (i.e., >500 mm in length) were found at all sites except STYX12, STYX15, STYX16 and STYX13. Elvers (juvenile eels, ≤120 mm) were only found at STYX03, STYX15 and STYX16. A high proportion of common and upland bullies found were above 50 mm indicating a high adult population. Only juvenile (<100 mm) kanakana were recorded. It is important to note that the presence / abundance of īnanga and larger brown trout are underestimated by electric fishing techniques, so these species may have been more abundant across the catchment than shown in Table 10.

Catch per unit effort (CPUE) for sites that were electric fished ranged from 62 fish per 100 m^2 at STYX11 to 3 fish per 100 m^2 at STYX12. At sites that were trapped, CPUE ranged from 0 per trap per night at STYX13 to 3 per trap per night at STYX08. We attributed the lack of fish observed at STYX13 to difficult fishing conditions, however fish catch was low at this site in 2018, with species found as singletons, with the exception of 2 shortfin eels (InStream Consulting Ltd, 2018). CPUE has fluctuated over time at STYX07, STYX08, and STYX16 and has remained stable at STYX06 and STYX15. At STYX11 and STYX03, CPUE effort was two and four times greater, respectively, in 2023 compared to 2018 and 2013. This greater CPUE at STYX11 was due to an increased abundance of common bully; at STYX03 it was due to an increase abundance of longfin eels and elvers (Table 10).

Importantly, many of the freshwater fishes present in the Pūharakekenui / Styx River catchment are migratory, requiring access to the sea to complete their lifecycles. There are multiple in-stream structures (e.g., culverts, flood gates) that may impede fish movement, and therefore restrict the persistence of species in the Pūharakekenui / Styx River catchment.

<u>Annual monitoring</u>

A total of 78 fish, belonging to four species, were captured in the Wilsons Drain and Cashmere Stream annual monitoring sites. Species richness ranged from one at OTUKAI02 to four at HEATH27. It is important to note that while five Gee minnow traps and two fyke nets were set at OTUKAI02, only two Gee Minnow traps were left in-site – the other traps were removed or stolen before we returned in the morning. So, the results from this survey (for 2023) may not be fully relied upon for annual monitoring purposes. Common bully individuals were found at all annual monitoring sites, shortfin eels and elvers were found at two sites, and longfin eels and upland bully were only found at HEATH27 (Table 10). CPUE in this survey compared to 2022 was similar at both Ōtūkaikino sites. In the Cashmere Stream catchment, however, CPUE was lower in this survey compared to 2022, this may have been due to high macrophyte cover affecting the efficacy of the fishing methods, rather than a decrease in fish populations present in the waterway.

Table 10. Total number of fish caught (or seen) at each of the sixteen sites surveyed in 2023. Size (mm) ranges are shown in parentheses. Where the minimum and maximum size were the same, only one value is shown. Different fishing methods were used between sites. EFM = electric fishing; Traps = fyke nets and Gee minnow traps. *Indicates fish were not all caught, and size was unable to be measured or estimated. Bold values indicate this species was found at the site in 2023, but not in any previous years. Red values indicate this species had been recorded at the site at least once in previous years (2008, 2013, or 2018), but not in 2023. * Indicates sites where trapping and netting methods were used in this survey, but electric fishing was used in previous surveys (2008, 2013 and 2018).

Site name	Fishing method	Lamprey	Giant bully	Common bully	Upland bully[7]	Bully species	Īnanga[8]	Longfin eel	Shortfin eel	Eel species	Elver	Brown trout
Five-yearly ecology monitoring												
STYX16: Styx River at Claridges Road	EFM	**13 (80-100)**	0	0	0	0	0	0	0	0	1 (110)	0
STYX14: Styx River at Styx Mill Reserve	EFM	0	0	0	4 (54-65)	1 (25)	0	4 (230-555)	4 (220-360)	0	0	0
STYX13: Styx River at Styx Mill Dog Area	Traps*	0	0	0	0	0	0	0	0	0	0	0
STYX12: Styx River at Styx Mill Conservation Reserve	EFM	0	0	0	0	1*	0	1 (310)	1 (160)	2*	0	1 (350)
STYX03: Styx River at Main North Road	EFM	0	0	5 (55-130)	2 (42-50)	0	**1 (50)**	14* (130-1020)	2 (135-185)	3*	13 (70-120)	1 (150)
STYX06: Styx River at Marshland Road	Traps	0	0	5 (35-120)	0	0	3 (70-85)	3 (650-1050)	2 (500-550)	0	0	0
STYX07: Styx River at Richards Bridge / Teapes Road	Traps	0	**1 (180)**	5 (30-55)	0	0	1 (65)	1 (550)	1 (500)	0	0	0
STYX08: Styx River at Kainga Road/Harbour Road Bridge	Traps	0	1 (75)	9 (35-80)	0	0	5 (65-105)	1 (450)	3 (350-800)	0	0	0
STYX15: Smacks Creek at Husseys Road	EFM	0	0	0	4 (25-72)	0	0	4 (220-370)	1 (160)	2* (300-320)	2 (100-120)	0
STYX10: Kā Pūtahi Creek between Blakes and Belfast Roads	Traps*	0	0	9 (38-104)	0	5 (25-30)	0	0	2 (450-550)	0	0	0

[7] Non-migratory bullies, such as upland bullies, can be underestimated by trapping (Joy et al. 2013).

[8] Īnanga can be underestimated by electric fishing (Joy et al. 2013).

Site name	Fishing method	Lamprey	Giant bully	Common bully	Upland bully[7]	Bully species	Īnanga[8]	Longfin eel	Shortfin eel	Eel species	Elver	Brown trout
STYX09: Kā Pūtahi Ouruhia reserve	EFM	0	0	5 (32-54)	7 (35-68)	0	0	0	9 (240-650)	0	0	0
STYX11: Horners Drain at Hawkins Road	EFM	0	0	25 (38-104)	3 (48-63)	4*	0	3 (170-500)	1 (140)	1* (450)	0	0
Annual monitoring												
OTUKAI02: Wilsons Drain at Main North Road	Traps*	0	0	4 (30-50)	0	0	0	0	0	0	0	0
OTUKAI06 Wilsons Drain Tyrone Street	EFM	0	0	1 (65)	0	0	0	0	8 (130-400)	4*	2 (70-120)	0
HEATH27: Cashmere Stream behind 406 Cashmere Road	EFM	0	0	17 (25-80)	4 (45-55)	4*	0	3 (130-300)	9 (120-400)	5*	3 (100-105)	0
HEATH28: Cashmere Stream behind 420-426 Cashmere Road	EFM	0	0	5* (30-48)	0	0	0	0	0	6* (135)	0	0

4.0 Discussion

4.1 Current state and trends in aquatic ecology

4.1.1 Water quality

The basic water quality parameters of conductivity, pH, and water temperature recorded at the five-yearly ecology monitoring sites were within ranges expected in spring-fed – plains environments during base-flow conditions. Moreover, measures of these parameters were similar to previous years and met the LWRP guideline values. Findings were similar for the annual monitoring sites, where conductivity, pH, and water temperature were within expected ranges; measures were similar to previous years and met the LWRP guideline value. However, DO levels were variable among sites and three of the nine five-yearly monitoring sites did not meet LWRP guideline value of at least 70% saturation. Conversely, only one (OTUKAI06) of the annual monitoring sites had DO levels that did not met the LWRP guideline value; DO concentrations at this site have not met the guideline value for the last monitoring occasions, and this could be due to shallow water depth. The downstream site, OTUKAI02, which has deeper water, has met the DO level guideline on the past three monitoring occasions. DO can vary diurnally and seasonally, and macrophyte and algal abundances at a site can greatly influence DO concentrations. Two sites (STYX15 and STYX16) that did not meet the LWRP guideline value in 2023 (this survey), also failed to meet the guideline in the 2018 sampling round (InStream Consulting Ltd, 2018).

4.1.2 Riparian and in-stream habitat

For most sites, including the five-yearly monitoring sites in Pūharakekenui / Styx River and the annual monitoring sites in Cashmere Stream and Wilsons Drain, there has been no detectable change in riparian vegetation habitat conditions. However, at three of the five-yearly ecology monitoring sites (STYX03, STYX06, and STYX10) planting of indigenous vegetation and willow control has led to improvements in riparian habitat conditions. Nevertheless, we noted that willow saplings were becoming abundant at STYX10, and this warrants attention to ensure this species doesn't again dominate the riparian margin. The dominance of willows can be seen at STYX12 and STYX13, where riparian habitat conditions have deteriorated since 2018; willows are starting to encroach into the waterway. All other sites were typically buffered by grassed margins, or by indigenous vegetation. Active bank erosion had increased at sites in the upper and upper mid catchment, STYX16, STYX13 and STYX12 compared to 2018.

In-stream habitat conditions gave variable results; total macrophyte cover was found to be lower in 2023 than previous years, with the exception of STYX10. Substrate composition (as measured by the Substrate Index) has stayed fairly similar across the monitoring occasions at most sites, but embeddedness and sediment depth and cover at some sites appear to have increased since monitoring first commenced in 2008. Sites STYX03 and STYX15 were the exception, where the stream bed at these sites remained dominated by cobble and gravel substrates. Only one site (STYX15) met the CSNDC attribute target level with less than less than 20% fine sediment cover. Interestingly, STYX10, STYX09, and STYX11 had high SI, indicating dominance of indicating coarser substrates (e.g., large cobbles and pebbles), yet indicated by high sediment cover and embeddedness these larger substrates were covered by a layer of fine sediment. Moreover, at sites with high bank erosion (STYX16, STYX13 and STYX12) sediment cover had remained high (STYX16) or had increased in 2023. Our results of increased sediment cover align with an analysis of long-term data from 50 m intervals across waterways in the Pūharakekenui / Styx River Catchment showed a catchment wide increase in sediment depth (Boffa Miskell Ltd, 2023). These changes in substrate composition, and particularly increased cover and depth of fine sediments means coarser substrates, like cobbles, are less available to aquatic biota (for grazing, egg laying, using as refugia). Larger substrates becoming unavailable highlights the need to prioritise stabilising banks, using best practice stormwater treatment, and minimising intensive land-use change in the catchment to reduce inputs of fine sediments.

4.1.3 Sediment quality

Sediment concentrations of copper, lead, and total PAHs were low and complied with CSNDC target levels. While concentrations of some of these parameters have varied within a site over the various monitoring occasions, these have always been within the CSNDC target levels. Conversely, zinc concentrations found attached to the fine sediments exceeded CSNDC target levels at three of the nine five-yearly ecology monitoring sites (STYX04, STYX05 and STYX07). In 2018, zinc and total PAHs were the only contaminants to exceed target levels, at three (STYX04, STYX05, and STYX08) and one site (STYX06), respectively. Overall, sediment concentrations of zinc, other metals and total PAHs were similar those recorded from the Ōtūkaikino, Ōtakaro / Avon and Heathcote River catchments, where zinc commonly exceeds target levels (Boffa Miskell Ltd, 2022; InStream Consulting Ltd, 2019, 2020). Elevated zinc concentrations can reflect the urbanisation of catchments (e.g., galvanised roofing and spouting can be major sources of zinc). Best practice stormwater management techniques should be prioritised where urban development is increasing. Untreated, or poorly treated, stormwater can bring contaminants into waterways, which can be toxic to freshwater fauna. This is especially important for the Pūharakekenui / Styx River catchment where EPT taxa, including mayflies still occur.

4.1.4 Macroinvertebrate community

Macroinvertebrates are an important and commonly used measure of stream, or ecosystem, health. Only two sites (STYX13 and STYX14) met the CSNDC consent target for spring-fed – plains waterways of QMCI ≥5, indicating only two sites had ‘good’ stream health in the Pūharakekenui / Styx River catchment. Similarly, in previous monitoring occasions, STYX13 and STYX14, were the only sites to have met the QMCI target. Of the sites that did not meet the QMCI target in 2023 or 2018 the contribution of sensitive macroinvertebrate taxa (e.g., mayflies, caddisflies) to community composition had decreased at STYX16, STYX12, and STYX10 in 2023 compared to 2018, indicating likely further stream health decline. Moreover, taxonomic richness was lower in 2023 compared to previous years at most sites, this was most notable in caddisflies where some sites had up to six less taxa in 2023 compared to 2018 (Table 8). These differences in diversity of sensitive macroinvertebrate taxa at some sites could be as a result of several factors, including laboratory processing differences (full count versus fixed count processing), changes (e.g., degradation) in habitat conditions, and general conditions preceding the survey. Notably, the 2018 and 2023 laboratory processing of macroinvertebrate samples identified some individuals to different taxonomic resolutions; in 2018, some macroinvertebrate taxa were identified to species level, including the caddisflies *Hudsonema, Psilochorema*, and *Hydrobiosis*. These were identified to genus level in 2023, as species-level identifications could not be confirmed. Therefore, the differences in taxonomic richness could be due to differences in taxonomic resolution. However, when the taxon lists were condensed, community composition (presence absence and abundance) remained significantly difference between years, indicating temporal or environmental drivers to this change in abundance and diversity. Increased fine sediment cover has been correlated with decreased EPT taxonomic richness and abundance (Clapcott et al., 2011). Therefore, it is likely that increased embeddedness, sediment cover and / or sediment depth at STYX16, STYX12, and STXY10 may have driven a reduction in sensitive taxa at these sites. A reduction in %EPT and loss of notable pollution-sensitive taxa from sites and increasing sedimentation over time may be of concern for the long-term persistence of these taxa, especially in a semi-urban catchment where EPT taxa are typically less common. This is something that warrants further investigation, ideally in the next sampling season, to determine if declines are occurring and catchment- or site-level interventions are required to halt this.

Neither of the annual monitoring sites in the Ōtūkaikino River or the Cashmere Stream catchments met the QMCI guideline values. However, the Balguerie Stream site met the CSNDC guideline for QMCI and the NPS-FM Bottom-Line values for MCI and ASPM, in 2023 and on all other occasions over the last 10 years.

Notably, kēkēwai were found at STYX14 at both Cashmere Stream annual monitoring sites, captured during the electric-fishing surveys. Also of interest, InStream Consulting Ltd searched 20 locations in the Pūharakekenui / Styx River catchment for kākahi in the 2022-2023 summer season. Kākahi were found, in low densities, at three sites: in Pūharakekenui / Styx River at Radcliffe Road, and at Marshland Road (STYX06), and in Kā Pūtahi Creek at Ouruhia Reserve (STYX09) (Dr Greg Burrell, *pers. comm.* InStream Consulting Ltd). This is the first record of kākahi in Kā Pūtahi Creek, which is a promising sign for their persistence in the wider catchment.

4.1.5 Fish community

Freshwater fish species, including seven indigenous species and the introduced brown trout, were present within the Pūharakekenui / Styx River catchment, with the exception of STYX13 where no fish were caught. Most importantly, one site supported kanakana (Threatened, Nationally Vulnerable), eight sites supported longfin eels, (At Risk, Declining), four sites supported īnanga (At Risk, Declining), and two sites supported giant bully (At Risk, Declining). Īnanga may have been present at other sites; however, īnanga can be underestimated using electric fishing techniques (Joy et al., 2013). The presence of elvers (juvenile eels, both longfin or shortfin) at five sites is encouraging and can be a good sign for population recruitment and persistence. Larval and juvenile kanakana have been recorded throughout the catchment on multiple occasions (EOS Ecology, 2013; InStream Consulting Ltd, 2018). During InStream Consulting's survey for kākahi (discussed above), one juvenile (macrophthalmia) kanakana was also found in Kā Pūtahi Creek at Factory Road. This is the first record of kanakana in Kā Pūtahi Creek. We electro-fished a site in the mainstem of the Pūharakekenui / Styx River, in March 2023, between Main North Road and Styx Mill Road c. 3.2 km downstream of STYX16. Here, three kanakana larvae (ammocoetes) were found in sediment beds, plus two silver-blue macrophthalmia juveniles.

The presence of larval and juvenile kanakana at multiple sites indicates kanakana are likely to be spawning in both the mainstem and tributaries Pūharakekenui / Styx River. Deposited kanakana eggs adhere to the underside of large, nested boulders in freshwater systems (Baker et al., 2017). Once hatched, ammocoetes are typically found in beds of fine substates (e.g., sand <1 mm), macrophthalmia are typically found in downstream reaches with coarser substrates before migrating to sea (James, 2008). Therefore, to support spawning habitat in the Pūharakekenui / Styx River catchment, multiple substrate types should be present throughout the catchment. Currently, larger boulders suitable for egg nests, are likely lacking in the catchment, potentially limiting spawning potential. The absence of large emergent and submerged boulders is a trend seen in many urban and peri-urban waterways, which can result in the loss of critical egg-laying habitats for freshwater fauna (e.g., hydrobiosid caddisflies lay eggs on boulders which can be absent from Christchurch's urban streams Blakely et al., 2006).

Of the sites that were comparable between years, there was some fluctuation in the fish community composition and CPUE over time. There are multiple in-stream barriers that may impede fish movement through the catchment, therefore, could restrict their presence, abundance, and persistence. In-stream barriers along the Pūharakekenui / Styx River mainstem are mostly bridges and larger culverts, which, when designed and installed well, can pose less of a risk to fish passage. However, sites which had a decreased CPUE, namely STYX14, STYX12, and STYX09, the decline in fish abundance was more likely due to macrophyte beds or water depth affecting the efficiency of the fishing methods, rather than a decrease in fish populations present in the waterway.

In the annual monitoring sites of Wilsons Drain and Cashmere Stream, only indigenous species were caught. For the two Cashmere Stream sites, fish were found in similar abundances in 2023 compared to previous years. In the Cashmere Stream catchment, CPUE was lower in this survey compared to 2022. This was likely due to high macrophyte cover found at the time of the 2023 survey, which may have affected the efficacy of the fishing methods (i.e., rather than a decrease in fish populations present in the waterway).

4.2 Comparison to consent attribute target levels

Five-yearly monitoring

The CCC's CSNDC has attribute target levels for sediment concentrations of copper, lead, zinc, and total PAHs, fine sediment cover, total macrophyte cover, long filamentous algae cover, and QMCI scores. Consent targets for sediment copper, lead, zinc, and total PAHs have been mostly compliant, with only zinc exceeding the consent target at three sites (STYX04, STYX05, and STYX07) in 2023. Comparatively, the lead consent target was exceeded at 3 sites, zinc at 6 sites, and total PAHs at 1 site in 2018 (Table 11).

Fine sediment cover was within the guidelines at most sites in 2018, however, in 2023 all but one site (STYX15) exceeded the consent target of a maximum of 20% fine sediment cover. Consent targets for long filamentous algae cover have been met at all sites sampled over the last two sampling occasions. Total macrophyte cover has been mostly compliant for the last ten years. Compliance with QMCI scores has been consistent over time, with 16.6% of sites complying with the QMCI target of 5 or greater in 2013, 25% of sites complied in 2018, and 16.6% in 2023 (Table 11).

Table 11. Percent of five-yearly sites that comply with sediment quality and ecological consent attribute target levels over time. Current consent target levels are shown in black font. Some consent target levels have changed, with previous (2013 and 2018) targets shown in red. Pūharakekenui / Styx River catchment sites are all considered spring-fed – plains sites.

Parameter	Consent target level	2013 (0 sites)	2018 (12 sites)	2023 (8 sites)
Copper	65 (mg / kg)	-	100%	100%
Lead	50 (mg / kg)	-	75%	100%
Zinc	200 (mg / kg)	-	50%	50%
Total PAHs	10 (mg / kg)	-	91.6%	100%
Parameter	**Consent target level**	**2013 (12 sites)**	**2018 (9 sites)**	**2023 (9 sites)**
Fine sediment cover	20% (40%)	-	81.8%	11.1%
Maximum total macrophyte cover	50%	83.3%	90.9%	88.8%
Maximum total filamentous algae cover	30%	91.6%	100%	100%
Parameter	**Consent target level**	**2013 (12 sites)**	**2018 (12 sites)**	**2023 (12 sites)**
QMCI	5 (4.5)	16.6%	25%	16.6%

Annual monitoring

Fine sediment cover exceeded the consent target at all four annual monitoring sites in 2021, 2022 and 2023. Consent targets for long filamentous algae cover have been met at all sites sampled over the last three sampling occasions. Compliance with total macrophyte cover has fluctuated, decreasing from 75% of sites meeting the targets in 2022, to 50% in 2023. Compliance with QMCI scores has been consistent over time, with only one site (BP03) complying with the QMCI target of 5 or greater in the last 3 years. All other annual monitoring sites have not met the QMCI target (Table 12).

Table 12. Percent of sites in the annual monitoring sites that comply with the relevant consent attribute target levels over time.

Parameter	Consent target level	2021 (4 sites)	2022 (4 sites)	2023 (4 sites)
Fine sediment cover	20 %	0%	0%	0%
Maximum total macrophyte cover	SP: 50 % BP: 30 %	25%	75%	50%
Maximum total filamentous algae cover	SP: 30 % BP: 20 %	100%	100%	100%
Parameter	**Consent target level**	**2021 (5 sites)**	**2022 (5 sites)**	**2023 (5 sites)**
QMCI	5	20%	20%	20%

A summary of sites and the relevant guideline exceedance for five-yearly and annual monitoring sites are provided in Table 13.

Table 13. Summary of in-stream sediment quality, and aquatic ecology from 16 sites in 2023 and relevant guideline exceedance.

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring
Five-yearly monitoring					
STYX16	Pūharakekenui / Styx River	Styx River at Claridges Road	-	•Moderate- high shading, low algae and macrophyte cover, dominated by fine sediment •Did not meet the LWRP guideline for dissolved oxygen % •Exceeded in fine sediment cover •Did not meet QMCI guideline. Notable caddisfly taxa not found •Kanakana / lamprey (‘Threatened, Nationally Vulnerable) and elver eels present	-
STYX14	Pūharakekenui / Styx River	Styx River Upstream of Styx Mill Reserve	-	•Moderate shading, some willow encroachment, no algae and moderate-low macrophyte cover, moderate-high fine sediment •Exceeded in fine sediment cover •Met QMCI guidelines •Kēkēwai (At Risk, Declining), upland bully, longfin eel (‘At Risk, Declining) and shortfin eel present	-
STYX13	Pūharakekenui / Styx River	Styx River Adjacent to Styx Mill Dog Area Carpark	-	•High shading, willow encroachment, low macrophyte cover, high fine sediment •Exceeded in fine sediment cover •Met QMCI guidelines •No fish found at this site	-

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring
STYX12	Pūharakekenui / Styx River	Styx River at Styx Mill Conservation Reserve	•No guidelines exceeded	•High shading, willow encroachment, moderate-low macrophyte cover, high fine sediment •Exceeded in fine sediment cover •Did not meet QMCI guidelines •Bully species, brown trout, longfin eel (At Risk, Declining) and shortfin eel present	-
STYX03	Pūharakekenui / Styx River	Styx River at Main North Road	•No guidelines exceeded	•Moderate shading, no algae and low macrophyte cover, moderate fine sediment •Exceeded in fine sediment cover •Did not meet QMCI guidelines •Common bully, upland bully, brown trout, elver, longfin eel (At Risk - Declining) and shortfin eel present	-
STYX06	Pūharakekenui / Styx River	Styx River at Marshland Road Bridge	•No guidelines exceeded	•Low shading, bankside observations of no algae, high macrophyte cover, high fine sediment •Did not meet QMCI guidelines •Common bully, īnanga (At Risk - Declining), longfin eel (At Risk - Declining) and shortfin eel present	-
STYX07	Pūharakekenui / Styx River	Styx River at Richards Bridge/ Teapes Road	•Exceeded zinc guidelines	•Low to moderate shading, bankside observations of no algae, high macrophyte cover, high fine sediment •Did not meet QMCI guidelines •Giant bully (At Risk, Naturally Uncommon), common bully, īnanga (At Risk - Declining), longfin eel (At Risk - Declining) and shortfin eel present	-

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring
STYX08	Pūharakekenui / Styx River	Styx River at Kainga Road/ Harbour Road Bridge	•No guidelines exceeded	•Low- moderate shading, bankside observations of no algae, high fine sediment •Did not meet the LWRP guideline for dissolved oxygen % •Did not meet QMCI guidelines •Giant bully (At Risk, Naturally Uncommon), common bully, īnanga (At Risk, Declining), longfin eel (At Risk, Declining) and shortfin eel present	-
STYX15	Pūharakekenui / Styx River	Smacks Creek at Hussey Road	•No guidelines exceeded	•High shading, no algae and low macrophyte cover, low fine sediment •Did not meet the LWRP guideline for dissolved oxygen % •Met the maximum fine sediment cover target •Did not meet QMCI guidelines •Upland bully, elver, longfin eel (At Risk, Declining) and shortfin eel present	-
STYX04	Pūharakekenui / Styx River	Kā Pūtahi Creek at Blakes Road	•Exceeded zinc guidelines	-	-
STYX10	Pūharakekenui / Styx River	Kā Pūtahi Creek Between Blakes and Belfast Roads	-	•Moderate shading, willow encroachment, moderate algae cover and high macrophyte cover, high fine sediment •Exceeded fine sediment cover and total macrophyte cover targets •Did not meet QMCI guidelines. Notable caddisfly taxa not found	-

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring
				•Common, upland bully and shortfin eel present	
STYX09	Pūharakekenui / Styx River	Kā Pūtahi Creek at Ouruhia Reserve	-	•Moderate shading, low algae and moderate-low macrophyte cover, high fine sediment •Exceeded in fine sediment cover •Did not meet QMCI guidelines •Common bully, upland bully, and shortfin eel present	-
STYX05	Pūharakekenui / Styx River	Kā Pūtahi Creek at Belfast Road (lower)	•Exceeded zinc guidelines	-	-
STYX11	Pūharakekenui / Styx River	Horners Drain at Hawkins Road	-	•Low-moderate shading, low macrophyte cover, high fine sediment •Exceeded in fine sediment cover •Did not meet QMCI guidelines •Common, upland bully, longfin eel ('At Risk, Declining) and shortfin eel present	-
Annual monitoring					
OTUKAI02	Ōtūkaikino River	Wilsons Drain at Main North Road	-	-	•Moderate shading, low algae and macrophyte cover, dominated by fine sediment •Exceeded in fine sediment cover •Did not meet QMCI guideline •Common bully present

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring
OTUKAI06	Ōtūkaikino River	Wilsons Drain at Tyrone Street	-	-	•Low shading, high macrophyte cover no algae, dominated by fine sediment •Exceeded fine sediment cover, and total macrophyte cover •Low dissolved oxygen •Did not meet QMCI guideline •Common bully, elver eels and shortfin eel present
HEATH27	Cashmere Stream	Cashmere Stream behind 406 Cashmere Road (downstream of stormwater discharge)	-	-	•Low shading, no algae and moderate-low macrophyte cover, moderate-high fine sediment •Exceeded in fine sediment cover •Did not meet QMCI guidelines •Kēkēwai (At Risk, Declining), common, upland bully, elver, longfin eel (At Risk, Declining) and shortfin eel present
HEATH28	Cashmere Stream	Cashmere Stream behind 420-426 Cashmere Road (upstream of stormwater discharge)	-	-	•Moderate shading, no algae and moderate-low macrophyte cover. Dominated by fine sediment •Exceeded in fine sediment cover •Did not meet QMCI guidelines •Kēkēwai (At Risk, Declining), common bully and eel species present
BP03	Balguerie Stream	Downstream of Settlers Hill (road)	-	-	•No guidelines exceeded

4.3 Recommendations

- Enhance in-stream habitat to support kanakana spawning through the Pūharakekenui / Styx River catchment. Kanakana spawn by laying eggs in a ‘nest’ cluster under large hard surfaces (e.g., boulders), therefore the addition or maintenance of larger substrate types should be prioritised for the mid-upper Pūharakekenui / Styx River catchment.
    - Utilising existing catchment wide habitat mapping data (e.g., CREAS) or additional surveys specific to spawning habitats, to identify current or potential spawning habitat locations for management opportunities.
- Further investigate potential causes where zinc concentrations exceeded guideline values (at sites OTUKAI02, STYX04, STYX05, and STYX07), with the aim of identifying and addressing sources in the catchment.
- Bank erosion was moderate to high and had increased at some sites across the Pūharakekenui / Styx River catchment. Enhancement of the riparian margins, particularly at sites where bank erosion was highest (STYX16, STYX13, STYX12 and STYX08; Table 6) may assist in reducing localised inputs of fine sediment.
    - Infill planting the riparian margin with a variety of ecologically appropriate species can help to bind soils and stabilise banks. Where in-stream and bank side maintenance works occur, exposed banks should be avoided, and overhanging vegetation should be retained to buffer the bank from direct water flows. Densely planted riparian margin, with a range of plant grades can aid shading of the waterway, which may subsequently limit the growth of nuance macrophytes, limited the need for in-stream maintenance works.
- Willow sapling, or encroachment of large willows into the stream margin was observed at most sites in the Pūharakekenui / Styx River catchment. Enhancement of the riparian margins at sites willow encroachment was observed (STYX10, STYX12, STYX13, and STYX14) may assist in maintaining and improving ecological health. Staged and considered willow removal (e.g., through ‘drill and fill’ techniques to leave roots *in situ*, and planting of riparian margins with indigenous and ecologically sensitive species would provide canopy cover without concentrated leaf fall periods in the autumn. This would aid in reducing macrophyte and algae growth, provide a buffer for overland flow run-off, and provide a consistent and appropriate supply of leaf litter resources (food) for the macroinvertebrate community.
- Increases to in-stream habitat heterogeneity, especially where there is limited habitat, would assist in enhancing ecological health. The addition of habitats (such as woody debris and logs, leaf packs, maintaining some macrophyte beds, and undercut banks) all support a diverse range of macroinvertebrate and fish communities and are essential for maintaining and improving stream health. Emergent and submerged boulders are lacking at many sites, and the addition of these would provide habitat essential for egg-laying substrates for both aquatic insects and fishes (also see kanakana spawning habitat, below).
    - Reduced inputs of fine sediment and additions of in-stream habitats should be prioritised to support notable macroinvertebrate species.
- Consideration should be given to appropriate fishing methodologies in future surveys. Habitat conditions, namely water depth and/or encroaching willows, at STYX16,

STYX14, and STYX12 made these sites marginal for electric-fishing techniques. It may become more suitable to set traps and nets at these sites in future surveys.

- Best practice stormwater management techniques should be considered, especially when urban development in the area is increasing. Untreated, or poorly treated, stormwater can bring fine sediments and contaminants into waterways, which smother the stream bed and can be directly consumed by freshwater fauna. Reducing inputs of fine sediments is essential when enhancing and protecting habitat for aquatic species such as pollution-sensitive macroinvertebrate taxa, and many freshwater fishes. This is especially important for the Pūharakekenui / Styx River catchment where EPT taxa, including mayflies still occur.
- Minimising intensive land-use change (e.g., urbanisation, intensive farming) in the catchment may assist in maintaining aquatic ecological health.

5.0 References

ANZECC. (2000). *Australian and New Zealand guidelines for fresh and marine water quality*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Baker, C., Jellyman, D., Reeve, K., Crow, S., Stewart, M., Buchinger, T., & Li, W. (2017). First observations of spawning nests in the pouched lamprey (*Geotria australis*). *Canadian Journal of Fisheries and Aquatic Sciences*, *74*(10).

Blakely, T. J., Harding, J. S., McIntosh, A. R., & Winterbourn, M. J. (2006). Barriers to the recovery of aquatic insect communities in urban streams. *Freshwater Biology*, *51*(9), 1634–1645.

Boffa Miskell Ltd. (2022). *Ōtūkaikino and Cashmere Monitoring 2022: Five-yearly and annual aquatic ecology monitoring* (Report BM211177A). Prepared by Boffa Miskell Ltd for Christchurch City Council.

Boffa Miskell Ltd. (2023). *Pūharakekenui / Styx River catchment: Pilot analyses of Pūharakekenui / Styx River CREAS data* (Report BM200378). Prepared by Boffa Miskell Ltd and Avisure for Christchurch City Council.

Christchurch City Council. (2014). *Styx Stormwater Management Plan Sediment Quality Monitoring*.

Clapcott, J., Young, R. G., Harding, J. S., Matthaei, C., Quinn, J., & Death, R. (2011). *Sediment assessment methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values*. Cawthron Institute.

Clarke, K. R., & Warwick, R. M. (2001). *Change in marine communities: An approach to statistical analysis and interpretation* (2nd edition). PRIMER-E Ltd.

Dunn, N. R., Allibone, R. M., Closs, G. P., Crow, S. K., David, B. O., Goodman, J. M., Griffiths, M., Jack, D. C., Ling, N., Waters, J. M., & Rolfe, J. R. (2018). *Conservation status of New Zealand freshwater fishes, 2017* (New Zealand Threat Classification Series 24). Department of Conservation.

EOS Ecology. (2008). *Long-term monitoring of aquatic invertebrates in Christchurch's Waterways: Ōtukaikino and Styx River catchments* (Report 06064-CCC02-01). Prepared by EOS Ecology for Christchurch City Council.

EOS Ecology. (2013). *Long-term monitoring of aquatic invertebrates and fish: Styx River catchment* (Report 12074-CCC02-01). Prepared by EOS Ecology for Christchurch City Council.

Golder Associates. (2009). *Styx River sediment study*. Prepared by Golder Associates for Christchurch City Council.

Grainger, N., Harding, J. S., Drinan, T., Collier, K., Smith, B., Death, R., Makan, T., & Rolfe, J. R. (2018). *Conservation status of New Zealand freshwater invertebrates, 2018* (New Zealand Threat Classification Series 28). Department of Conservation.

Harding, J. S., Clapcott, J., Quinn, J., Hayes, J. W., Joy, M. K., Storey, R. G., Greig, H., Hay, J., James, T., Beech, M., Ozane, R., Meredith, A., & Boothroyd, I. (2009). *Stream habitat: Assessment protocols for wadeable rivers and streams of New Zealand*. School of Biological Sciences, University of Canterbury.

InStream Consulting Ltd. (2018). *Styx River catchment aquatic ecology 2018*. Prepared by InStream Consulting Ltd for Christchurch City Council.

InStream Consulting Ltd. (2019). *Avon River catchment aquatic ecology 2019*. Prepared by InStream Consulting Ltd for Christchurch City Council.

InStream Consulting Ltd. (2020). *Heathcote River, Linwood Canal, and Banks Peninsula aquatic ecology 2020*. Prepared by InStream Consulting Ltd for Christchurch City Council.

InStream Consulting Ltd. (2021a). *Christchurch aquatic ecology monitoring 2021*. Prepared by InStream Consulting Ltd for Christchurch City Council.

InStream Consulting Ltd. (2021b). *Kākahi (freshwater mussel) monitoring in Christchurch City*. Prepared by InStream Consulting Ltd for Christchurch City Council.

James, A. (2008). *Ecology of the New Zealand Lamprey (*Geotria australis*): A literature review*. Department of Conservation Wanganui Conservancy.

Joy, M. K., David, B., & Lake, M. D. (2013). *New Zealand freshwater fish sampling protocols. Part 1: Wadeable rivers and streams* [New Zealand Freshwater Fish Sampling Protocols]. Massey University.

NIWA. (2015). *Sediment quality survey for Heathcote River Catchment, City Outfall Drain and Estuary Drain* (NIWA Client Report AKL-2015-021). Prepared by NIWA for Christchurch City Council.

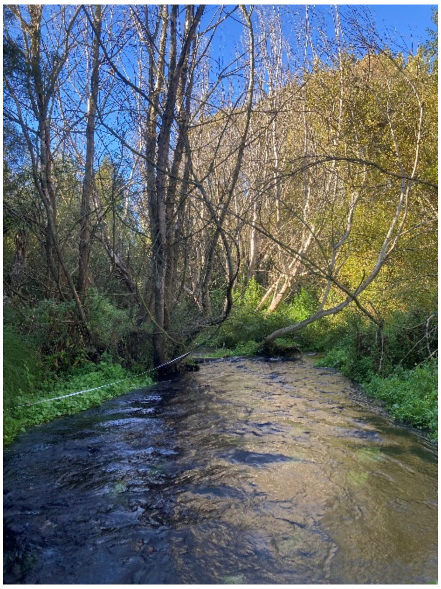
Quinn, G. P., & Keough, M. J. (2002). *Experimental design and data analysis for biologists*. Cambridge University Press.

RStudio Team. (2020). *RStudio: Integrated development for R* [Computer software]. RStudio, PBC. http://www.rstudio.com/

Stark, J. D., Boothroyd, I. K. G., Harding, J. S., Maxted, J. R., & Scarsbrook, M. R. (2001). *Protocols for sampling macroinvertebrates in wadeable streams* (p. 65). Prepared for the Ministry for the Environment.

Stark, J. D., & Maxted, J. R. (2007). *A user guide for the Macroinvertebrate Community Index* (Cawthron Report 1166). Prepared by Cawthron Institute for the Ministry for the Environment.

Appendix 1: Site Photographs from 2023



Site STYX03 upstream looking downstream (left) and downstream looking upstream (right)

Site STYX06 upstream looking downstream (left) and downstream looking upstream (right)

Site STYX07 upstream looking downstream (left) and downstream looking upstream (right)

Site STYX08 upstream looking downstream (left) and downstream looking upstream (right)

Site STYX09 upstream looking downstream (left) and downstream looking upstream (right)

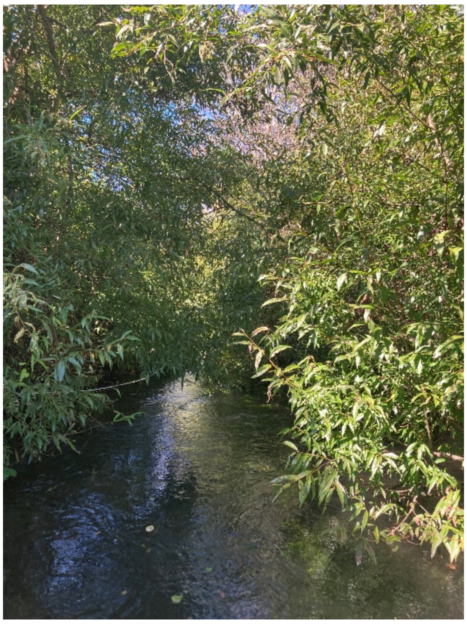
Site STYX010 upstream looking downstream (left) and downstream looking upstream (right)

Site STYX011 upstream looking downstream (left) and downstream looking upstream (right)

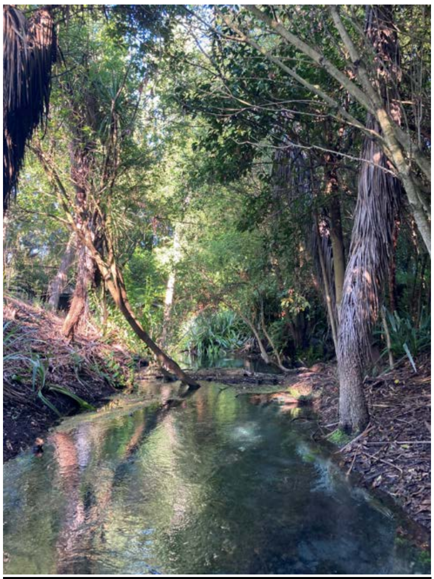
Site STYX012 upstream looking downstream (left) and downstream looking upstream (right)




Site STYX013 upstream looking downstream (left) and downstream looking upstream (right)


Site STYX014 upstream looking downstream (left) and downstream looking upstream (right)


Site STYX015 upstream looking downstream (left) and downstream looking upstream (right)

Site STYX016 upstream looking downstream (left) and downstream looking upstream (right)

Site OTUKAI02 upstream looking downstream (left) and downstream looking upstream (right)

Site OTUKAI06 upstream looking downstream (left) and downstream looking upstream (right)

Site HEATH27 upstream looking downstream (left) and downstream looking upstream *(right)*

Site HEATH28 upstream looking downstream (left) and downstream looking upstream *(right)*

Appendix 2: Sediment quality results

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Boffa Miskell Limited	**Lab No:**	3187258 SPv1
Contact:	Jessica Schofield	**Date Received:**	01-Mar-2023
	C/- Boffa Miskell Limited	**Date Reported:**	21-Mar-2023
	PO Box 110	**Quote No:**	115912
	Christchurch 8140	**Order No:**	
		Client Reference:	
		Submitted By:	Jessica Schofield

Sample Type: Sediment

Sample Name:		Otukaio 2 A (BM211177) 01-Mar-2023 6:45 pm	Otukaio 2 B (BM211177) 01-Mar-2023 6:45 pm	Otukaio 2 C (BM211177) 01-Mar-2023 6:45 pm	Styx 4 A (BM211177) 28-Feb-2023 11:00 am	Styx 4 B (BM211177) 28-Feb-2023 11:00 am
Lab Number:		3187258.1	3187258.2	3187258.3	3187258.4	3187258.5
Individual Tests						
Dry Matter	g/100g as rcvd	29	31	28	12.9	17.2
Particle size analysis*‡		See attached report	See attached report	See attached report	See attached report	See attached report
Total Recoverable Copper	mg/kg dry wt	26	22	23	18.0	42
Total Recoverable Lead	mg/kg dry wt	40	39	37	35	90
Total Recoverable Phosphorus	mg/kg dry wt	1,140	1,210	1,320	1,380	1,020
Total Recoverable Zinc	mg/kg dry wt	300	240	260	460	340
Total Organic Carbon*	g/100g dry wt	4.8	4.4	5.5	11.4	5.8
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Total of Reported PAHs in Soil	mg/kg dry wt	4.2	2.8	3.8	0.7	0.7
1-Methylnaphthalene	mg/kg dry wt	0.019	0.012	0.012	< 0.012	< 0.009
2-Methylnaphthalene	mg/kg dry wt	0.018	0.014	0.013	< 0.012	< 0.009
Acenaphthene	mg/kg dry wt	0.017	0.008	0.013	< 0.012	< 0.009
Acenaphthylene	mg/kg dry wt	0.037	0.027	0.040	< 0.012	0.009
Anthracene	mg/kg dry wt	0.074	0.047	0.067	< 0.012	0.016
Benzo[a]anthracene	mg/kg dry wt	0.25	0.167	0.24	0.033	0.047
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.33	0.23	0.32	0.055	0.053
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.39	0.26	0.37	0.069	0.062
Benzo[e]pyrene	mg/kg dry wt	0.20	0.136	0.190	0.035	0.030
Benzo[g,h,i]perylene	mg/kg dry wt	0.27	0.184	0.25	0.044	0.036
Benzo[k]fluoranthene	mg/kg dry wt	0.150	0.097	0.137	0.024	0.024
Chrysene	mg/kg dry wt	0.29	0.179	0.26	0.047	0.048
Dibenzo[a,h]anthracene	mg/kg dry wt	0.048	0.033	0.046	< 0.012	< 0.009
Fluoranthene	mg/kg dry wt	0.60	0.39	0.47	0.097	0.108
Fluorene	mg/kg dry wt	0.044	0.031	0.039	< 0.012	0.013
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.24	0.159	0.23	0.038	0.034
Naphthalene	mg/kg dry wt	0.03	< 0.03	< 0.03	< 0.06	< 0.05
Perylene	mg/kg dry wt	0.137	0.089	0.125	0.033	0.018
Phenanthrene	mg/kg dry wt	0.41	0.26	0.34	0.068	0.093
Pyrene	mg/kg dry wt	0.65	0.41	0.58	0.104	0.108
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	0.49	0.33	0.47	0.081	0.078
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	0.48	0.33	0.47	0.080	0.077

Sample Type: Sediment						
Sample Name:		Styx 4 C (BM211177) 28-Feb-2023 11:00 am	Styx 5 A (BM211177) 28-Feb-2023 2:15 pm	Styx 5 B (BM211177) 28-Feb-2023 2:15 pm	Styx 5 C (BM211177) 28-Feb-2023 2:15 pm	Styx 6 A (BM211177) 01-Mar-2023 9:30 am
Lab Number:		3187258.6	3187258.7	3187258.8	3187258.9	3187258.10
Individual Tests						
Dry Matter	g/100g as rcvd	68	15.7	15.7	18.9	51
Particle size analysis*‡		See attached report	See attached report	See attached report	See attached report	See attached report
Total Recoverable Copper	mg/kg dry wt	9.0	22	24	21	3.4
Total Recoverable Lead	mg/kg dry wt	24	48	55	47	8.7
Total Recoverable Phosphorus	mg/kg dry wt	370	1,270	1,310	1,130	250
Total Recoverable Zinc	mg/kg dry wt	191	370	400	380	63
Total Organic Carbon*	g/100g dry wt	6.5	12.3	14.4	10.9	1.03
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Total of Reported PAHs in Soil	mg/kg dry wt	0.36	1.0	1.2	1.69	0.94
1-Methylnaphthalene	mg/kg dry wt	0.006	0.028	0.033	0.034	< 0.003
2-Methylnaphthalene	mg/kg dry wt	0.006	0.028	0.030	0.029	< 0.003
Acenaphthene	mg/kg dry wt	0.003	< 0.011	< 0.010	< 0.008	< 0.003
Acenaphthylene	mg/kg dry wt	0.004	0.010	0.011	0.012	0.006
Anthracene	mg/kg dry wt	0.008	0.014	0.015	0.020	0.017
Benzo[a]anthracene	mg/kg dry wt	0.020	0.053	0.067	0.111	0.065
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.026	0.079	0.093	0.141	0.091
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.031	0.102	0.118	0.168	0.099
Benzo[e]pyrene	mg/kg dry wt	0.015	0.051	0.059	0.087	0.049
Benzo[g,h,i]perylene	mg/kg dry wt	0.018	0.063	0.074	0.105	0.060
Benzo[k]fluoranthene	mg/kg dry wt	0.012	0.036	0.042	0.050	0.038
Chrysene	mg/kg dry wt	0.023	0.065	0.076	0.119	0.071
Dibenzo[a,h]anthracene	mg/kg dry wt	0.003	0.011	0.014	0.021	0.011
Fluoranthene	mg/kg dry wt	0.050	0.123	0.146	0.23	0.118
Fluorene	mg/kg dry wt	0.005	< 0.011	< 0.010	0.010	0.005
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.017	0.060	0.072	0.101	0.062
Naphthalene	mg/kg dry wt	< 0.010	< 0.06	< 0.05	0.04	< 0.013
Perylene	mg/kg dry wt	0.007	0.028	0.032	0.041	0.049
Phenanthrene	mg/kg dry wt	0.047	0.077	0.081	0.108	0.060
Pyrene	mg/kg dry wt	0.050	0.138	0.164	0.26	0.127
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	0.038	0.117	0.139	0.21	0.131
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	0.038	0.115	0.137	0.21	0.130

Sample Name:		Styx 6 B (BM211177) 01-Mar-2023 9:30 am	Styx 6 C (BM211177) 01-Mar-2023 9:30 am	Styx 7 A (BM211177) 01-Mar-2023 12:30 pm	Styx 7 B (BM211177) 01-Mar-2023 12:30 pm	Styx 7 C (BM211177) 01-Mar-2023 12:30 pm
Lab Number:		3187258.11	3187258.12	3187258.13	3187258.14	3187258.15
Individual Tests						
Dry Matter	g/100g as rcvd	33	57	19.2	22	21
Particle size analysis*‡		See attached report	See attached report	See attached report	See attached report	See attached report
Total Recoverable Copper	mg/kg dry wt	8.8	6.0	27	24	23
Total Recoverable Lead	mg/kg dry wt	16.2	12.0	41	37	37
Total Recoverable Phosphorus	mg/kg dry wt	370	350	1,440	1,310	1,160
Total Recoverable Zinc	mg/kg dry wt	163	127	380	340	320
Total Organic Carbon*	g/100g dry wt	2.7	1.16	8.8	8.2	8.0
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Total of Reported PAHs in Soil	mg/kg dry wt	0.92	0.31	1.5	0.86	0.9
1-Methylnaphthalene	mg/kg dry wt	< 0.03 #1	< 0.010 #1	< 0.03 #1	< 0.02 #1	< 0.03 #1
2-Methylnaphthalene	mg/kg dry wt	0.008	< 0.003	0.011	0.008	< 0.008
Acenaphthene	mg/kg dry wt	< 0.005	< 0.003	< 0.008	< 0.008	< 0.008
Acenaphthylene	mg/kg dry wt	0.008	0.002	0.015	0.010	0.009

Sample Type: Sediment						
Sample Name:		Styx 6 B (BM211177) 01-Mar-2023 9:30 am	Styx 6 C (BM211177) 01-Mar-2023 9:30 am	Styx 7 A (BM211177) 01-Mar-2023 12:30 pm	Styx 7 B (BM211177) 01-Mar-2023 12:30 pm	Styx 7 C (BM211177) 01-Mar-2023 12:30 pm
Lab Number:		3187258.11	3187258.12	3187258.13	3187258.14	3187258.15
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Anthracene	mg/kg dry wt	0.016	0.004	0.020	0.012	0.011
Benzo[a]anthracene	mg/kg dry wt	0.055	0.021	0.076	0.042	0.044
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.076	0.029	0.114	0.066	0.071
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.088	0.033	0.149	0.087	0.091
Benzo[e]pyrene	mg/kg dry wt	0.045	0.017	0.074	0.043	0.047
Benzo[g,h,i]perylene	mg/kg dry wt	0.059	0.021	0.102	0.062	0.068
Benzo[k]fluoranthene	mg/kg dry wt	0.033	0.012	0.051	0.031	0.033
Chrysene	mg/kg dry wt	0.059	0.022	0.098	0.051	0.056
Dibenzo[a,h]anthracene	mg/kg dry wt	0.010	0.004	0.017	0.011	0.011
Fluoranthene	mg/kg dry wt	0.122	0.038	0.184	0.102	0.104
Fluorene	mg/kg dry wt	0.010	0.003	0.018	0.012	0.011
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.055	0.020	0.093	0.054	0.061
Naphthalene	mg/kg dry wt	< 0.03	< 0.012	< 0.04	< 0.04	< 0.04
Perylene	mg/kg dry wt	0.036	0.012	0.084	0.052	0.054
Phenanthrene	mg/kg dry wt	0.083	0.022	0.129	0.076	0.072
Pyrene	mg/kg dry wt	0.128	0.042	0.20	0.109	0.122
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	0.111	0.042	0.171	0.100	0.106
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	0.110	0.042	0.169	0.099	0.105

Sample Name:		Styx 8 A (BM211177) 01-Mar-2023 11:30 am	Styx 8 B (BM211177) 01-Mar-2023 11:30 am	Styx 8 C (BM211177) 01-Mar-2023 11:30 am
Lab Number:		3187258.16	3187258.17	3187258.18
Individual Tests				
Dry Matter	g/100g as rcvd	55	55	45
Particle size analysis*‡		See attached report	See attached report	See attached report
Total Recoverable Copper	mg/kg dry wt	3.1	5.2	5.6
Total Recoverable Lead	mg/kg dry wt	11.8	11.0	14.8
Total Recoverable Phosphorus	mg/kg dry wt	300	400	470
Total Recoverable Zinc	mg/kg dry wt	56	61	69
Total Organic Carbon*	g/100g dry wt	0.61	1.43	1.64
Polycyclic Aromatic Hydrocarbons Trace in Soil*				
Total of Reported PAHs in Soil	mg/kg dry wt	0.82	0.21	12.0
1-Methylnaphthalene	mg/kg dry wt	< 0.003	< 0.003	0.128
2-Methylnaphthalene	mg/kg dry wt	< 0.003	< 0.003	0.054
Acenaphthene	mg/kg dry wt	< 0.003	< 0.003	0.103
Acenaphthylene	mg/kg dry wt	0.012	< 0.003	0.152
Anthracene	mg/kg dry wt	0.023	< 0.003	0.59
Benzo[a]anthracene	mg/kg dry wt	0.062	0.011	0.79
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.071	0.018	0.71
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.071	0.022	0.70
Benzo[e]pyrene	mg/kg dry wt	0.034	0.011	0.32
Benzo[g,h,i]perylene	mg/kg dry wt	0.038	0.016	0.35
Benzo[k]fluoranthene	mg/kg dry wt	0.029	0.007	0.29
Chrysene	mg/kg dry wt	0.056	0.014	0.66
Dibenzo[a,h]anthracene	mg/kg dry wt	0.009	0.003	0.094
Fluoranthene	mg/kg dry wt	0.125	0.024	1.78
Fluorene	mg/kg dry wt	0.012	< 0.003	0.50
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.040	0.014	0.39
Naphthalene	mg/kg dry wt	< 0.012	< 0.013	0.087
Perylene	mg/kg dry wt	0.020	0.012	0.155
Phenanthrene	mg/kg dry wt	0.081	0.012	2.3

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

SPv1

Client:	Boffa Miskell Limited	**Lab No:**	3188455
Contact:	Jessica Schofield C/- Boffa Miskell Limited PO Box 110 Christchurch 8140	**Date Received:**	02-Mar-2023
		Date Reported:	21-Mar-2023
		Quote No:	115912
		Order No:	
		Client Reference:	
		Submitted By:	Jessica Schofield

Sample Type: Sediment

Sample Name:		Styx03 A (BM211177) 02-Mar-2023 9:15 am	Styx03 B (BM211177) 02-Mar-2023 9:15 am	Styx03 C (BM211177) 02-Mar-2023 9:15 am	Styx12 A (BM211177) 02-Mar-2023 1:45 pm	Styx12 B (BM211177) 02-Mar-2023 1:45 pm
Lab Number:		3188455.1	3188455.2	3188455.3	3188455.4	3188455.5
Individual Tests						
Dry Matter	g/100g as rcvd	35	68	68	29	41
Particle size analysis*‡		See attached report	See attached report	See attached report	See attached report	See attached report
Total Recoverable Copper	mg/kg dry wt	3.1	2.6	2.8	9.7	4.5
Total Recoverable Lead	mg/kg dry wt	6.5	7.6	6.2	13.4	7.5
Total Recoverable Phosphorus	mg/kg dry wt	340	360	340	480	320
Total Recoverable Zinc	mg/kg dry wt	65	55	55	78	53
Total Organic Carbon*	g/100g dry wt	0.76	0.57	0.58	3.6	1.36
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Total of Reported PAHs in Soil	mg/kg dry wt	0.11	< 0.05	0.08	0.26	0.10
1-Methylnaphthalene	mg/kg dry wt	0.005	< 0.002	< 0.002	< 0.005	< 0.004
2-Methylnaphthalene	mg/kg dry wt	0.005	< 0.002	< 0.002	< 0.005	< 0.004
Acenaphthene	mg/kg dry wt	< 0.004	< 0.002	< 0.002	< 0.005	< 0.004
Acenaphthylene	mg/kg dry wt	< 0.004	< 0.002	< 0.002	< 0.005	< 0.004
Anthracene	mg/kg dry wt	< 0.004	< 0.002	< 0.002	< 0.005	< 0.004
Benzo[a]anthracene	mg/kg dry wt	0.004	< 0.002	< 0.002	0.012	0.005
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.007	0.002	0.002	0.020	0.008
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.010	0.003	0.003	0.026	0.010
Benzo[e]pyrene	mg/kg dry wt	0.004	< 0.002	< 0.002	0.013	0.005
Benzo[g,h,i]perylene	mg/kg dry wt	0.005	< 0.002	< 0.002	0.016	0.006
Benzo[k]fluoranthene	mg/kg dry wt	< 0.004	< 0.002	< 0.002	0.009	0.004
Chrysene	mg/kg dry wt	0.005	0.002	0.002	0.020	0.006
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.004	< 0.002	< 0.002	< 0.005	< 0.004
Fluoranthene	mg/kg dry wt	0.011	0.004	0.003	0.031	0.011
Fluorene	mg/kg dry wt	< 0.004	< 0.002	< 0.002	< 0.005	< 0.004
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.004	< 0.002	< 0.002	0.013	0.006
Naphthalene	mg/kg dry wt	< 0.019	< 0.010	< 0.010	< 0.03	< 0.018
Perylene	mg/kg dry wt	0.007	0.003	0.052	0.021	0.008
Phenanthrene	mg/kg dry wt	0.014	0.004	0.003	0.022	0.008
Pyrene	mg/kg dry wt	0.011	0.003	0.003	0.035	0.012
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	0.0104	< 0.0049	< 0.0049	0.029	0.0122
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	0.0103	< 0.0049	< 0.0049	0.029	0.0121

Sample Type: Sediment					
Sample Name:		Styx12 C (BM211177) 02-Mar-2023 1:45 pm	Styx15 A (BM211177) 02-Mar-2023 10:30 am	Styx15 B (BM211177) 02-Mar-2023 10:30 am	Styx15 C (BM211177) 02-Mar-2023 10:30 am
Lab Number:		3188455.6	3188455.7	3188455.8	3188455.9
Individual Tests					
Dry Matter	g/100g as rcvd	30	63	31	64
Particle size analysis*‡		See attached report	See attached report	See attached report	See attached report
Total Recoverable Copper	mg/kg dry wt	5.7	11.6	14.5	8.7
Total Recoverable Lead	mg/kg dry wt	8.7	6.3	8.2	4.7
Total Recoverable Phosphorus	mg/kg dry wt	320	370	390	240
Total Recoverable Zinc	mg/kg dry wt	61	83	83	56
Total Organic Carbon*	g/100g dry wt	1.91	3.6	4.9	2.2
Polycyclic Aromatic Hydrocarbons Trace in Soil*					
Total of Reported PAHs in Soil	mg/kg dry wt	0.22	0.28	0.54	0.24
1-Methylnaphthalene	mg/kg dry wt	< 0.005	0.013	0.028	0.012
2-Methylnaphthalene	mg/kg dry wt	< 0.005	0.010	0.016	0.010
Acenaphthene	mg/kg dry wt	< 0.005	< 0.003	< 0.005	< 0.003
Acenaphthylene	mg/kg dry wt	< 0.005	0.002	0.005	0.005
Anthracene	mg/kg dry wt	< 0.005	0.005	0.012	0.007
Benzo[a]anthracene	mg/kg dry wt	0.014	0.017	0.029	0.013
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.020	0.021	0.043	0.017
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.024	0.022	0.043	0.018
Benzo[e]pyrene	mg/kg dry wt	0.012	0.011	0.023	0.009
Benzo[g,h,i]perylene	mg/kg dry wt	0.014	0.015	0.030	0.011
Benzo[k]fluoranthene	mg/kg dry wt	0.009	0.009	0.018	0.007
Chrysene	mg/kg dry wt	0.017	0.017	0.031	0.016
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.005	0.003	0.005	< 0.003
Fluoranthene	mg/kg dry wt	0.028	0.041	0.072	0.035
Fluorene	mg/kg dry wt	< 0.005	0.003	0.008	0.003
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.013	0.014	0.028	0.011
Naphthalene	mg/kg dry wt	< 0.03	< 0.011	< 0.03	< 0.011
Perylene	mg/kg dry wt	0.015	0.005	0.010	0.004
Phenanthrene	mg/kg dry wt	0.012	0.023	0.059	0.021
Pyrene	mg/kg dry wt	0.033	0.035	0.060	0.030
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	0.029	0.031	0.061	0.024
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	0.029	0.030	0.060	0.023

Analyst's Comments

It has been noted that the duplicate analyses for the PAH analysis on sample 3188455.7 showed greater variation than would normally be expected. This may reflect the heterogeneity of the sample. Averaged results have been reported.

‡ Analysis subcontracted to an external provider. Refer to the Summary of Methods section for more details.

Appendix No.1 - Waikato University Report

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-9
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation May contain a residual moisture content of 2-5%.	-	1-9
Polycyclic Aromatic Hydrocarbons Trace in Soil*	Sonication extraction, GC-MS analysis. Tested on as received sample. In-house based on US EPA 8270.	0.002 - 0.03 mg/kg dry wt	1-9

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

SPv1

Client:	Boffa Miskell Limited	**Lab No:**	3244298
Contact:	Jessica Schofield	**Date Received:**	17-Apr-2023
	C/- Boffa Miskell Limited	**Date Reported:**	08-May-2023
	PO Box 110	**Quote No:**	115912
	Christchurch 8140	**Order No:**	
		Client Reference:	
		Submitted By:	Jessica Schofield

Sample Type: Sediment

Sample Name:		STYX03Ia 17-Apr-2023 10:30 am	STYX03B 17-Apr-2023 10:30 am	STYX03Ic 17-Apr-2023 10:30 am
Lab Number:		3244298.1	3244298.2	3244298.3
Individual Tests				
Dry Matter	g/100g as rcvd	74	58	59
Particle size analysis*‡		See attached report	See attached report	See attached report
Total Recoverable Copper	mg/kg dry wt	4.6	5.2	4.7
Total Recoverable Lead	mg/kg dry wt	13.0	16.8	13.5
Total Recoverable Phosphorus	mg/kg dry wt	400	360	400
Total Recoverable Zinc	mg/kg dry wt	94	92	94
Total Organic Carbon*	g/100g dry wt	0.92	1.08	0.79
Polycyclic Aromatic Hydrocarbons Trace in Soil*				
Total of Reported PAHs in Soil	mg/kg dry wt	0.96	0.37	0.78
1-Methylnaphthalene	mg/kg dry wt	0.003	< 0.003	0.003
2-Methylnaphthalene	mg/kg dry wt	0.002	< 0.003	0.003
Acenaphthene	mg/kg dry wt	0.004	< 0.003	< 0.003
Acenaphthylene	mg/kg dry wt	0.007	0.005	0.011
Anthracene	mg/kg dry wt	0.025	0.007	0.019
Benzo[a]anthracene	mg/kg dry wt	0.071	0.027	0.050
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.083	0.033	0.062
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.082	0.037	0.068
Benzo[e]pyrene	mg/kg dry wt	0.043	0.019	0.036
Benzo[g,h,i]perylene	mg/kg dry wt	0.047	0.021	0.040
Benzo[k]fluoranthene	mg/kg dry wt	0.034	0.014	0.024
Chrysene	mg/kg dry wt	0.066	0.028	0.051
Dibenzo[a,h]anthracene	mg/kg dry wt	0.010	0.005	0.008
Fluoranthene	mg/kg dry wt	0.169	0.054	0.137
Fluorene	mg/kg dry wt	0.007	0.002	0.006
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.043	0.020	0.040
Naphthalene	mg/kg dry wt	< 0.010	< 0.012	< 0.012
Perylene	mg/kg dry wt	0.020	0.009	0.017
Phenanthrene	mg/kg dry wt	0.077	0.023	0.075
Pyrene	mg/kg dry wt	0.162	0.055	0.128
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	0.118	0.048	0.090
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	0.117	0.048	0.089

Appendix 3: SIMPER results 2018-2023

SIMPER

Similarity Percentages - species contributions

One-Way Analysis

Data worksheet

Name: Data1

Data type: Abundance

Sample selection: All

Variable selection: All

Parameters

Resemblance: S17 Bray-Curtis similarity

Cut off for low contributions: 100.00%

Factor Groups

Sample	Year
S13	2018
S14	2018
S15	2018
S16	2018
S17	2018
S18	2018
S19	2018
S20	2018
S21	2018
S22	2018
S23	2018
S24	2018
S1	2023
S2	2023
S3	2023

S4	2023
S5	2023
S6	2023
S7	2023
S8	2023
S9	2023
S10	2023
S11	2023
S12	2023

Group 2018

Average similarity: 63.85

Species	Av.Abund	Av.Sim	Sim/SD	Contrib %	Cum. %
Oligochaeta	1	3.56	8.81	5.58	5.58
Herpetocypris pascheri	1	3.56	8.81	5.58	11.16
Orthocladiinae, excl. Corynoneura	1	3.56	8.81	5.58	16.75
Polypedilum	1	3.56	8.81	5.58	22.33
Tanytarsini	1	3.56	8.81	5.58	27.91
Physa = Physella	1	3.56	8.81	5.58	33.49
Potamopyrgus	1	3.56	8.81	5.58	39.07
Sphaeriidae	1	3.56	8.81	5.58	44.65
PLATYHELMINTHES, excl. Rhabdocoela	1	3.56	8.81	5.58	50.24
Amphipoda, *Paracalliope fluviatilis*	0.92	3.06	2.16	4.79	55.03
Hudsonema amabile	0.92	2.99	2.13	4.68	59.71
Oxyethira	0.92	2.98	2.13	4.67	64.38
Triplectides	0.83	2.42	1.42	3.79	68.16
Collembola	0.75	1.94	1.07	3.04	71.2
Acarina	0.75	1.93	1.07	3.02	74.23
Psilochorema bidens	0.67	1.47	0.84	2.3	76.53
Gundlachia = Ferrissia	0.58	1.19	0.67	1.87	78.4
Pycnocentria	0.58	1.13	0.67	1.77	80.16
Hydrobiosis	0.58	1.1	0.67	1.73	81.89
Psilochorema sp. (Juveniles)	0.58	1.09	0.67	1.71	83.6

Deleatidium	0.5	0.81	0.53	1.27	84.87
Oecetis	0.5	0.8	0.53	1.25	86.12
Pycnocentrodes	0.5	0.75	0.53	1.18	87.3
Gyraulus	0.5	0.74	0.54	1.16	88.46
Empididae	0.42	0.56	0.42	0.87	89.33
Polyplectropus	0.42	0.53	0.42	0.83	90.16
Hydrobiosis parumbripennis	0.42	0.53	0.42	0.83	90.99
Hudsonema alienum	0.42	0.52	0.42	0.82	91.81
Ostracoda	0.42	0.51	0.42	0.8	92.61
Copepoda	0.42	0.5	0.42	0.79	93.4
Nemertera	0.42	0.49	0.42	0.76	94.16
Zygoptera	0.42	0.48	0.42	0.76	94.91
Paradixa	0.42	0.48	0.42	0.76	95.67
Tanypodinae	0.42	0.46	0.42	0.73	96.4
Cladocera	0.33	0.31	0.31	0.48	96.88
Sigara	0.33	0.28	0.31	0.44	97.31
Hygraula	0.25	0.16	0.22	0.25	97.56
Austrolesthes	0.25	0.16	0.22	0.25	97.82
Xanthocnemis	0.25	0.16	0.22	0.25	98.07
Corynoneura	0.25	0.16	0.22	0.25	98.32
Hydropsyche-Aoteapsyche	0.25	0.16	0.22	0.25	98.56
Hirudinea	0.25	0.15	0.22	0.23	98.79
Paroxyethira	0.25	0.14	0.22	0.22	99.01
Austrosimulium	0.25	0.14	0.22	0.22	99.23
Paratya	0.17	0.05	0.12	0.08	99.32
Harrisius	0.17	0.05	0.12	0.08	99.4
Elmidae	0.17	0.05	0.12	0.08	99.48
Oeconesidae	0.17	0.05	0.12	0.08	99.56
Chironomus sp. A	0.17	0.05	0.12	0.08	99.64
Hydrobiosis umbripennis	0.17	0.05	0.12	0.08	99.71
Hexatomini, excl. Paralimnophila	0.17	0.05	0.12	0.08	99.79
Rhabdocoela	0.17	0.05	0.12	0.07	99.86
Hydra	0.17	0.04	0.12	0.07	99.93
Microvelia	0.17	0.04	0.12	0.07	100

Group 2023

Average similarity: 57.94

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Oligochaeta	1	4.85	7.66	8.38	8.38
Ostracoda	1	4.85	7.66	8.38	16.76
Paracalliope	1	4.85	7.66	8.38	25.13
Potamopyrgus	1	4.85	7.66	8.38	33.51
PLATYHELMINTHES, excl. Rhabdocoela	0.92	4.12	2.12	7.11	40.62
Sphaeriidae	0.92	4.03	2.11	6.96	47.58
Physa = Physella	0.92	4.01	2.11	6.93	54.51
Orthocladiinae, excl. Corynoneura	0.83	3.16	1.43	5.45	59.96
Acaina	0.75	2.73	1.06	4.72	64.68
Chironomus	0.67	2.11	0.84	3.64	68.32
Hudsonema	0.58	1.59	0.67	2.74	71.05
Hydrobiosis	0.58	1.52	0.67	2.63	73.68
Triplectides	0.58	1.49	0.67	2.58	76.26
Oxyethira	0.58	1.42	0.68	2.44	78.7
Tanypodinae	0.5	1.14	0.53	1.97	80.67
Nemertea	0.5	1.11	0.53	1.91	82.58
Gundlachia = Ferrissia	0.5	1.07	0.54	1.85	84.43
Psilochorema	0.5	1.07	0.54	1.85	86.27
Pycnocentria	0.5	1.03	0.54	1.78	88.05
Tanytarsini	0.5	0.99	0.54	1.71	89.76
Deleatidium	0.42	0.73	0.42	1.26	91.02
Polypedilum	0.42	0.72	0.42	1.24	92.26
Oecetis	0.33	0.46	0.31	0.79	93.05
Pycnocentrodes	0.33	0.43	0.31	0.75	93.8
Paradixa	0.33	0.41	0.31	0.7	94.5
Nematoda	0.33	0.41	0.31	0.7	95.2
Xanthocnemis	0.33	0.39	0.31	0.67	95.86
Copepoda	0.33	0.38	0.31	0.66	96.52
Sigara	0.33	0.38	0.31	0.66	97.19
Gyraulus	0.33	0.38	0.31	0.66	97.85

Hydropsyche-Aoteapsyche	0.25	0.21	0.22	0.36	98.21
Paroxyethira	0.25	0.19	0.22	0.34	98.55
Cladocera	0.25	0.19	0.22	0.33	98.88
Corynoneura	0.25	0.19	0.22	0.33	99.21
Microvelia	0.25	0.19	0.22	0.32	99.53
Austrosimulium	0.17	0.08	0.12	0.13	99.67
Mischoderus	0.17	0.07	0.12	0.11	99.78
Oeconesidae	0.17	0.07	0.12	0.11	99.89
Hydra	0.17	0.06	0.12	0.11	100

Groups 2018 & 2023

Average dissimilarity = 53.25

Species	Group 2018 Av.Abund	Group 2023 Av.Abund	Av.Diss	Diss/SD	Contrib %	Cum. %
Herpetocypris pascheri	1	0	2.06	7.9	3.87	3.87
Paracalliope	0	1	2.06	7.9	3.87	7.73
Amphipoda, *Paracalliope fluviatilis*	0.92	0	1.92	3.07	3.6	11.33
Hudsonema amabile	0.92	0	1.89	3.02	3.56	14.89
Collembola	0.75	0	1.54	1.66	2.9	17.79
Chironomus	0	0.67	1.39	1.37	2.6	20.39
Psilochorema bidens	0.67	0	1.35	1.37	2.54	22.93
Ostracoda	0.42	1	1.23	1.16	2.31	25.24
Hudsonema	0	0.58	1.21	1.16	2.28	27.52
Polypedilum	1	0.42	1.21	1.16	2.27	29.79
Psilochorema sp. (Juveniles)	0.58	0	1.18	1.15	2.21	32
Tanytarsini	1	0.5	1.08	0.98	2.02	34.02
Pycnocentria	0.58	0.5	1.03	0.98	1.94	35.96
Tanypodinae	0.42	0.5	1.03	0.98	1.94	37.9
Gundlachia = Ferrissia	0.58	0.5	1.03	0.98	1.94	39.84
Nemertea	0.42	0.5	1.03	0.98	1.93	41.78
Deleatidium	0.5	0.42	1.03	0.98	1.93	43.71
Oecetis	0.5	0.33	1.03	0.98	1.93	45.64
Psilochorema	0	0.5	1.02	0.99	1.91	47.55

Pycnocentrodes	0.5	0.33	1.01	0.98	1.91	49.45
Gyraulus	0.5	0.33	1.01	0.99	1.89	51.34
Hydrobiosis	0.58	0.58	1	0.96	1.89	53.23
Copepoda	0.42	0.33	0.95	0.93	1.78	55.01
Paradixa	0.42	0.33	0.95	0.93	1.78	56.79
Triplectides	0.83	0.58	0.93	0.88	1.74	58.53
Oxyethira	0.92	0.58	0.92	0.85	1.73	60.27
Empididae	0.42	0.08	0.9	0.86	1.68	61.95
Polyplectropus	0.42	0.08	0.88	0.86	1.65	63.6
Sigara	0.33	0.33	0.88	0.88	1.65	65.25
Hydrobiosis parumbripennis	0.42	0	0.85	0.83	1.59	66.84
Hudsonema alienum	0.42	0	0.84	0.83	1.58	68.43
Xanthocnemis	0.25	0.33	0.84	0.83	1.57	70
Cladocera	0.33	0.25	0.83	0.84	1.57	71.56
Zygoptera	0.42	0	0.8	0.83	1.51	73.07
Acarina	0.75	0.75	0.76	0.76	1.44	74.51
Hydropsyche-Aoteapsyche	0.25	0.25	0.76	0.77	1.43	75.94
Corynoneura	0.25	0.25	0.75	0.77	1.41	77.35
Paroxyethira	0.25	0.25	0.74	0.77	1.39	78.74
Austrosimulium	0.25	0.17	0.67	0.69	1.25	79.99
Nematoda	0	0.33	0.66	0.7	1.24	81.23
Microvelia	0.17	0.25	0.64	0.7	1.2	82.43
Austrolesthes	0.25	0.08	0.59	0.64	1.12	83.55
Hirudinea	0.25	0.08	0.58	0.63	1.08	84.63
Oeconesidae	0.17	0.17	0.55	0.61	1.04	85.67
Hydra	0.17	0.17	0.53	0.61	0.99	86.66
Hygraula	0.25	0	0.51	0.57	0.96	87.62
Paratya	0.17	0.08	0.45	0.53	0.84	88.46
Mischoderus	0.08	0.17	0.45	0.53	0.84	89.3
Orthocladiinae, excl. Corynoneura	1	0.83	0.38	0.44	0.71	90.01
Harrisius	0.17	0	0.34	0.44	0.64	90.64
Chironomus sp. A	0.17	0	0.34	0.44	0.63	91.27
Hydrobiosis umbripennis	0.17	0	0.34	0.44	0.63	91.9
Elmidae	0.17	0	0.33	0.44	0.63	92.53
Hexatomini, excl. Paralimnophila	0.17	0	0.32	0.44	0.6	93.13

Rhabdocoela	0.17	0	0.31	0.44	0.58	93.71
Anisops	0.08	0.08	0.3	0.42	0.57	94.29
Ceratopogonidae	0.08	0.08	0.29	0.42	0.54	94.83
Isopoda, excl. Paranthura	0	0.08	0.2	0.3	0.37	95.2
Physa = Physella	1	0.92	0.18	0.3	0.33	95.54
Sphaeriidae	1	0.92	0.17	0.3	0.33	95.86
Psilochorema tautoru	0.08	0	0.17	0.3	0.32	96.18
Amphipoda, Paraleptamphopus sp.	0.08	0	0.17	0.3	0.32	96.5
Hydrobiosis clavigera	0.08	0	0.17	0.3	0.32	96.81
Dytiscidae, Antiporus	0	0.08	0.16	0.3	0.3	97.12
Amphipoda	0	0.08	0.16	0.3	0.3	97.42
Amphipoda, Talitridae	0	0.08	0.16	0.3	0.3	97.72
Ephydridae	0	0.08	0.16	0.3	0.3	98.02
Muscidae	0	0.08	0.16	0.3	0.3	98.32
Mauiulus	0	0.08	0.16	0.3	0.3	98.62
Neurochorema	0.08	0	0.16	0.3	0.3	98.92
PLATYHELMINTHES, excl. Rhabdocoela	1	0.92	0.16	0.3	0.3	99.21
Chironomus zealandicus	0.08	0	0.14	0.3	0.26	99.48
Sciomyzidae	0.08	0	0.14	0.3	0.26	99.74
Lymnaea	0.08	0	0.14	0.3	0.26	100

Appendix 4: SIMPER results 2018-2023 condensed taxonomic list

SIMPER

Similarity Percentages - species contributions

One-Way Analysis

Data worksheet

Name: Matrix final

Data type: Abundance

Sample selection: All

Variable selection: All

Parameters

Resemblance: S17 Bray-Curtis similarity

Cut off for low contributions: 100.00%

Factor Groups

Sample	Year
S13	2018
S14	2018
S15	2018
S16	2018
S17	2018
S18	2018
S19	2018
S20	2018
S21	2018
S22	2018
S23	2018
S24	2018
S1	2023

S2	2023
S3	2023
S4	2023
S5	2023
S6	2023
S7	2023
S8	2023
S9	2023
S10	2023
S11	2023
S12	2023

Group 2018

Average similarity: 28.69

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Potamopyrgus	3282.83	12.42	0.98	43.3	43.3
Amphipoda	2357.58	7.67	0.62	26.72	70.02
Herpetocypris pascheri	551.08	1.14	0.53	3.96	73.98
Pycnocentria	611.83	1.03	0.29	3.61	77.59
Physa = Physella	307.33	0.91	0.69	3.17	80.76
Sphaeriidae	172.5	0.73	0.7	2.53	83.29
OLIGOCHAETA	130	0.67	0.71	2.33	85.62
Pycnocentrodes	423.25	0.58	0.25	2.02	87.64
Polypedilum	105.33	0.58	1.1	2.01	89.65
Oxyethira	106.83	0.49	0.76	1.7	91.35
Orthocladiinae, excl. Corynoneura	133.5	0.49	0.62	1.7	93.05
Deleatidium	119.08	0.43	0.27	1.48	94.54
Hudsonema	76.67	0.4	0.78	1.39	95.93
Gundlachia = Ferrissia	48.67	0.22	0.51	0.75	96.68
PLATYHELMINTHES, excl. Rhabdocoela	30.25	0.21	0.82	0.74	97.42
Gyraulus	90.33	0.14	0.24	0.49	97.91
Tanytarsini	49.58	0.12	0.58	0.43	98.34

Triplectides	13.92	0.08	0.66	0.27	98.62
Psilochorema	13.17	0.07	0.63	0.24	98.85
COLLEMBOLA	16.5	0.06	0.74	0.21	99.07
Hydrobiosis	9.08	0.05	0.74	0.19	99.25
ACARINA	15.42	0.05	0.6	0.17	99.42
Zygoptera	11.25	0.03	0.36	0.1	99.52
Copepoda	19.33	0.03	0.32	0.09	99.62
Paradixa	8.67	0.02	0.24	0.06	99.67
Ostracoda	9	0.02	0.3	0.05	99.72
Sigara	7.5	0.01	0.21	0.04	99.77
Cladocera	4.17	0.01	0.27	0.03	99.79
Hydropsyche-Aoteapsyche	55.5	0.01	0.21	0.03	99.82
Oecetis	5.75	0.01	0.35	0.03	99.85
Tanypodinae	3.42	0.01	0.38	0.02	99.87
Polyplectropus	3.58	0.01	0.32	0.02	99.89
HIRUDINEA	4.5	0.01	0.21	0.02	99.91
NEMERTEA	2.42	0	0.31	0.02	99.93
Empididae	4.33	0	0.28	0.01	99.94
Corynoneura	8.42	0	0.15	0.01	99.96
Hygraula	6.33	0	0.21	0.01	99.97
Xanthocnemis	6.67	0	0.15	0.01	99.97
Paroxyethira	3.08	0	0.21	0	99.98
Austrosimulium	0.83	0	0.21	0	99.98
Hydra	2.83	0	0.12	0	99.98
Harrisius	0.33	0	0.12	0	99.99
Chironomous	0.67	0	0.12	0	99.99
Rhabdocoela	6.33	0	0.12	0	99.99
Microvelia	1.42	0	0.12	0	99.99
Austrolesthes	0.33	0	0.21	0	100
Oeconesidae	0.5	0	0.12	0	100
Elmidae	0.75	0	0.12	0	100
Hexatomini, excl. Paralimnophila	0.5	0	0.12	0	100
Paratya	0.17	0	0.12	0	100
Dytiscidae, Antiporus	0	0	SD=0!	0	100

Isopoda, excl. Paranthura	0	0	SD=0!	0	100
Paracalliope	0	0	SD=0!	0	100
Ceratopogonidae	0.17	0	SD=0!	0	100
Ephydridae	0	0	SD=0!	0	100
Mischoderus	0.08	0	SD=0!	0	100
Muscidae	0	0	SD=0!	0	100
Sciomyzidae	0.17	0	SD=0!	0	100
Mauiulus	0	0	SD=0!	0	100
Anisops	0.42	0	SD=0!	0	100
Lymnaea	1.33	0	SD=0!	0	100
NEMATODA	0	0	SD=0!	0	100
Neurochorema	0.17	0	SD=0!	0	100

Group 2023

Average similarity: 43.14

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Potamopyrgus	1117.5	14.81	1.49	34.33	34.33
Paracalliope	810.83	9.67	1.15	22.42	56.75
OLIGOCHAETA	597.5	9.24	1.35	21.4	78.16
Ostracoda	485.92	4	0.79	9.27	87.43
Pycnocentria	250.92	1.01	0.29	2.35	89.78
Sphaeriidae	93.33	0.68	0.7	1.58	91.36
PLATYHELMINTHES, excl. Rhabdocoela	39.17	0.56	1.14	1.31	92.67
Physa = Physella	106.92	0.5	0.47	1.16	93.83
Orthocladiinae, excl. Corynoneura	75.92	0.42	0.84	0.97	94.8
Oxyethira	56.75	0.3	0.43	0.69	95.5
Pycnocentrodes	124.17	0.28	0.28	0.65	96.15
Deleatidium	64.17	0.28	0.29	0.64	96.79
Hudsonema	53.33	0.26	0.53	0.6	97.39
Chironomus	24.25	0.13	0.61	0.3	97.69
ACARINA	10.92	0.11	0.66	0.27	97.96
Gundlachia = Ferrissia	33.33	0.11	0.46	0.26	98.21

Triplectides	12.58	0.09	0.51	0.21	98.42
Gyraulus	172.5	0.09	0.24	0.2	98.62
Copepoda	24.17	0.08	0.3	0.19	98.81
Cladocera	81.67	0.07	0.16	0.17	98.99
Corynoneura	43.33	0.07	0.15	0.15	99.14
Tanytarsini	17.58	0.06	0.41	0.14	99.28
NEMERTEA	8.42	0.05	0.42	0.12	99.4
Polypedilum	6.75	0.04	0.32	0.1	99.5
NEMATODA	11.67	0.04	0.3	0.09	99.59
Psilochorema	6.83	0.04	0.33	0.09	99.68
Paroxyethira	15.08	0.03	0.13	0.06	99.74
Oecetis	10.08	0.03	0.2	0.06	99.8
Tanypodinae	12.75	0.02	0.27	0.05	99.85
Xanthocnemis	13.42	0.02	0.23	0.04	99.89
Hydrobiosis	2.08	0.01	0.27	0.03	99.92
Hydropsyche-Aoteapsyche	31.75	0.01	0.13	0.03	99.95
Paradixa	3.5	0.01	0.16	0.02	99.97
Hydra	6.67	0.01	0.12	0.01	99.98
Microvelia	6.75	0.01	0.14	0.01	99.99
Sigara	3.58	0	0.31	0	100
Mischoderus	0.17	0	0.12	0	100
Oeconesidae	1.75	0	0.12	0	100
Austrosimulium	1.75	0	0.12	0	100

Groups 2018 & 2023

Average dissimilarity = 78.96

Species	Group 2018 Av.Abund	Group 2023 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Potamopyrgus	3282.83	1117.5	18.34	1.05	23.23	23.23
Amphipoda	2357.58	2.5	15.65	0.84	19.82	43.05
Paracalliope	0	810.83	7.09	1.1	8.99	52.04
Pycnocentria	611.83	250.92	5.85	0.73	7.41	59.44
OLIGOCHAETA	130	597.5	4.55	1.1	5.76	65.2

Ostracoda	9	485.92	3.87	0.92	4.91	70.11
Pycnocentrodes	423.25	124.17	3.75	0.64	4.76	74.87
Herpetocypris pascheri	551.08	0	3.33	0.67	4.21	79.08
Physa = Physella	307.33	106.92	2.64	0.58	3.34	82.42
Gyraulus	90.33	172.5	1.86	0.52	2.36	84.78
Sphaeriidae	172.5	93.33	1.45	0.79	1.84	86.62
Deleatidium	119.08	64.17	1.44	0.73	1.82	88.44
Orthocladiinae, excl. Corynoneura	133.5	75.92	1.21	0.72	1.53	89.97
Polypedilum	105.33	6.75	0.86	0.72	1.09	91.06
Hudsonema	76.67	53.33	0.8	0.67	1.01	92.07
Oxyethira	106.83	56.75	0.78	1.17	0.99	93.06
Cladocera	4.17	81.67	0.7	0.36	0.89	93.95
Hydropsyche-Aoteapsyche	55.5	31.75	0.68	0.43	0.87	94.82
Gundlachia = Ferrissia	48.67	33.33	0.56	0.77	0.71	95.53
Tanytarsini	49.58	17.58	0.43	0.61	0.54	96.07
Corynoneura	8.42	43.33	0.36	0.48	0.45	96.52
PLATYHELMINTHES, excl. Rhabdocoela	30.25	39.17	0.26	0.89	0.33	96.85
Copepoda	19.33	24.17	0.26	0.75	0.33	97.18
Chironomus	0.67	24.25	0.21	0.52	0.27	97.45
Paroxyethira	3.08	15.08	0.15	0.49	0.19	97.64
Xanthocnemis	6.67	13.42	0.15	0.53	0.19	97.82
ACARINA	15.42	10.92	0.13	1.16	0.17	97.99
Triplectides	13.92	12.58	0.13	1.04	0.16	98.15
COLLEMBOLA	16.5	0	0.13	0.72	0.16	98.32
Tanypodinae	3.42	12.75	0.12	0.42	0.15	98.47
Psilochorema	13.17	6.83	0.12	0.97	0.15	98.62
Oecetis	5.75	10.08	0.1	0.6	0.13	98.75
Zygoptera	11.25	0	0.1	0.55	0.12	98.88
Paradixa	8.67	3.5	0.1	0.62	0.12	99
NEMATODA	0	11.67	0.09	0.57	0.12	99.12
Sigara	7.5	3.58	0.08	0.58	0.1	99.22
Hydra	2.83	6.67	0.08	0.48	0.1	99.32

NEMERTEA	2.42	8.42	0.08	0.73	0.1	99.42
Hydrobiosis	9.08	2.08	0.07	1.02	0.09	99.51
Microvelia	1.42	6.75	0.06	0.42	0.08	99.59
Empididae	4.33	1.67	0.04	0.54	0.05	99.64
Polyplectropus	3.58	0.08	0.04	0.4	0.05	99.69
Hygraula	6.33	0	0.04	0.39	0.05	99.75
HIRUDINEA	4.5	1.67	0.04	0.57	0.05	99.8
Mauiulus	0	3.33	0.03	0.28	0.03	99.83
Rhabdocoela	6.33	0	0.03	0.34	0.03	99.87
Austrosimulium	0.83	1.75	0.02	0.42	0.03	99.89
Oeconesidae	0.5	1.75	0.02	0.37	0.02	99.92
Lymnaea	1.33	0	0.01	0.3	0.02	99.93
Anisops	0.42	1.67	0.01	0.35	0.02	99.95
Ephydridae	0	0.83	0.01	0.27	0.01	99.96
Hexatomini, excl. Paralimnophila	0.5	0	0.01	0.33	0.01	99.97
Elmidae	0.75	0	0.01	0.36	0.01	99.98
Harrisius	0.33	0	0	0.42	0.01	99.98
Austrolesthes	0.33	0.08	0	0.51	0	99.99
Paratya	0.17	0.08	0	0.48	0	99.99
Mischoderus	0.08	0.17	0	0.5	0	99.99
Sciomyzidae	0.17	0	0	0.3	0	99.99
Ceratopogonidae	0.17	0.08	0	0.42	0	100
Neurochorema	0.17	0	0	0.3	0	100
Dytiscidae, Antiporus	0	0.08	0	0.28	0	100
Isopoda, excl. Paranthura	0	0.08	0	0.28	0	100
Muscidae	0	0.08	0	0.29	0	100

About Boffa Miskell

Boffa Miskell is a leading New Zealand professional services consultancy with offices in Whangarei, Auckland, Hamilton, Tauranga, Wellington, Nelson, Christchurch, Dunedin, and Queenstown. We work with a wide range of local and international private and public sector clients in the areas of planning, urban design, landscape architecture, landscape planning, ecology, biosecurity, cultural heritage, graphics and mapping. Over the past four decades we have built a reputation for professionalism, innovation and excellence. During this time we have been associated with a significant number of projects that have shaped New Zealand's environment.

---

www.boffamiskell.co.nz

Whangarei	**Auckland**	**Hamilton**	**Tauranga**	**Wellington**	**Nelson**	**Christchurch**	**Queenstown**	**Dunedin**
09 358 2526	09 358 2526	07 960 0006	07 571 5511	04 385 9315	03 548 8551	03 366 8891	03 441 1670	03 470 0460