Mona Vale Weir Remediation – Year 1 Ecological Study

Prepared for

Christchurch City Council

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Quality Control Sheet

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Executive Summary

Some previously excluded migratory species have moved upstream of, or within, the constructed rock riffle following remediation. However, abundance is not yet high enough for a statistical increase to be detected upstream.

Christchurch City Council (the Council) identified that Weir A at Mona Vale presented a barrier to upstream migrating fish in Ōtākaro - Avon River. In May 2023, the weir was remediated to a constructed rock riffle following the fish passage guidelines. A baseline ecological study was completed by Pattle Delamore Partners (PDP) prior to remediation (PDP, 2023). One year following this, a post-remediation aquatic ecology survey was undertaken to determine if the objective of improving fish passage into the upper catchment has been achieved. This report presents the findings of the post-remediation survey, in context with the baseline study.

Aquatic surveys were conducted following protocols outlined in the Council's Comprehensive Stormwater Network Discharge Consent (CSNDC) Version 9 Environmental Monitoring Plan (EMP). This included measurements of basic physicochemical water quality, aquatic habitat assessments, and freshwater fish surveys at sites upstream and downstream of Mona Vale (i.e., the Weir A constructed rock riffle). A post-remediation benthic macroinvertebrate sample was also collected in the constructed rock riffle footprint/bed to compare to the pre-remediation benthic macroinvertebrate community. A follow-up survey for kākahi, that were salvaged from the works zone and relocated to a side channel, was completed to determine success of translocation.

Analyses of data were completed using both statistical and qualitative methods. Survey data showed that new native migratory fish species (common bully, giant bully, bluegill bully and īnanga) are now present upstream of (or in) the constructed rock riffle and there was no significant difference in the upstream versus downstream population density of migratory fish in 2024. There was also no statistically significant increase in migratory fish population density upstream of the constructed rock riffle over time post-remediation. The non-significant upstream response compare to downstream post-remediation may be due to a combination of higher fish cover downstream, reduced migratory species population density downstream over time, and high water velocities through the constructed rock riffle.

Further post-remediation surveys are recommended in years 3, 5, and 10 to determine if the objective of improving fish passage has been achieved. It is possible that November-timed surveys may coincide with small post-whitebait īnanga that are not yet strong enough to navigate the weir. If the Year-3 follow-up study shows a low detection of īnanga upstream compared to downstream, an additional targeted īnanga survey upstream in January/early February may be informative.

Macroinvertebrate data shows that there has been an increase in number of taxa, but these taxa have low MCI scores. As such, we can conclude that there are more ecological niches present post-remediation. The absence of high MCI scoring taxa could indicate there are potential issues with an upstream source of pollution-sensitive EPT taxa. None of the relocated kākahi were found at the translocation site, indicating either high mobility or mortality.

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1.0 Introduction

Pattle Delamore Partners (PDP) was engaged by Christchurch City Council (the Council) to undertake Year One (post-remediation) aquatic ecology surveys at sites located upstream, downstream and within the constructed rock riffle in the northern branch of the Ōtākaro - Avon River at Mona Vale. The rock riffle was constructed to replace the historic Mona Vale Weir (Weir A, Figure 1, Figure 2), which was impeding fish passage to the upper catchment (Instream Consulting Limited, 2020). The Avon River at this point is about 18 km from the sea with a catchment upstream of 25 km^2, a mean flow of 1200 L/s and a mean annual low flow of about 530 L/s. Because of its proximity to the coast, a high diversity of fish species is likely (Jowett and Richardson 1996). Surveys were completed as part of the monitoring for Ōtākaro - Avon River at Mona Vale Weir Remediation Project. The aim was to determine if remediation has achieved the objective of improving fish passage and communities upstream of the weir.

1.1 Background

The Council's fish passage remediation programme identified Weir A as a fish passage barrier. While Weir A had existing fish passage mitigation in the form of a trout ladder, it still presented a barrier to fish passage for most species including salmonids. The objective of the remediation project was to increase fish migration to and from the upper catchment of Ōtākaro - Avon River, and to promote improved diversity and abundance in the upper catchment. The remediation should make approximately nine kilometres of favourable habitat in the upper catchment available to species that had been found downstream of the Weir A, but not upstream. These species include īnanga (*Galaxias maculatus*), bluegill bully (*Gobiomorphus hubbsi*) (both classified as 'At Risk – Declining' (Dunn et al., 2018)) and lamprey (*Geotria australis*) (classified as 'Threatened – Nationally Vulnerable' (Dunn et al., 2018)).

Figure 1. Looking upstream at the Mona Vale Weir (Weir A) pre-remediation. A trout ladder was constructed on the true right bank but still presented a barrier to salmonids.

Figure 2. Looking upstream at the constructed rock riffle (Weir A) post-remediation.

1.2 Previous work

Baseline) ecological surveys were completed in April to May, August and November 2022 before remediation of the weir. Assessments undertaken included (Appendix A, Table A1):

- April/May 2022:
  - sampling of habitat, water quality, a visual scan for kākahi, and fishing in Wairarapa Stream, Waimairi Stream and Ōtākaro – Avon River (upstream of Weir A) and in Ōtākaro – Avon River (downstream of weir A). This excluded Site 5 (the constructed rock riffle footprint).
  - A macroinvertebrate sample in the rock riffle footprint.

- August 2022:
  - Trout spawning habitat in Ōtākaro – Avon River (upstream of Weir A). A survey for trout spawning was to occur downstream of the weir in 2022, however water was too turbid for this survey to be completed.
- November 2022: fish surveys to capture the upstream migration of juvenile fish.
- February 2023: Kākahi that were salvaged from the rock riffle footprint on the 9th and 15th February 2023 were released into the Mill Stream section of the Ōtākaro – Avon River at Mona Vale (PDP, 2023). Salvaged kākahi were etched with one, two or three lines which indicated size and identifies them as relocated kākahi.

Remediation of the weir structure was completed in May 2023 and design principles followed the New Zealand Fish Passage Guidelines (Franklin et al., 2018) for a rock riffle construction. The remediation was designed by WSP New Zealand Ltd with input from local and international ecologists. In July 2023, a large flood caused damage to the constructed design and subsequent repairs were completed in April 2024. The findings of this study represent Year One following completion of all remediation and repair works (i.e., 18 months post initial construction, and seven months post remedial works).

1.3 Scope and purpose

This study reports on the Year 1 post-impact monitoring carried out in April (macroinvertebrates only) and November (all other data) 2024. It assesses whether there are early signs that weir remediation has successfully improved fish migration to and from the upper catchment of Ōtākaro - Avon River. Macroinvertebrates were also assessed to determine changes in the macroinvertebrate community in riffle/footprint.

Following Council protocols, the below scope of works was completed:

1. Freshwater fish surveys, aquatic habitat assessments, and basic physiochemical water quality assessments upstream, downstream and within Weir A. Unlike the baseline study, this did not include a visual scan for kākahi (*Echyridella menziesii*)[1]. However, resurvey of the kākahi release site was completed to determine the success of the baseline relocation.

[1] kākahi surveys were completed in Ōtākaro - Avon catchment in early 2024 as part of the Council's Comprehensive Stormwater Network Discharge Consent (CSNDC) monitoring program. Therefore, no kākahi data was collected for any of these sites.

2. Qualitative and statistical analyses to robustly determine pre- and post-weir remediation impacts on:

   i) Fish diversity, abundance, size structure, and community composition (via non-parametric statistical analysis and non-metric multidimensional scaling or NMDS) upstream and downstream of the remediated weir.

   ii) Macroinvertebrate community metrics at the location of the constructed rock ramp.

   iii) Habitat and water quality.

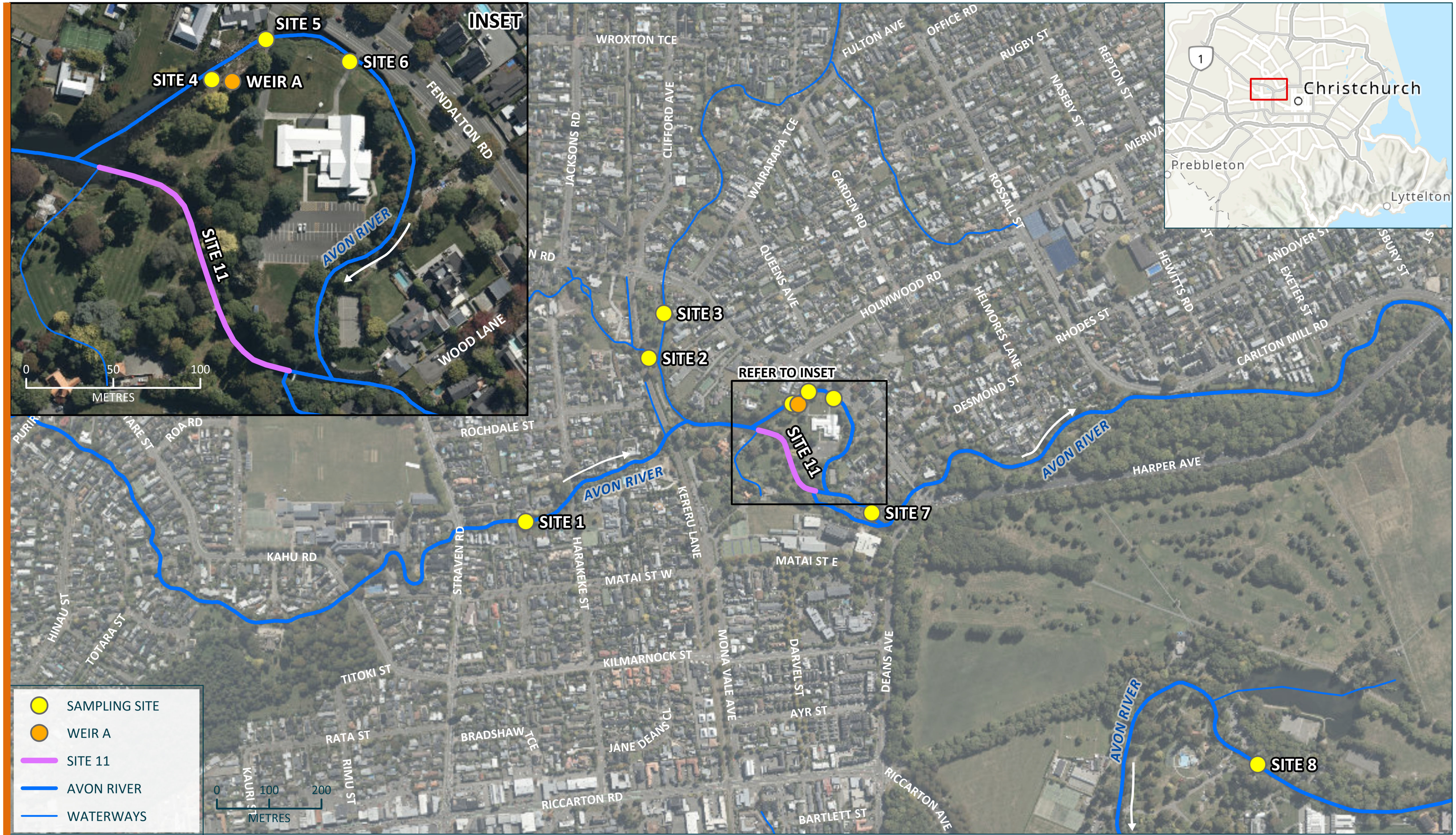

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FIGURE 3 : ECOLOGICAL ASSESSMENT SITE OVERVIEW

MONA VALE WEIR REPLACEMENT - ECOLOGICAL ASSESSMENT

SOURCE:
1. AERIAL IMAGERY (FLOWN 2020 - 2023): EAGLE TECHNOLOGY, LINZ, STATSNZ, NIWA, NATURAL EARTH, © OPENSTREETMAP CONTRIBUTORS., EAGLE TECHNOLOGY, LAND INFORMATION NEW ZEALAND, GEBCO, COMMUNITY MAPS CONTRIBUTORS, EAGLE TECHNOLOGY, LINZ.
2. WATERWAYS AND CATCHMENTS SOURCED FROM ENVIRONMENT CANTERBURY.
3. EXISTING MONITORING SITES SOURCED FROM ENVIRONMENT CANTERBURY AND CHRISTCHURCH CITY COUNCIL WHERE STATED.

SCALE : REFER INDIVIDUAL MAP FRAMES (A4)

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REVISION: 1.0 | DATE: AUG 25 | BY: MS
CLIENT: CHRISTCHURCH CITY COUNCIL

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2.0 Methodology

2.1 Site locations and timing

Nine sites were monitored, which encompassed the constructed rock riffle location, as well as sites upstream and downstream (Figure 3). The nine sites monitored were:

- Site 1 - Upstream of the rock riffle on Ōtākaro - Avon River, downstream of Barrier 13 (Boys High Weir). Located between Straven Road and Harakeke Street.
- Site 2 - Upstream of the rock riffle on Waimairi Stream at the long-term Council monitoring Site 22 (Waimairi Stream Downstream of Railway Bridge).
- Site 3 - Upstream of the rock riffle on Wairarapa Stream at the long-term Council monitoring Site 23 (Wairarapa Stream Downstream of Fendalton Road).
- Site 4 - Immediately upstream of the constructed rock riffle on Ōtākaro - Avon River.
- Site 5 - Ōtākaro - Avon River at the location of the constructed rock riffle.
- Site 6 - Downstream of the constructed rock riffle on Ōtākaro - Avon River.
- Site 7 - Downstream of the constructed rock riffle on Ōtākaro - Avon River at the long-term Council monitoring Site 24.
- Site 8 - Downstream of the constructed rock riffle on Ōtākaro - Avon River at the long-term Council monitoring Site 26.
- Site 11 - Ōtākaro - Avon River upstream of Weir B (true right fork) in the kākahi relocation zone.

Post-impact monitoring methods differed slightly from those undertaken under baseline conditions before remediation of the weir took place. This was primarily for the purpose of streamlining data collection and reporting, while retaining an accurate temporal comparison of key ecological characteristics (Appendix A, Table A1).

Sites 1-8 were sampled for basic water quality, habitat and fish. A macroinvertebrate sample was also collected from Site 5 within the constructed rock riffle. Site 11 was surveyed for kākahi only. These nine sites replicate those sampled in the baseline survey, except for Site 5 which was only sampled for macroinvertebrates pre-impact.

A pre-remediation survey was completed in the brown trout spawning reach (Site 10). This survey was not replicated post-impact either because changes in brown trout spawning (Site 10) will be picked up during routine CSNDC ecological surveys. Sites 1-8 were fished in November 2024 to ensure key migratory species had sufficient time to migrate into the system (e.g., īnanga). Macroinvertebrates were sampled from Site 5 in April 2024, while kākahi were surveyed at Site 11 in December 2024.

2.1 Collection methodology

2.1.1 Water quality

Surface water quality spot measurements were taken at each site using a calibrated water quality probe (YSI Pro DSS). Data measured was water temperature, dissolved oxygen (DO), electrical conductivity (EC), pH and turbidity.

2.1.2 Habitat assessments

Water velocity measurements were collected using a Sontek Flowtracker. Physical habitat measurements were made following the standard Council methodology, as described in Version 9 of the CSNDC Environmental Monitoring Programme (EMP). At each site, habitat assessments were undertaken at three transects, working in an upstream direction (0 m, 25 m, 50 m).

The following parameters were assessed:

- Site-wide: flow composition and water permanence.
- At each transect: bank features (material, height, erosion, slope, undercut), surrounding land use, riparian/ground cover vegetation, canopy cover, overhanging vegetation, and wetted width.
- At each location along a transect: water depth, fine sediment (depth and percentage cover), substrate composition, emergent macrophytes (composition and percentage cover), total macrophytes (composition, percentage cover, depth, species present, and ratio of native to exotic), periphyton (class type and percentage cover), organic matter (type and percentage cover).

Site photographs were also taken at each site (see Appendix B).

2.1.3 Macroinvertebrates

Semi-quantitative macroinvertebrate sampling was completed at Site 5, within the constructed rock riffle, using Collection Protocol C1 for hard bottomed streams (Stark et al., 2001). Macroinvertebrates were identified to the lowest practical taxonomic level.

The kākahi relocation reach (Site 11) was assessed via a timed visual survey, and included an up and downstream buffer to account for any potential movement outside of the relocation zone. Kākahi were measured and returned to the streambed immediately (rather than collected) to minimise disturbance.

2.1.4 Fish

Sites 1-8 were fished in sequential order, starting at the most downstream site (Site 8). A 50 m reach was established at all sites except Site 5, where the reach extended the length of the rock riffle (25 m). All sites, except Sites 4 and 5, were fished using a combination of trapping/netting and single pass electric fishing. At Site 4, water depth and flow conditions were unsuitable for electric fishing, so only trapping/netting techniques were deployed. Similarly, at Site 5 water depth and flow conditions were unsuitable for trapping/netting therefore only electric fishing was used.

For trapping/netting, two large, fine mesh, fyke nets and five gee minnow traps were placed throughout the 50 m reach in the afternoon, left unbaited overnight, and collected the following morning. The fish caught in the traps were counted, identified to species level where practical, and had their length measured and recorded to the nearest millimetre. If required for identification and safer handling, fish were anaesthetised with clove oil. Fish were then placed in a well aerated bucket to recover while electric fishing was undertaken. Single-pass electric fishing was conducted in a downstream to upstream direction. Fish caught were processed as above, and once all measurements were recorded, all fish were released back into the site.

To avoid a misrepresentation of change in species-specific presence upstream of the weir/constructed riffle, juvenile bullies and eels that could not confidently be identified to species level were identified to genus level.

2.2 Data analysis

All statistical analysis was completed using the open-source statistical computing and graphics software, R. The statistical packages MASS (Venables & Ripley, 2013) and 'emmeans' were used in addition to base R packages to complete generalised linear models and interpretation as detailed in Section 0 below. Macroinvertebrate and fish community analyses (Section 0) were completed using the Vegan Package (Oksanen et al., 2013).

2.2.1 Water quality and habitat

Water quality and habitat data were compared to relevant CSNDC EMP (version 9) guidelines and a qualitative assessment undertaken.

2.2.2 Macroinvertebrates

A variety of metrics commonly used and adopted by the Ministry for the Environment as stream health indicators were used to assess the health of the macroinvertebrate community, and in accordance with CSNDC. A description of the metrics used is provided below:

- Taxa richness: the number of different taxa present in a sample. Streams supporting a high number of different taxa can indicate healthy communities.
- EPT taxa: the number of and percent abundance of macroinvertebrates classified by the Ephemeroptera, Plecoptera, Trichoptera insect orders (%EPT taxa and %EPT abundance, respectively). Both metrics were calculated with the *Oxyethira* and *Paroxyethira* genera (axe-head caddisfly and purse caddisfly, respectively) removed. *Oxyethira* and *Paroxyethira* are often excluded from EPT calculations throughout the New Zealand literature (Clapcott et al., 2017).
- Hard-bottom Macroinvertebrate Community Index (MCI_{hb}): the MCI allocates macroinvertebrate taxa a score between 1 (pollution tolerant) and 10 (pollution sensitive), depending on each taxon's tolerance to organic enrichment. A macroinvertebrate community score is generated based on the scaled average score calculated from all taxa within the community sampled (i.e., presence/absence data).
- Quantitative Macroinvertebrate Community Index (QMCI): a variant of the MCI, the QMCI is sensitive to changes in the relative abundance of different taxa.

Stream health can be inferred from the MCI and QMCI scores using Table 1.

It was intended to complete non-metric multidimensional scaling (NMDS) ordination and SIMPER analysis of abundance data. However, this approach could not be used to assess how the community changed between monitoring rounds as there was only two samples to compare (i.e., 2022, 2024). As such, only the Bray-Curtis dissimilarity index was calculated (using abundance data). This provides a measure of dissimilarity between the two samples.

Table 1: Benthic macroinvertebrate indices and threshold limits

	Classification	Descriptions	MCI	QMCI
Stark and Maxted (2007) 'Quality Class'	Excellent	Clean water	>119	>6.00
	Good	Doubtful quality/possible mild pollution	100-119	5.00-5.99
	Fair	Probable moderate pollution	80-99	4.00-4.99
	Poor	Probable severe enrichment	<80	<4.00
National Policy Statement – Freshwater Management (2020) NOF	National Bottom Line	Community largely composed of taxa insensitive to inorganic pollution/nutrient enrichment	90	4.5[1]
CSNDC Attribute Target Level	Spring-fed-plains – urban waterways	-	-	3.5

Notes:

1. Identical to the Land and Water Regional Plan Freshwater Outcome for Spring-fed -plains urban waterways

2.2.3 Fish

Population density was described using catch per unit effort (CPUE). CPUE was calculated as fish per net per night for netting and trapping or count per 100 m^2 for electric fishing. Fishing area was defined by multiplying the mean wetted stream width by the reach length. Fish length distributions were graphed and described per taxonomic group, while changes in taxonomic richness were assessed qualitatively.

Generalised Linear Models (GLMs), assuming Poisson or negative binomial distributions, were used to test for differences in fish population density upstream and downstream of the weir. Specifically, statistical analyses were undertaken on:

- combined fish density (all fish, migratory and non-migratory) by:
  - location
  - year
  - location x year.
- Fish density for each species by:
  - location.
  - year.

Where relevant, NMDS ordination was run to determine if the fish community found was similar among the sites surveyed, between control (i.e., downstream) and impacted (i.e., upstream) sites, and over time. An analysis of similarities (ANOSIM), with 100 permutations, was used to test for significant differences in fish community composition over time. Similarity percentages (SIMPER) was also calculated to show which species are driving any differences. The rock riffle remediation site (Site 5) has not been included in any statistical analysis as there is no pre-remediation data to compare to.

3.0 Results

3.1 Water quality

Physicochemical surface water quality results are presented in Table 2. On the date of the assessment, sites were characterised as follows:

- **Temperature:** surface water temperatures were consistently cool throughout the assessment sites, measuring below the CSNDC Median Guideline Value (20°C). Variation between assessment sites was moderate, with a range of 2.9°C between the coolest (Site 8) and warmest (Site 5) sites. The highest temperatures were recorded at Sites 4-6, which are in very close proximity to each other. The most upstream of these sites (Site 4) was characterised by slower flow conditions and a wider channel, which may have resulted in increased solar warming of the waters. There was no notable difference in mean temperature upstream or downstream of the constructed rock riffle (15.5 and 15.4°C respectively).
- **Dissolved Oxygen (DO):** DO measurements were all well above the lower guideline limit specified in the CSNDC (70%), with the lowest measure recorded at Site 1 (95.6%). DO saturation was slightly lower upstream, with a mean of 101% compared to 108% downstream.
- **Electrical Conductivity (EC):** There is no EC guideline in Version 9 of the CSNDC; however, measurements were all above the upper ANZG (2018) Default Guideline Limit (DGV) for the assessment sites. This guideline is congruent to the CSNDC Version 10 EC guideline. Conductivity was comparable upstream and downstream, at 171 µS/cm and 174 µS/cm respectively.
- **pH:** pH levels were within the guideline range specified in the CSNDC EMP (6.5-8.5), with levels circumneutral at all assessment sites. Mean levels were also the same upstream and downstream at 7.0.
- **Turbidity:** turbidity levels were all well below the CSNDC Waterway Guideline (1.3 NTU).

Table 2: Physicochemical surface water quality results for all sites in November 2024. Sites were located upstream, downstream and within the rock riffle footprint (Weir A).

Parameter	Upstream of rock riffle				Rock Riffle	Downstream of rock riffle			CSNDC Median Guideline Level[1]
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	
Temperature (°C)	14.7	14.6	15.9	16.6	16.8	16.4	15.9	13.9	≤20
DO (% saturation)[2]	95.6	100.8	103.2	104.4	109.8	107.2	107.2	109.6	≥70
DO (mg/L)[2]	9.75	10.29	10.25	10.2	10.64	10.48	10.64	11.32	-
EC[3] (µS/cm)	180.2	174.6	153.4	175.5	174.8	174.1	175.6	172.9	-
pH	6.88	7.31	6.9	7.1	7.03	6.98	7.09	7.05	6.5-8.5
Turbidity (NTU)[4]	-	0.21	0.12	0.23	0.85	0.64	0.44	-	≤1.3

Notes:

1. *Shaded cells indicate non-compliance with CSNDC Waterway Guideline Levels, as per Table 3 of the CSNDC EMP (version 10, January 2025). Note, that all sites complied therefore no cells are shaded.*
2. *DO = Dissolved oxygen*
3. *EC = Specific electrical conductivity, i.e., standardised to 25°C*
4. *Turbidity data was not collected from Site 1 and Site 8 due to instrument error.*

3.2 Habitat assessment

Aquatic habitat assessment results for each assessment site are presented in Appendix C. Summary stream habitat results are presented below. Unless otherwise stated, all data presented is the site mean. Habitat data was not collected in November 2022, therefore no comparison of habitat changes can be made.

3.2.1 Surrounding land use, riparian, and bank features

The surrounding land-use for assessment sites was characterised as urban, park or residential. All sites had either fully or partially artificial banks.

Mean measurements relating to riparian habitat of the assessment sites are presented in (Figure 4). Bank undercut was variable between sites, ranging from 0 cm at Sites 2-5, to 29 cm at Site 7. All downstream sites recorded bank undercuts (Sites 6-8) but only one upstream site did (Site 1). Overhanging vegetation was recorded at all sites, ranging from 3.5 cm at Site 3 to 242 cm at Site 8. Site 8 had atypically high overhanging vegetation compared to the other survey sites, which did not show a notable upstream/downstream difference. Sites had either a partially (4-33%; Sites 1-3, and 6-8), or fully (Sites 4 and 5) open canopy comprised of a combination of grass, shrubs, flaxes, ferns, and exotic and native trees. Canopy cover was more variable upstream than downstream, where both higher and lower cover was recorded upstream. Standard deviation was high at all sites where bank undercuts, overhanging vegetation and canopy cover were recorded, indicating high within site variability.

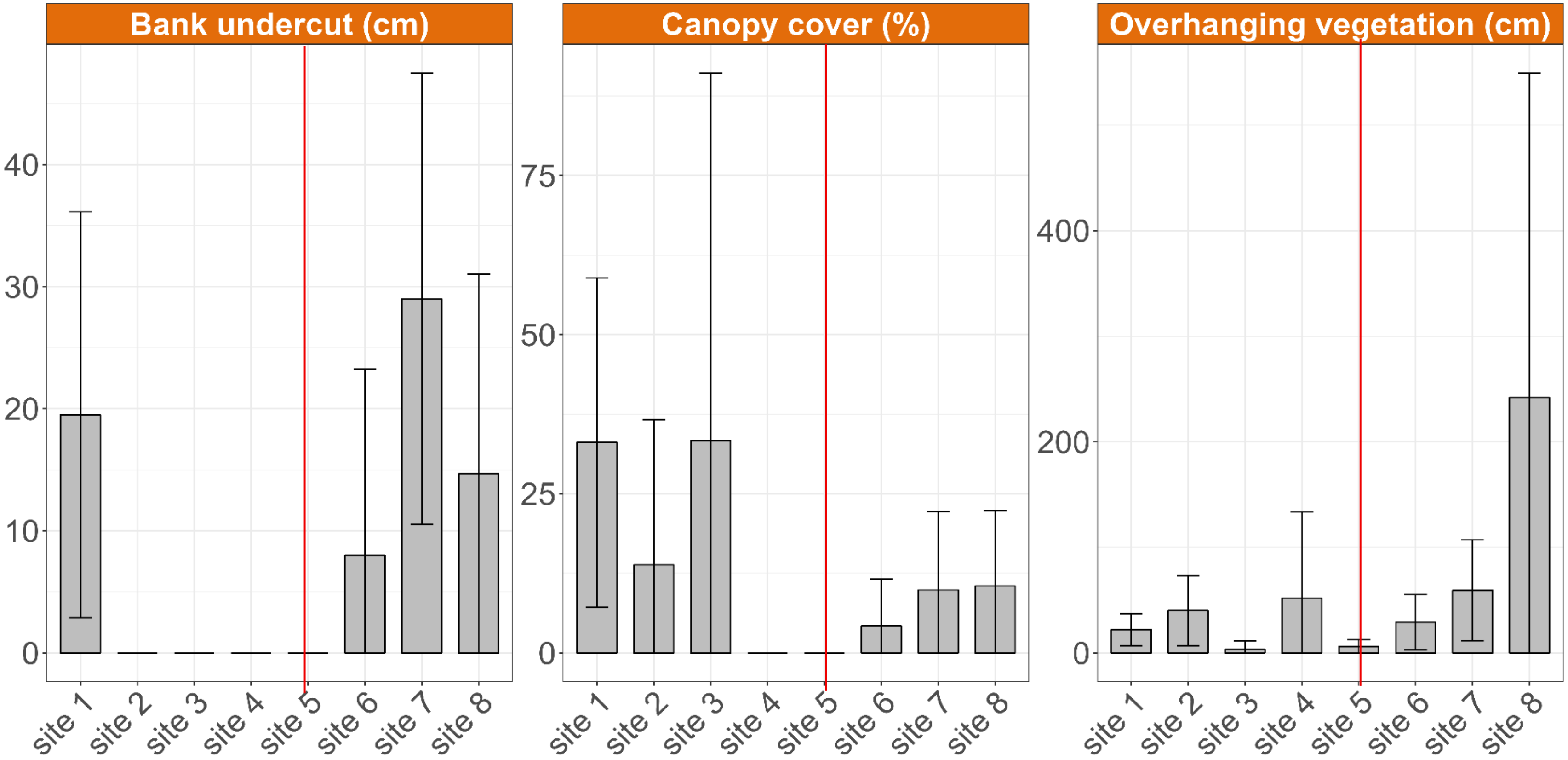

Figure 4. Mean (±1 SD) riparian and bank features for Ōtākaro - Avon River and Ōtākaro - Avon River tributary sites located upstream (left of red line) and downstream (right of red line) from the Mona Vale Weir A in 2024. Note that SD bars have been truncated to end at zero

3.2.2 Flow conditions

Perennial flow conditions were noted for each of the assessment sites. Runs were the sole flow type at most sites. Site 2 also had 30% riffle. Site 5 (the constructed rock riffle) had the most diverse mesohabitat types, with pool, run, riffle and rapids being recorded (Figure 5).

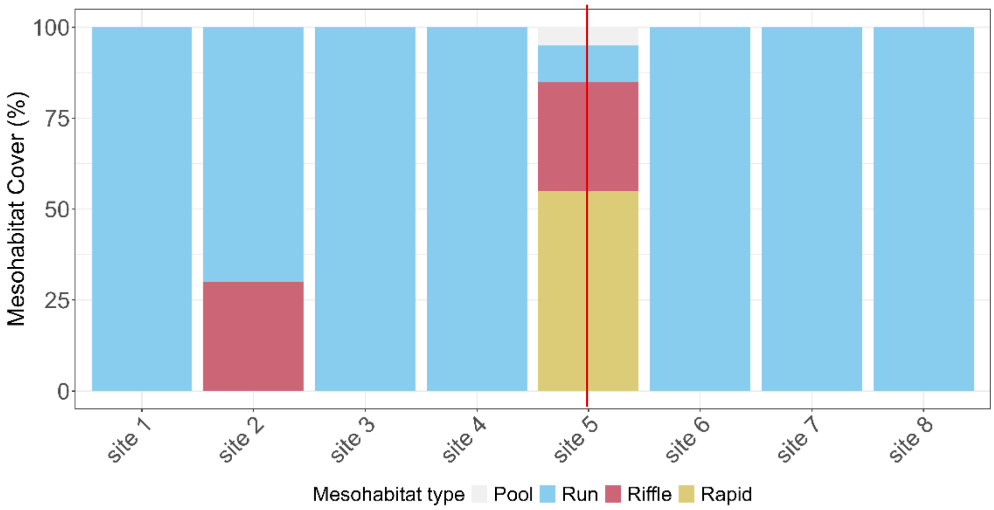

Figure 5: Percentage of stream flow conditions for assessment sites located upstream (left of red line, Sites 1-4) and downstream (right of red line, Sites 6-8) from Weir A in 2024.

Mean measurements relating to the hydrology and channel morphology of the assessment sites are presented in (Figure 6). At the site-level, mean water depth was variable but generally higher at sites downstream of the constructed rock riffle (upstream mean was 342 mm, downstream mean was 447 mm). Water depth was lowest at Site 5 (the weir – 240 mm). Wetted width was highly variable between sites both upstream and downstream, although was generally wider downstream (upstream range: 3.79-16.47 m, mean: 9.41 m; downstream range: 7.01-15.33 m, mean: 10.54 m).

At the upstream sites, velocity decreased in a downstream direction, while there was no pattern downstream of the weir. Mean upstream velocity was lower than downstream of the rock riffle, at 0.24 m/s and 0.44 m/s respectively. Velocity was markedly higher at Site 5 (0.95 m/s), but was highly variable within the site itself.

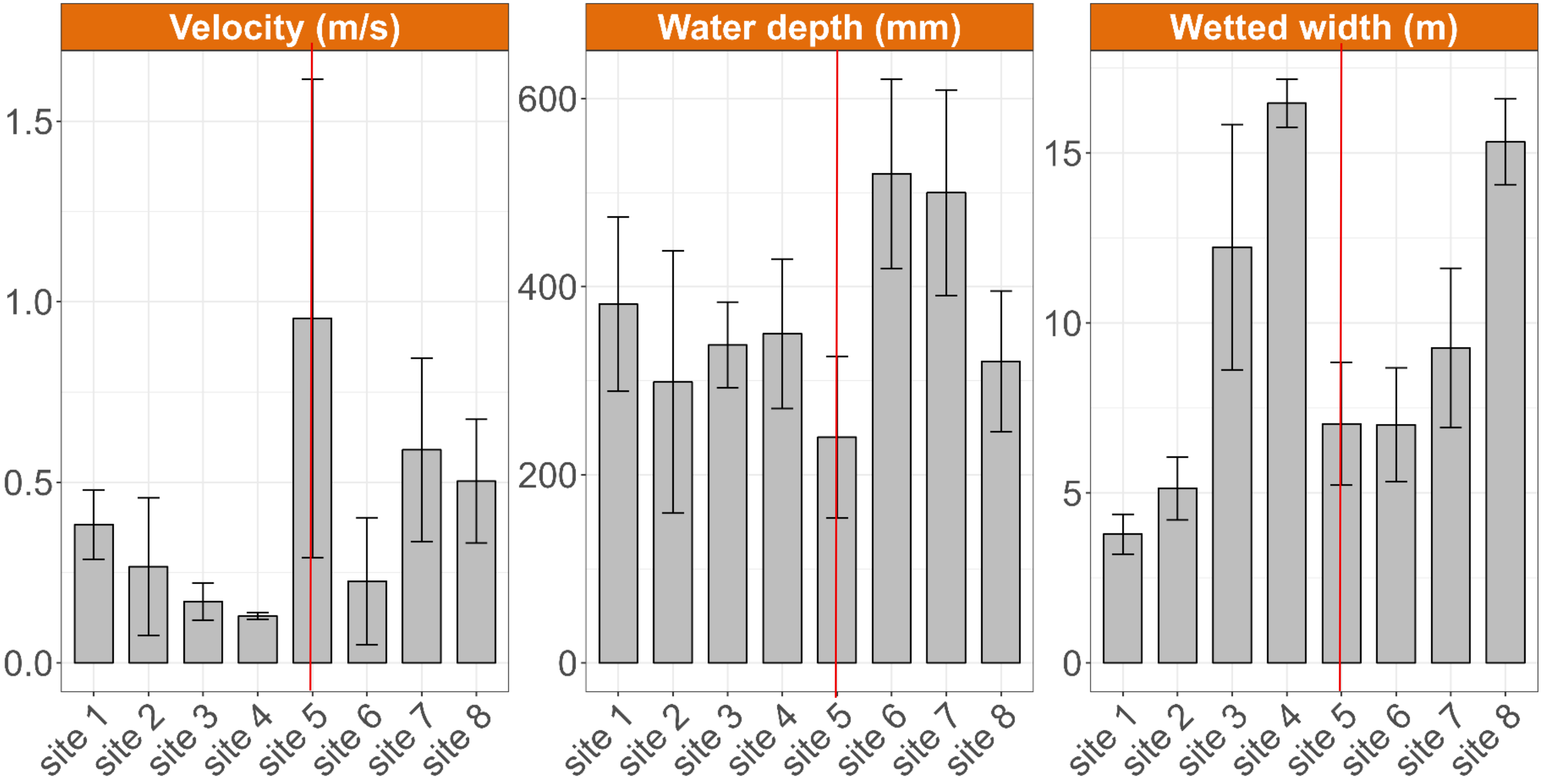

Figure 6. Mean (± 1 SD) channel morphology and hydrological features for Ōtākaro - Avon River and Ōtākaro - Avon River tributary sites located upstream (left of red line) and downstream (right of red line) from the Mona Vale Weir A in 2024.

3.2.3 Stream bed substrate

At all sites except Site 5, the dominant bed substrate was fine sediment (sand/silt, Figure 7). This resulted in the CSNDC Attribute Target Level for fine sediment cover (30%) being exceeded at all sites except Site 5. Of the sediment-dominated sites, Site 1 had the lowest proportion of silt/sand (54%) and had the most diverse substrate with five types recorded (silt/sand, gravels, pebbles, small cobbles and bedrock/artificial substrate). At least two sediment types were recorded from all sites except Site 4. Site 5 was the only site to have all seven substrate types recorded, with large cobbles forming the highest proportion at 28%.

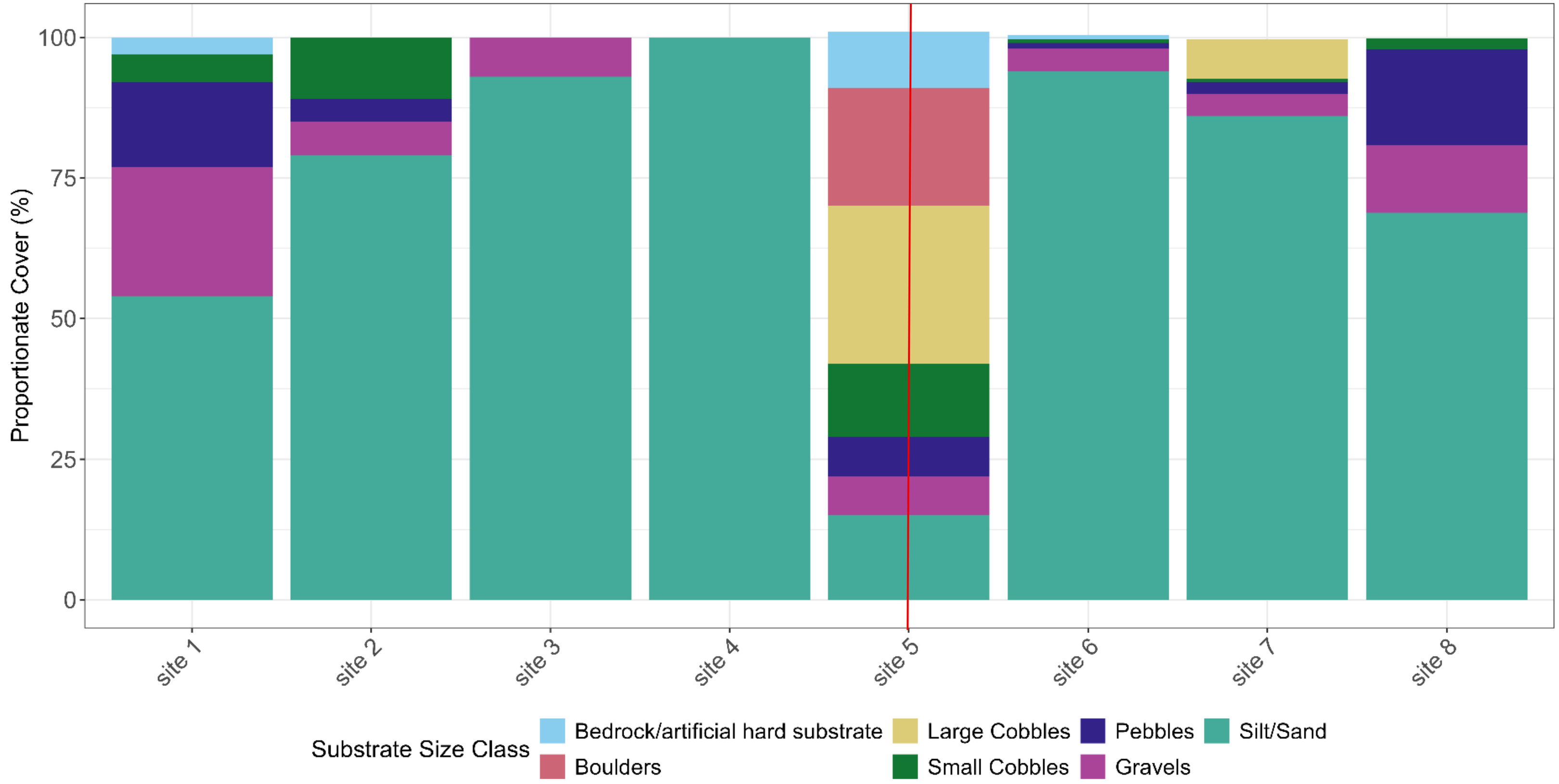

Figure 7: Mean percentage cover of stream bed substrate size classes recorded from Ōtākaro - Avon River and Ōtākaro - Avon River tributary sites located upstream (left of red line) and downstream (right of red line) from the Mona Vale Weir A in 2024.

At sites upstream of the remediation site, embeddedness and fine sediment depth increased with distance downstream (Figure 8). However, the converse was true at the downstream sites, where they decreased with distance downstream. Despite this, mean embeddedness was comparable upstream and downstream at 81% and 84% respectively. In contrast, fine sediment was typically deeper at upstream sites, with a mean depth of 293 mm compared to 45 mm downstream. Overall, both metrics were lowest at Site 5 (25% and 3 mm respectively). However, embeddedness was highly variable at Site 5 but fine sediment depth was consistently low. Embeddedness was generally highly variable within sites, except for Site 4 which recorded 100% at all sampling locations. In contrast, fine sediment depth was highly variable at sites upstream, and less so at those downstream.

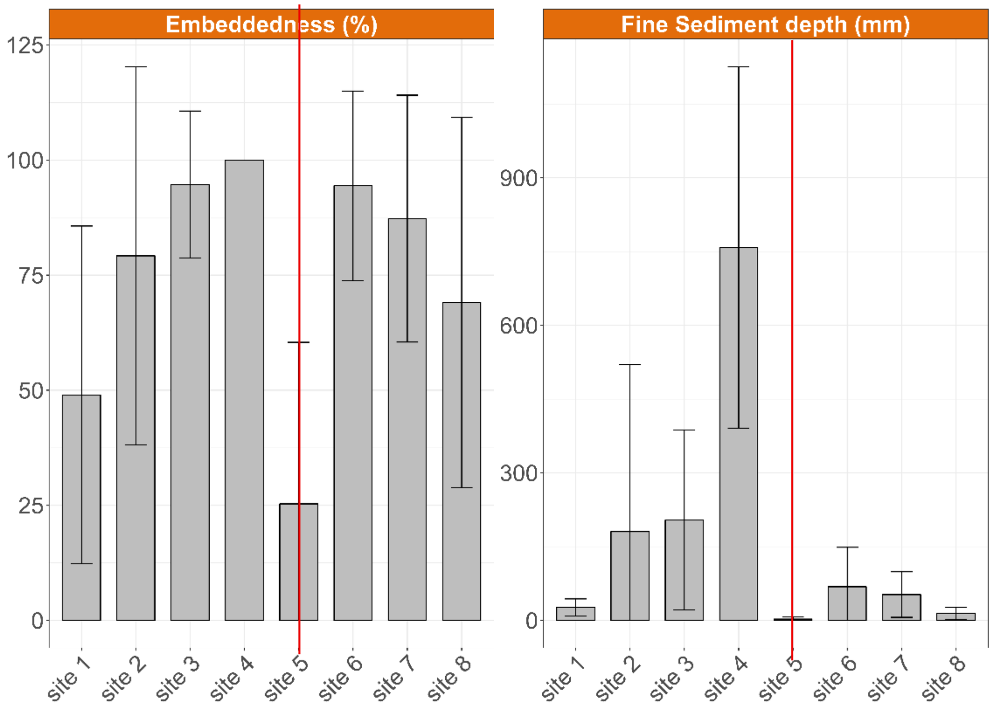

Figure 8: Mean (± 1 SD) fine sediment depth and embeddedness recorded from Ōtākaro - Avon River and Ōtākaro - Avon River tributary sites located upstream (left of red line) and downstream (right of red line) from the Mona Vale Weir A in 2024. Note that SD bars have been truncated to end at zero

3.2.4 Periphyton

Total periphyton percentage cover was highly variable amongst assessment sites (Figure 9). Excluding Site 5, the highest mean periphyton cover was measured from Site 8 (50%) and lowest at Site 4 (0%). Mean total periphyton cover was generally higher downstream (31%) than upstream (11%), but thin mat periphyton was comparable (9% and 7% respectively). Periphyton cover was dominated by the thin-mat subcategory at all sites for which periphyton was present, except Sites 6 and 8 which were dominated by the long filamentous subcategory. Long filamentous periphyton was more common downstream, and short filamentous and thick mat periphyton were found downstream but not upstream. Percentage cover of medium and thick mat, and short filamentous periphyton, were low (or absent) at all sites.

Average long filamentous periphyton cover did not exceed the upper limit specified as the CSNDC Attribute Target Level (30%) at any of the assessment sites.

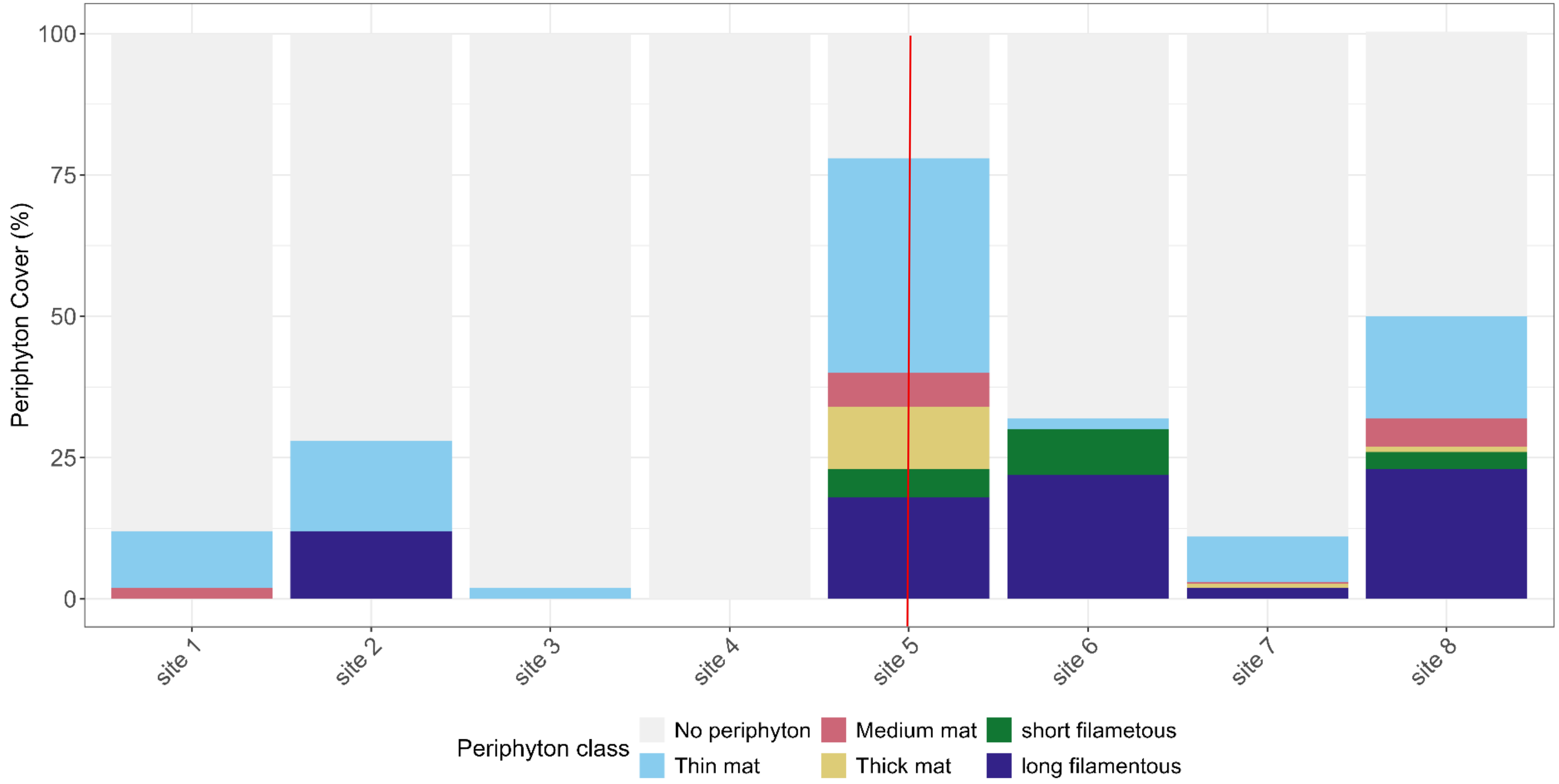

Figure 9: Mean percentage cover of periphyton, by subcategory, recorded from Ōtākaro - Avon River and Ōtākaro - Avon River tributary sites located upstream (left of red line) and downstream (right of red line) from the Mona Vale Weir A in 2024.

3.2.5 Macrophytes

Mean macrophyte cover and depth measurements from assessment sites located upstream and downstream from Weir A are presented in Figure 10. The Council undertook weed clearing in Wairarapa Stream (upstream, Site 3) in late September/October 2024, and in the Ōtākaro - Avon River downstream of Mona Vale from December 2024 (pers. comm Kirsty Patten). As such, survey sites were not recently impacted by weed clearing, but higher macrophyte cover may be expected at downstream sites.

Emergent macrophytes were absent from all sites except Site 6, where they were only recorded from one location, giving Site 6 a mean cover of 7%. In contrast, submerged macrophytes were present at all sites, including a combination of Canadian pond weed (*Elodea canadensis*), curly pond weed (*Potamogeton crispus*), monkey musk (*Erythranthe guttata*), watercress (*Nasturtium* sp.), mint (*mentha* sp.), milfoils (*Myriophyllum* spp.), starwort (*Callitriche* sp.), glyceria (*Glyceria* sp.), and macroalgae (Charophyta). Of these taxa, most are exotic; however, the observed milfoil is native at this location, and the macroalgae is also likely to be native.

Total macrophyte cover was more consistent and higher among downstream sites, and the highest mean cover was measured at the downstream Site 6 (87%). The lowest cover was comparable between three sites, ranging from 7-9% at Sites 1, 3, and 5. Macrophyte cover was highly variable within each site, with no upstream or downstream pattern noted with respect to variability.

Mean total macrophyte cover levels exceeded the CSNDC Attribute Target Level of 60% cover at Site 2 (74%), Site 6 (87%), and Site 7 (85%).

Macrophyte depth assessments (expressed as percentage relative to water column depth) indicated that mean macrophyte depth was generally higher at the monitoring sites located downstream (20%) than those upstream (6%), which reflected cover and water measurements. Sites 1, 3-5 had notably lower macrophyte depth ranging from 0.4%-2.8%, where Sites 2, 6-8 ranged from 7-31%.

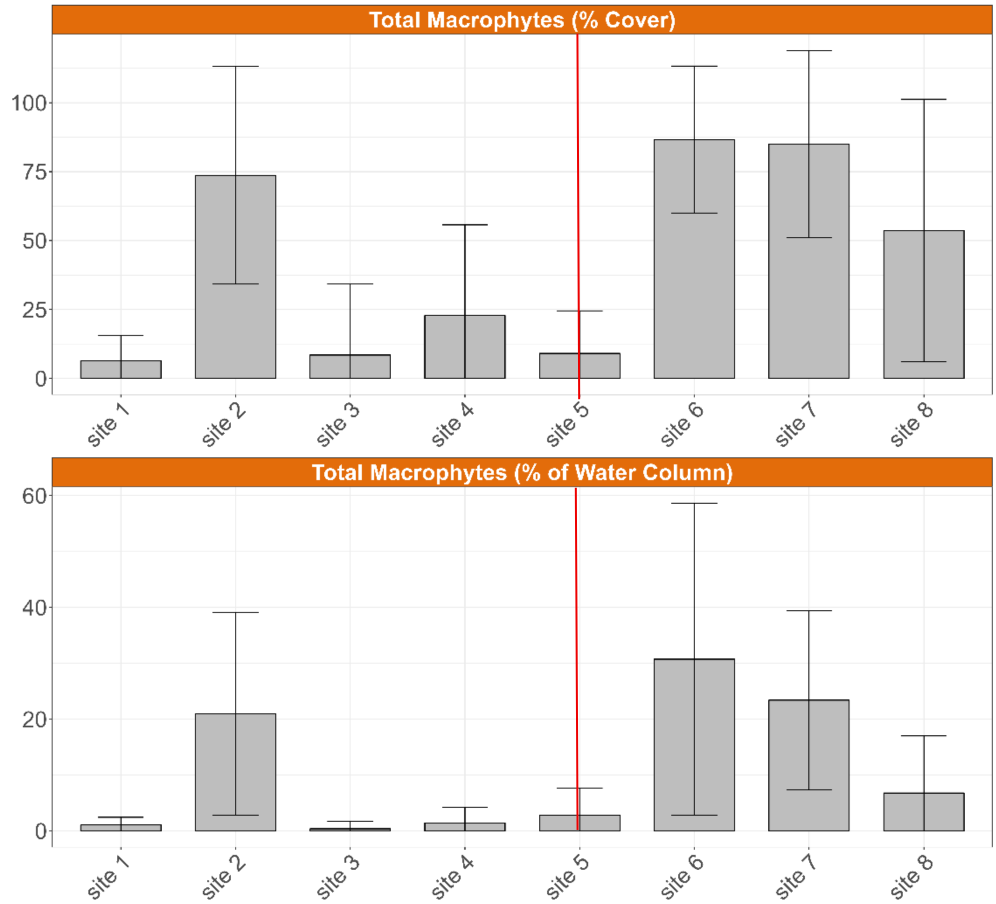

Figure 10: Mean (± 1 SD) percentage total macrophyte cover and mean (±SD) percentage macrophyte depth for Ōtākaro - Avon River and Ōtākaro - Avon River tributary sites located upstream (left of red line) and downstream (right of red line) from Weir A in 2024. Note that lower limits of the SD bars have been truncated where necessary to end at zero.

3.3 Macroinvertebrates

3.3.1 Benthic kick-net

Results for the macroinvertebrate samples collected within the rock riffle/footprint (Site 5) in 2024 and 2022 are compared in Figure 11 and Figure 12. Macroinvertebrate community metrics for 2022 and 2024 are presented in Table 3. A full list of macroinvertebrate taxa recorded in 2022 and 2024 is presented in Appendix D, Table D1.

Pre-remediation, the macroinvertebrate community was made up exclusively of three broad taxonomic classifications: caddisflies (Trichoptera), crustaceans (Crustacea) and molluscs (Mollusca). However, post-remediation true flies (Diptera), and other macroinvertebrates were also present. Pre-remediation, Crustacea were numerically dominant in the community and was almost entirely comprised of Ostracoda. Post-remediation Molluscs predominated, with a large proportion comprised of the New Zealand mud snail (*Potamopyrgus antipodarum)*.In both years caddisflies were numerically scarce but formed the most taxonomically rich group.

Total taxonomic richness was higher following remediation, increasing from 11 to 20 taxa. Percentage EPT abundance was low yet similar between pre- and post-remediation (6.64% and 6.35% respectively). Six EPT taxa were recorded from the 2022 study and five were recorded in 2024, although taxonomic resolution varied. For example, in 2024 some hydrobiosids were identified to genus level while others were classified as Hydrobiosidae. Therefore, depending on the taxa classified as Hydrobiosidae, there may be four of five EPT taxa in 2024.

Between 2022 and 2024, MCI scores declined from 'good' to 'poor', and QMCI declined from 'fair' to 'poor' (Stark and Maxted (2007) narrative quality class). This corresponds to NPS-FM Attribute Band C for the MCI score and D for the QMCI score in 2022. Scores for both metrics were consistent with Attribute Band D in 2024, and were below the national bottom line. At 3.61, the QMCI score was above the CSNDC spring-fed-plains-urban waterways Attribute Target Level of 3.5.

The Bray-Curtis dissimilarity index showed that the macroinvertebrate communities were moderately dissimilar between 2022 and 2024 (0.65[2]). Visual assessment indicates the community shift seen in 2024 was primarily due to a substantial decrease in the abundance of *Paracalliope* sp. and increase in the New Zealand mud snail (Appendix D, Table D1). To a lesser extent, *Physa* snail relative abundance was also lower in 2024, and Ostracoda and Oligochaeta relative abundance was higher.

[2] Scores vary from 0-1, with 0 representing identical communities, and 1 communities with no species in common.

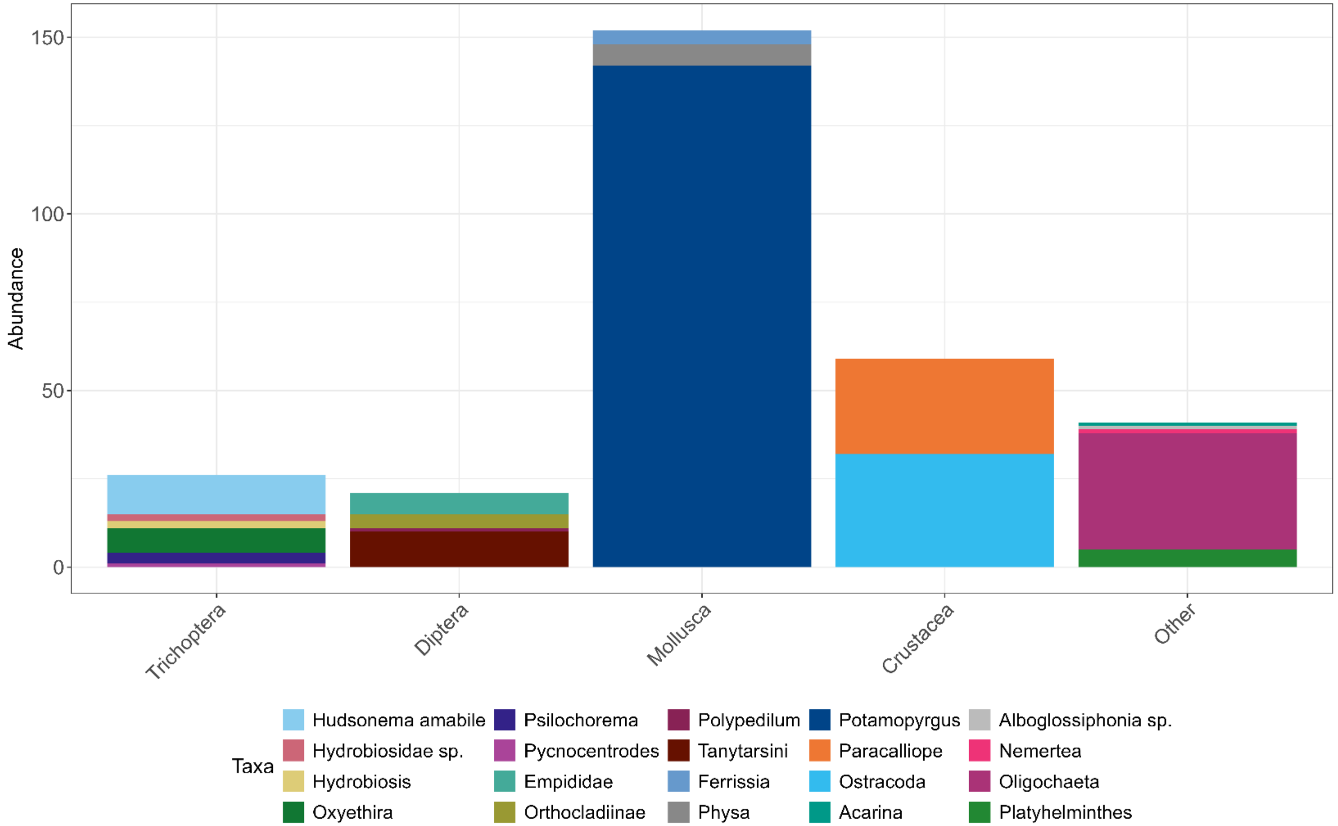

Figure 11: Macroinvertebrate community composition, arranged by key taxonomic groupings, sampled from the constructed rock riffles (Site 5) in April 2024. Vertical axis represents total sampled abundance for the 200 fixed count plus scan for rare taxa methodology (i.e., Protocol P2 in Stark et al. (2001)).

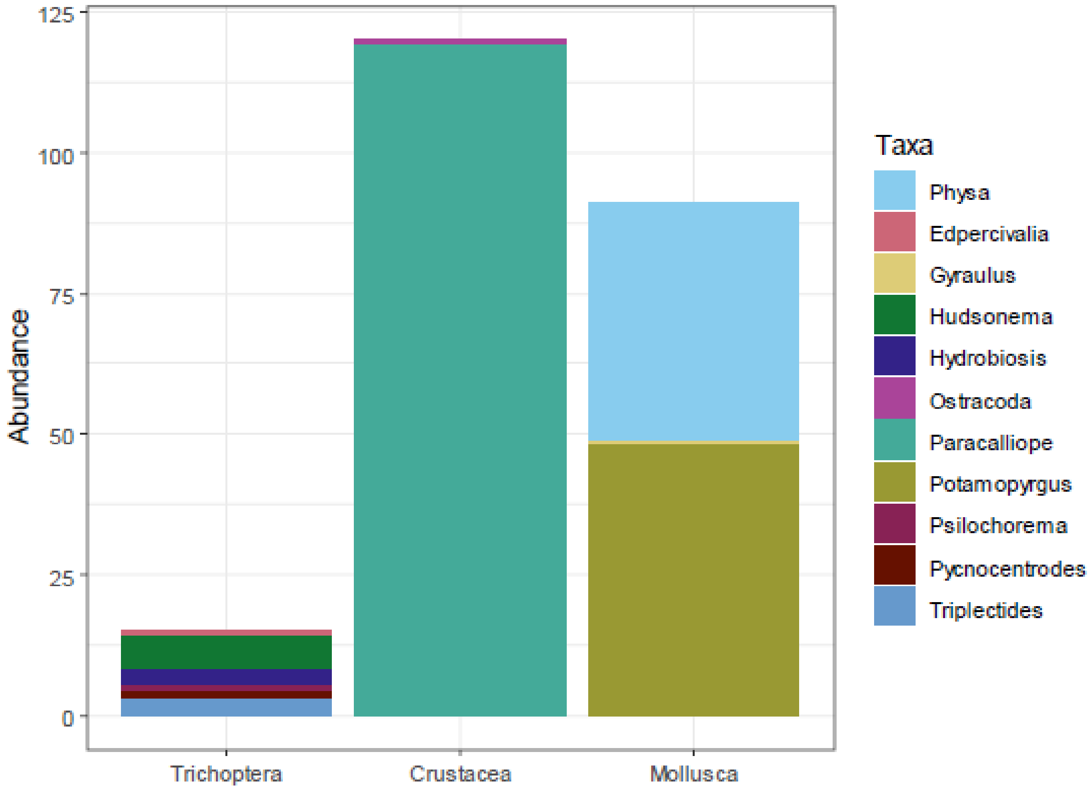

Figure 12. Macroinvertebrate community composition, arranged by key taxonomic groupings, sampled from the Mona Vale Weir A footprint site (Site 5) in April 2022. Vertical axis represents total sampled abundance for the 200 fixed count plus scan for rare taxa methodology (i.e., Protocol P2 in Stark et al. (2001)).

Table 3: Community metrics calculated from the macroinvertebrate samples collected from Site 5 in April 2022 (the rock riffle footprint) and April 2024 (constructed rock riffle).

Community Metric	April 2022	April 2024
Taxonomic Richness	11	20
%EPT	6.64	6.35
%EPT Taxa	54.55	25
MCI[1]	101.82 (Good/Band C)	76 (Poor/Band D)
QMCI[1]	4.46 (Fair/Band D)	3.61 (Poor/Band D)

Notes:

1. *Narrative descriptions for MCI and QMCI values derived from Stark and Maxted (2007) and Attribute Bands from the National Policy Statement – Freshwater Management (2020)*

3.3.2 Kākahi survey

After one hour of searching, a total of three live kākahi were found in the relocation zone (Site 11). Two kākahi shells were also found. All kākahi were found as solitary individuals and evenly distributed through the survey reach. In 2022 ten live kākahi were found in the relocation zone, and 19 were transferred from the works footprint.

Live kākahi were 72 mm in length, and the one dead kākahi measured was 80 mm in length. None of the kākahi found had etch marks (Figure **13**), indicating they were not kākahi that had been relocated from the work zone prior to the remediation of the weir.

Figure 13. A kākahi located from Site 11 in 2024 (top). No etchings are visible, indicating this is not a relocated individual. Kākahi relocated from the works zone in 2022 showing etch marks (bottom).

3.4 Fish

A statistical analysis, comparing the freshwater fish communities upstream and downstream from Weir A and between the 2022/2024 assessment years, was completed separately for the active fishing (i.e., electric fishing) and passive fishing (i.e., fyke netting and Gee minnow trapping) methods used. It is noted that passive fishing methods were used at all sites except for Site 5 (the rock riffle site), while the active electric fishing methodology was employed at all sites except Site 4 due to inappropriate sampling conditions. Results are presented separately below, while combined summary catch data is in Appendix E, Tables E1-E2.

3.4.1 Active fishing

3.4.1.1 Taxonomic richness

In 2022, mean taxonomic richness of fish was lower upstream of the weir compared to downstream (3.0 and 5.0 taxa, respectively) (Table 4). However, in 2024 mean taxonomic richness was the same upstream and downstream (4.3). Mean taxonomic richness was calculated with unidentified bullies and eels excluded.

Similarly, in 2022 a lower mean taxonomic richness of migratory taxa was recorded from sites located upstream of the weir when compared to downstream (2.0 and 4.0 respectively) (Table 4). However, in 2024 mean taxonomic richness was comparable upstream and downstream of the weir (2.7 and 3.0 respectively).

In 2024, two migratory species were recorded upstream of the weir that were not recorded in the 2022 survey (giant bully and common bully[3]).

[3] A common bully was reported upstream in the baseline assessment; however, upon review of photographs it was reclassified as unidentified.

Table 4: Total taxonomic richness from active fishing at sites upstream and downstream of the Mona Vale Weir/new rock riffle pre and post impact. Species listed in brackets indicates species recorded in that year only. Migratory species are in bold. Note that elvers and unidentified bullies have been excluded from taxonomic richness as they are very likely one of the other species already recorded

Location	Site	2022	2024
Upstream	Site 1	3	5 (**common bully**, brown trout)
	Site 2	3	5 (**giant bully,** brown trout)
	Site 3	3	3
Constructed rock riffle	Site 5	N/A	5 (upland bully, **bluegill bully**, **common bully**, **īnanga**, **longfin eel**)
Downstream	Site 6	4 (**shortfin eel**)	5 (**īnanga**, brown trout)
	Site 7	6 (**lamprey, common bully, bluegill bully**)	3
	Site 8	5 (**freshwater shrimp**)	5 (**longfin eel**)

3.4.1.1 Population density

Electric fishing results were recorded in CPUE (i.e., abundance per 100 m^2) to control for the effect of sampling area on fish abundance per site. Results are presented in Figure 14 and summary tables in Appendix E.

In 2022, the highest CPUE (33.9 per 100m^2) was recorded from Site 6. In 2024, excluding Site 5, the highest CPUE was recorded from Site 1 (12.1 per 100m^2). In 2024, CPUE at Site 5 (34.1 per 100 m^2) was slightly higher than Site 6 in 2022. The lowest CPUE was recorded from Site 3 in both years (5.7 per 100 m^2 and 2.0 per 100 m^2 respectively). Site CPUE was notably lower at most sites in 2024 compared to 2022. The mean CPUE recorded from sites located downstream from the rock riffle was 20.9 per 100 m^2 in 2022 compared to 5.5 per 100 m^2 in 2024. Upstream it was 10.2 per 100 m^2 in 2022 compared to 6.0 per 100 m^2 in 2024.

Results from statistical analyses are presented in Appendix E, Tables E3-E4. Several key scenarios need to be tested to determine whether fish passage objectives have been achieved:

- Did the upstream and downstream migratory fish population density differ in 2022? Yes. Migratory fish abundance was significantly lower upstream in 2022.
- Did the upstream and downstream population density differ in 2024? No (all fish, migratory fish, non-migratory fish). There were no statistically significant (i.e., p values were all greater than 0.05) differences in fish CPUE between upstream and downstream monitoring sites in 2024 for all fish (6.0 per 100m^2 and 5.5 per 100m^2 respectively), migratory fish (4.0 per 100m^2 and 3.0 per 100m^2 respectively), and non-migratory fish (2.0 per 100 m^2 and 2.5 per 100 m^2 respectively).
- If there is no longer a difference upstream and downstream abundance, did upstream population density change post-remediation? No (all fish and migratory fish), yes (non-migratory fish). There was no statistically significant difference between upstream density pre- and post-remediation for all fish and migratory fish; however, non-migratory fish density was significantly higher in 2022.
- If there was no change in migratory fish upstream over time, did downstream population density change post-remediation? Yes (all fish, migratory fish and non-migratory fish). Fish density was significantly lower downstream of the constructed rock riffle in 2024 than 2022 for all fish, migratory fish and non-migratory fish.

The effects of site location and year on taxon-specific CPUE were further explored (Appendix E, Table E5). Due to the low frequency at which īnanga, giant bullies, bluegill bullies, lamprey, brown trout and freshwater shrimp were recorded, statistical analysis was not considered meaningful and was therefore not undertaken.

Results indicate that sampling year had a significant effect on the CPUE of shortfin eel and upland bully ($p<0.05$), with lower CPUE in 2024 (1.1 and 2.0 respectively) compared to 2022 (6.2 and 6.5 respectively). Results for all other tested taxa were not significant for either year or location (common bully, unidentified bullies, longfin eel, and unidentified eels).

Qualitative assessment of taxon-specific abundance shows that common bully, giant bully and brown trout were found upstream in 2024, but were absent in 2022. No unidentified bullies were found upstream in 2024, where they were in 2022. However, even if these were a migratory bully species (rather than the non-migratory upland bully), abundance was notably higher in 2024.

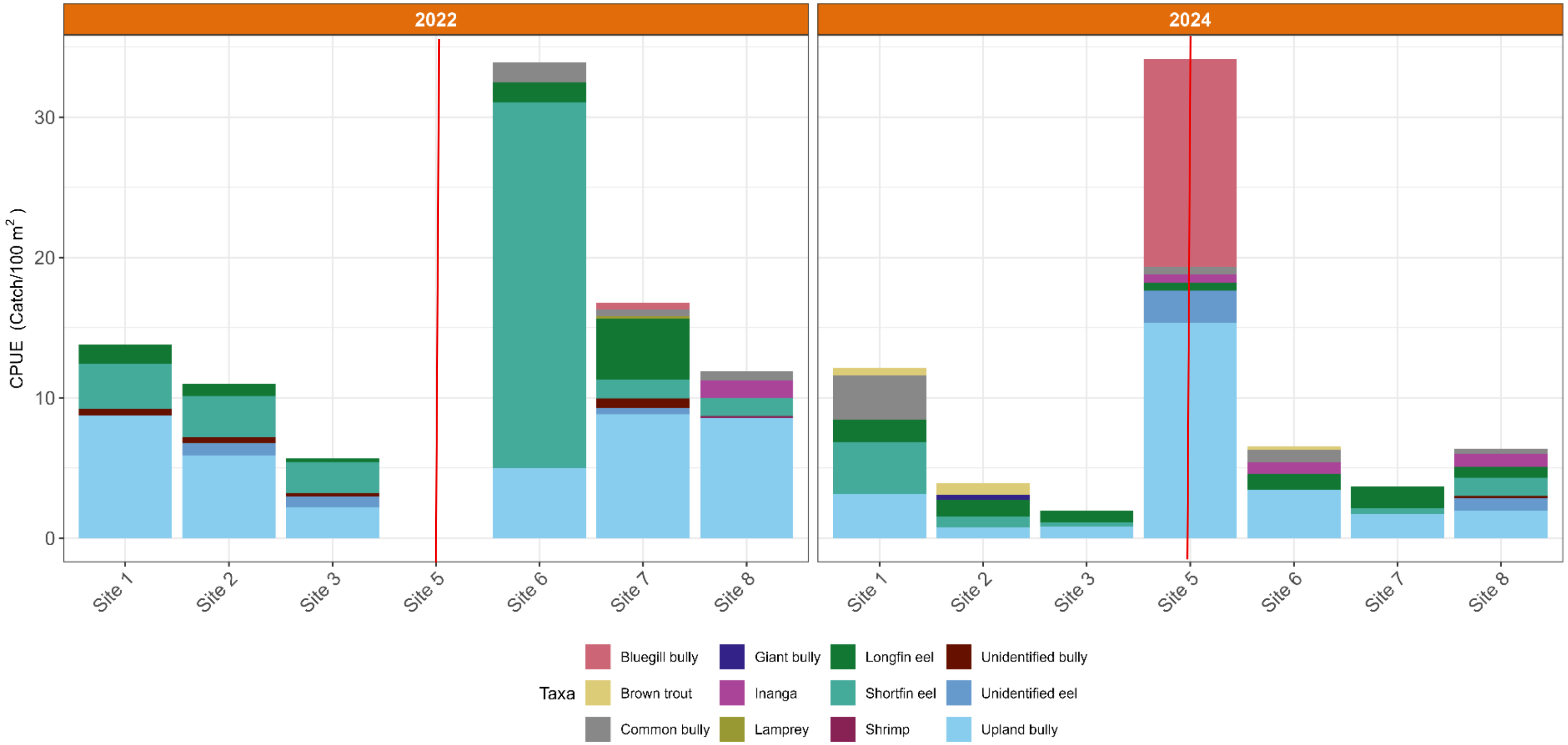

Figure 14: Freshwater fish community composition scaled by CPUE. Electric fishing results from both pre-remediation (November 2022) and post-remediation (November 2024) assessments presented. For both years, to the left of the red line indicates sites located upstream of the constructed rock riffle (Mona Vale Weir A); to the right of the red line indicates sites located downstream from the rock riffle (Weir A). Sites are presented in an upstream to downstream direction, with Site 5 being the rock riffle, which was not sampled in 2022.

3.4.1.2 Community composition

The community-scale effects of site location and year were explored using NMDS ordination on fish CPUE results (Figure 15). NMDS ordination results showed points were loosely clustered by year, indicating communities were somewhat different between years. Additionally, upstream and downstream communities were more dissimilar pre-remediation (2022), indicating communities are more similar post-remediation.

ANOSIM analysis was used to assess the statistical significance of community dissimilarity between years and site locations, with sites located upstream and downstream assessed separately. ANOSIM results indicate there was no statistically significant difference in freshwater fish communities upstream or downstream pre- and post-remediation (Appendix E, Table E7).

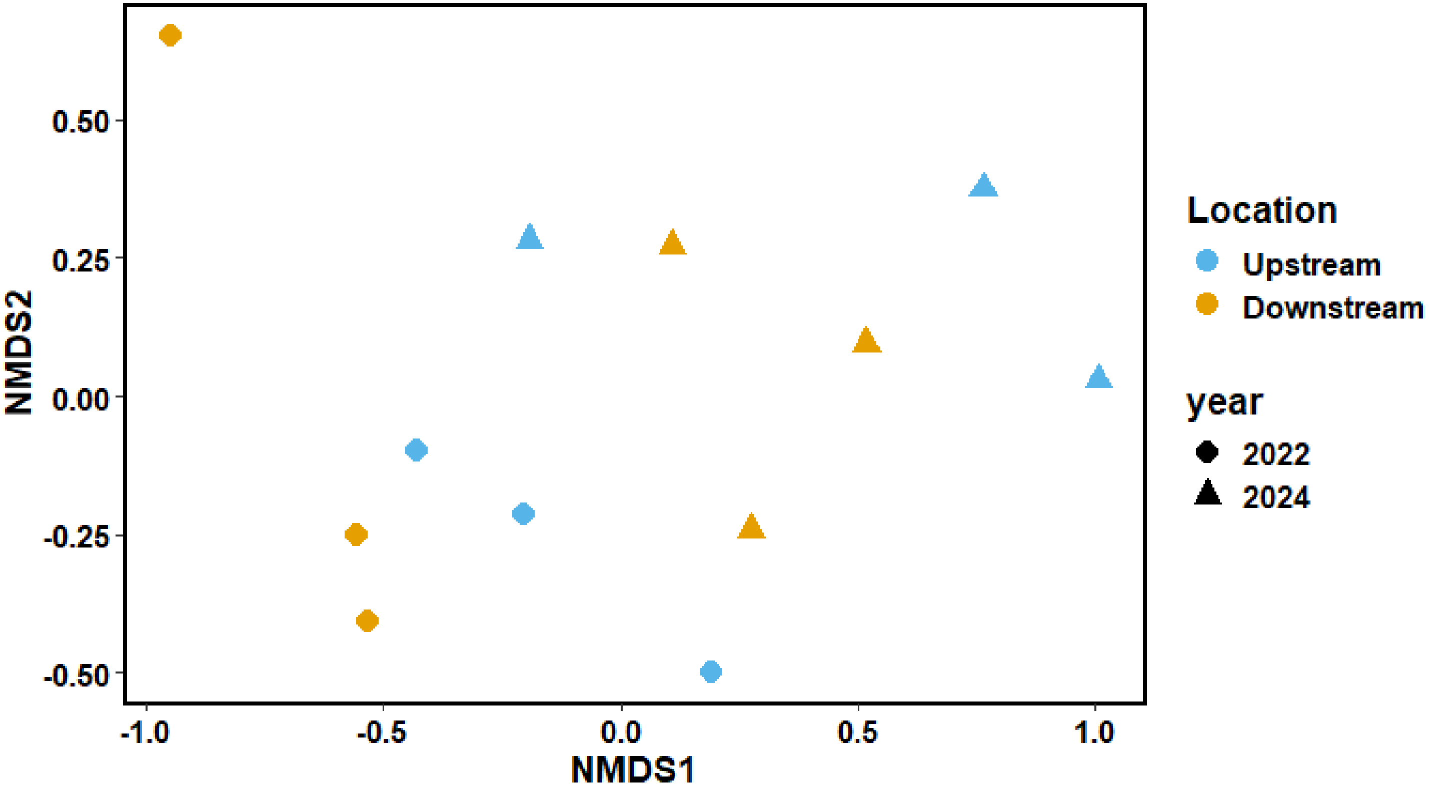

Figure 15: Non-metric multidimensional scaling (NMDS) ordination results for freshwater fish community results (from electric fishing) from Ōtākaro - Avon River and Ōtākaro - Avon River tributary sites surveyed upstream and downstream from Weir A in November 2022 (pre-remediation) and November 2024 (post-remediation). Stress test shows the model is a good fit (0.0734[4]).

3.4.1.3 Fish length

Fish length data is presented to determine if species lengths have changed pre- or post-remediation, which could help to highlight if there are any age cohorts within each species that are not able to navigate the constructed rock riffle. Summary results for fish lengths are presented in Figure 16 and Figure 17, while summary results tables are available in Appendix E. Most taxa had some variation but overall there was no clear pattern in fish length between years (i.e., pre or post remediation). Similarly, there was no consistent pattern in variation in fish length upstream and downstream of the rock riffle. It should also be noted that for many taxa (e.g., bluegill bullies and īnanga), catches were consistently very low, and it is not reasonable to attribute variation in fish length to the effects of assessment year or location.

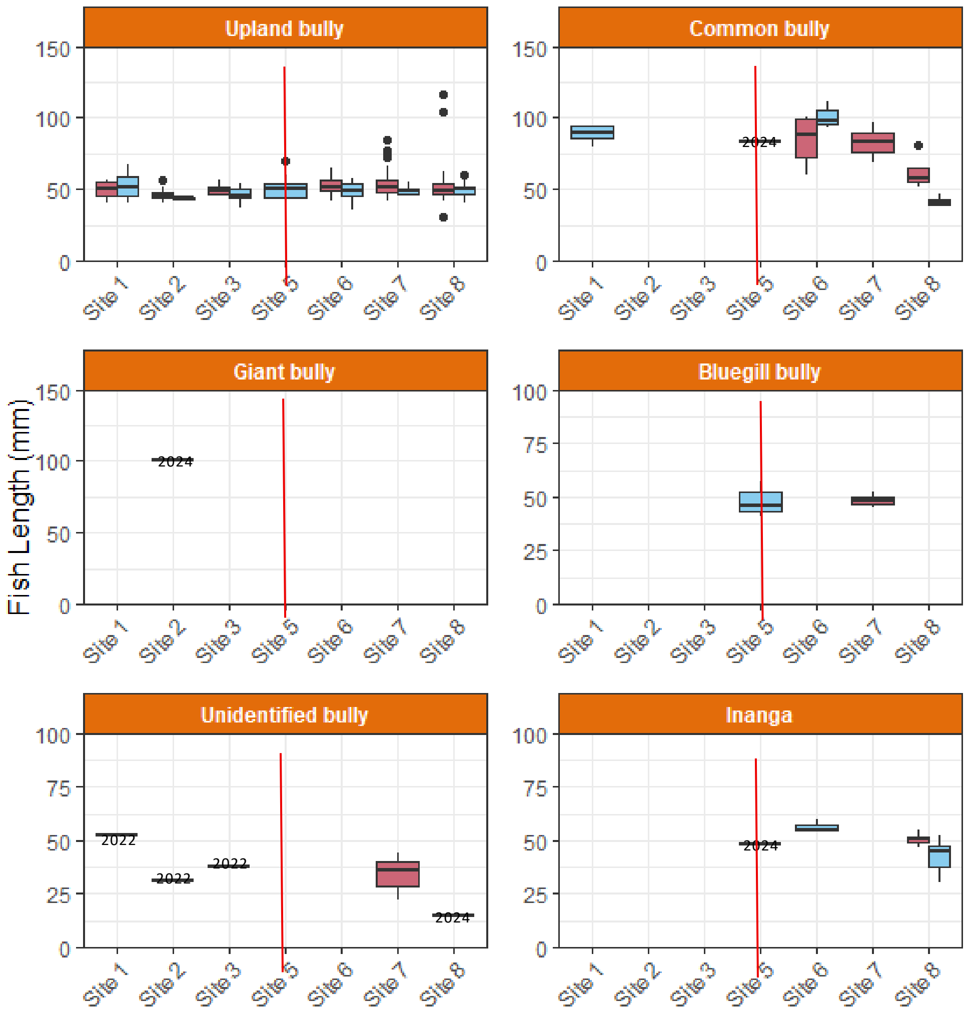

Figure 16: Fish length by taxon from active fishing methods (i.e., electric fishing) pre-impact (2022 – red boxes) and post-impact (2024 – blue boxes). To the left of the red line indicates sites located upstream of the constructed rock riffle (Mona Vale Weir A); to the right of the red line indicates sites located downstream from the rock riffle (Weir A).

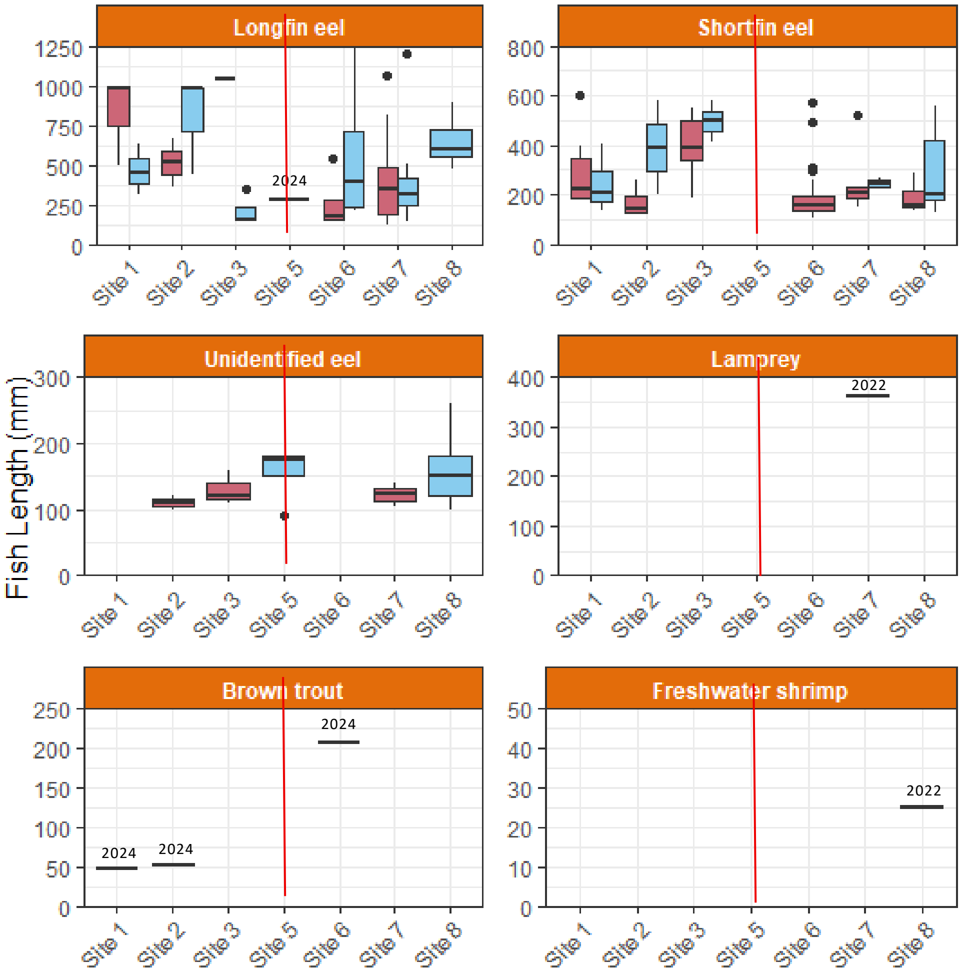

Figure 17: Fish length by taxon from active fishing methods (i.e., electric fishing) pre-impact (2022 – red boxes) and post-impact (2024 – blue boxes). To the left of the red line indicates sites located upstream of the constructed rock riffle (Mona Vale Weir A); to the right of the red line indicates sites located downstream from the rock riffle (Weir A).

3.4.2 Passive fishing

3.4.2.1 Taxonomic richness

Total fish taxonomic richness from passive fishing is presented in Table 5. Slightly higher mean taxonomic richness was recorded from fish communities located downstream from the constructed rock riffle in both 2022 and 2024, with mean downstream taxonomic richness of 3.3 and 2.67 respectively and mean upstream taxonomic richness of 2.75 and 2.5. Slightly higher mean taxonomic richness was also recorded in 2022 than in 2024, both upstream and downstream.

When considering migratory taxa separately, in 2022 mean taxonomic richness was lower upstream (1.5) of the constructed rock riffle compared to downstream (2.67). However, in 2024 mean taxonomic richness was marginally higher upstream (1.75) compared to downstream (1.67). This also shows that despite the decrease in migratory taxa downstream, upstream has still increased.

In 2024, two migratory species were recorded upstream of the weir for the first time (īnanga and common bully).

Table 5: Total fish taxonomic richness at sites upstream and downstream of the Mona Vale Weir/new rock riffle pre and post impact from passive fishing methods. Species listed in brackets indicates species recorded in that year only. Migratory species are in bold. Note that elvers and unidentified bullies have been excluded from taxonomic richness as they are very likely one of the other species already recorded

Location	Site	2022	2024
Upstream	Site 1	3 (brown trout, upland bully)	1
	Site 2	3 (**shortfin eel**)	3 (**īnanga**)
	Site 3	2	4 (**common bully, longfin eel**)
	Site 4	3 (**shortfin eel**)	2
Downstream	Site 6	2 (**Īnanga**)	3 (**giant bully**, upland bully)
	Site 7	3 (**common bully, shortfin eel**)	2 (**longfin eel**)
	Site 8	5 (**common bully**, **freshwater shrimp**)	3

3.4.2.3 Population abundance

Although passive fishing methods were consistent between sites, fishing effort has been standardised to catch per net/trap per night in line with the Council protocol.

Abundance was notably highest downstream in 2024 (post-impact) (Figure 18). The average fish relative abundance recorded from downstream sites was 1.9 in 2022 and 3.2 in 2024, compared to 1.7 and 1.9 recorded from upstream sites respectively.

Statistical assessment results, comparing total, migratory, and non-migratory fish abundance between sites located upstream and downstream from Weir A between the 2022 and 2024 assessment rounds, are presented in Appendix E, Tables E7-E8. No statistically significant differences were found for total and migratory fish; however, non-migratory fish density was significantly lower downstream in 2024 compared to 2022, with the same pattern reflected upstream over time. Results for 2022 confirmed that migratory fish population density was higher downstream in than upstream in 2022.

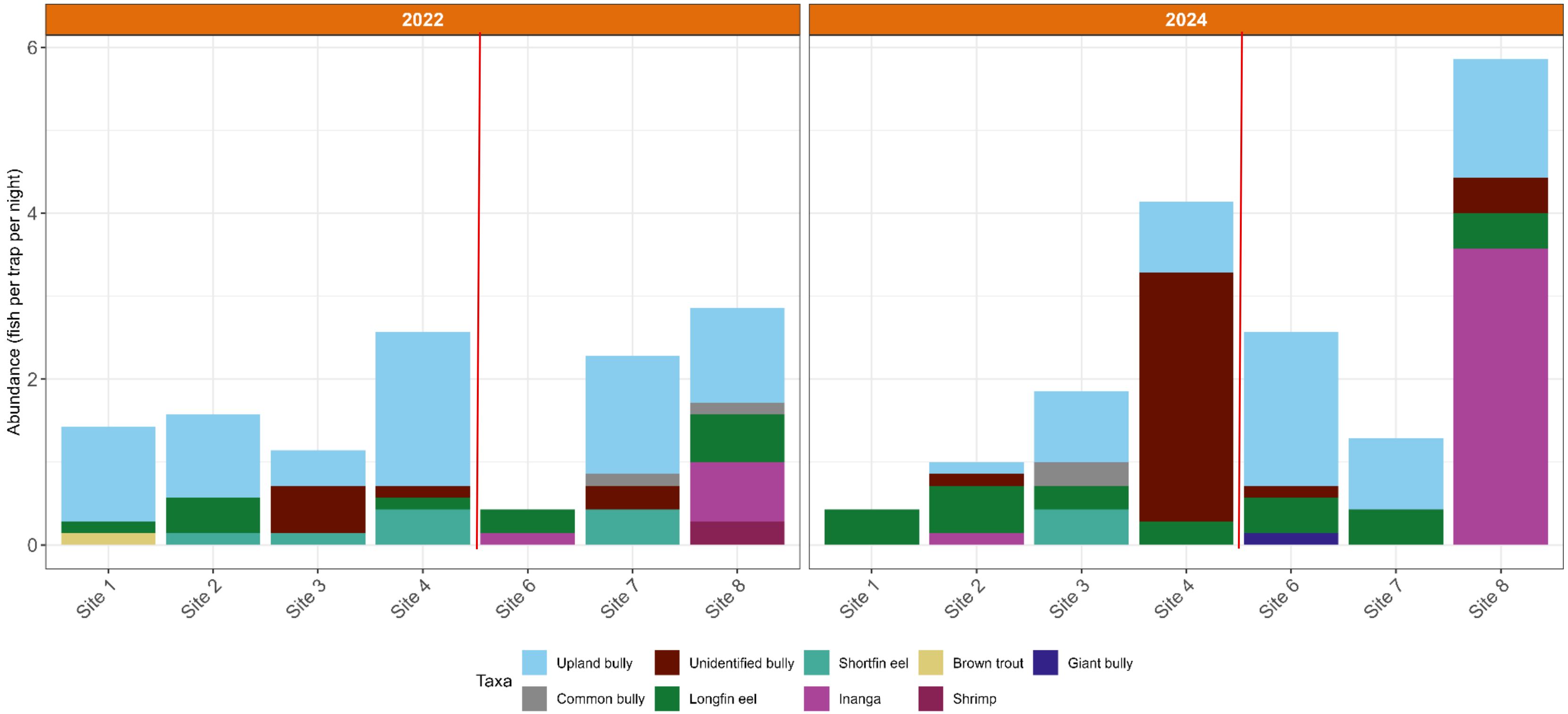

Figure 18. Freshwater fish community composition scaled by catch per trap per night. Trapping/netting results from both pre-impact (November 2022) and post-impact (November 2024) assessments presented. Left of the red line indicates sites located upstream of the rock riffle (Mona Vale Weir A); right of the red line indicates sites located downstream from the rock riffle (Weir A). Sites are presented in an upstream to downstream direction. Site 5 (the rock riffle) was not netted in either year.

Statistical analysis was completed to assess the effect of site location and assessment round on taxon-specific abundance recorded from passive sampling methods (Appendix E, Table E9). Due to low catch rates, interaction effects could not be explored at the species level. Further, some fish species were encountered sporadically, as such statistical analysis for these species was not considered meaningful, so were not undertaken (common bully, giant bully, brown trout and freshwater shrimp). There was no significant effect on īnanga abundance between years, but there was a significant effect of location ($p < 0.05$), with more īnanga located downstream. No other statistically significant differences in fish abundance between assessment site locations or survey years were found (longfin eel, shortfin eel, upland bully, unidentified bullies).

3.4.2.4 Community composition

NMDS ordination was used to broadly characterise differences in fish communities sampled using passive fishing methods, between assessment site locations and years (Figure 19). Points were generally widely dispersed; however, some patterns could be seen. There was no overlap between downstream sites in 2022 and 2024, indicating the communities were dissimilar. Of note, the downstream community points were clustered in 2024 where they were not in 2022, which suggests that the downstream community was more similar between sites in 2024.

Fish community dissimilarity was assessed statistically using ANOSIM. No statistically significant differences in fish communities were found between assessment site locations or years (Appendix E, Table E6). As such, no simper analysis is reported here.

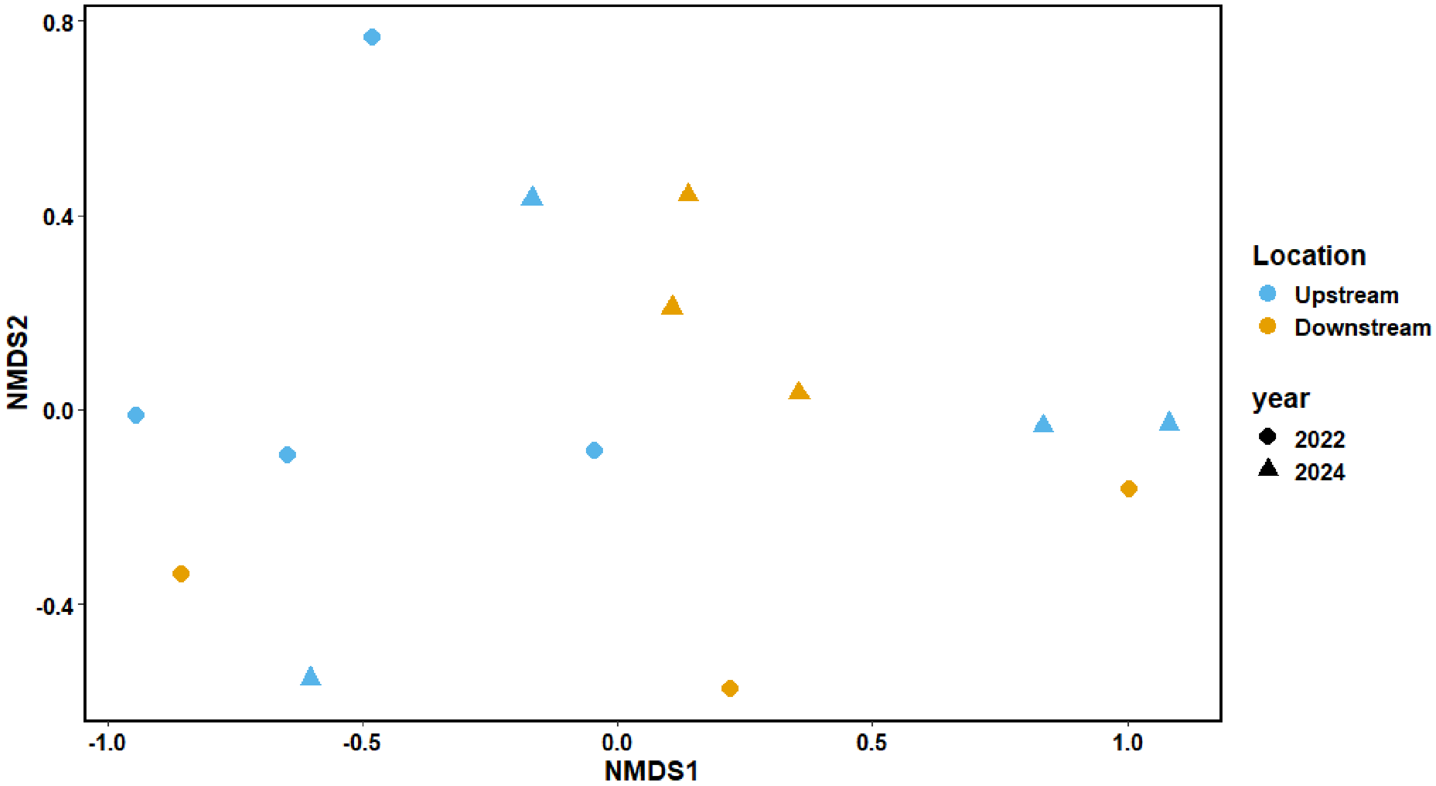

Figure 19: Non-metric multidimensional scaling (NMDS) ordination results for freshwater fish community results (from fyke net and Gee minnow traps) from Ōtākaro - Avon River and Ōtākaro - Avon River tributary sites surveyed upstream and downstream Weir in November 2022 (pre-impact) and November 2024 (post-impact). Stress test shows the model is a fair fit (0.1246[5]).

[5] https://library.virginia.edu/data/articles/starting-non-metric-multidimensional-scaling-nmds

3.4.2.5 Fish length

Summary results for fish lengths are presented in Figure 20 and Figure 21, while summary results tables are available in Appendix E. Most species were not caught frequently enough for meaningful differences to be clear either over time or upstream/downstream of the weir. Exceptions to this were upland bully and longfin eels. However, neither of these species displayed a consistent variation in length with location or time.

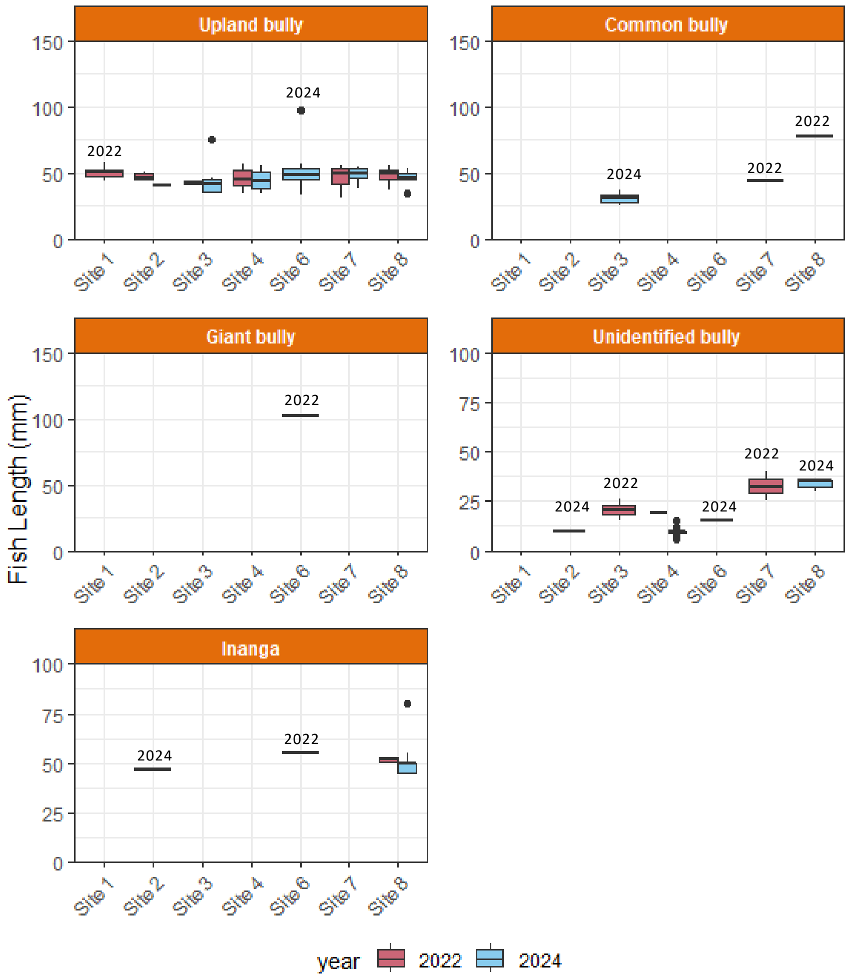

Figure 20: Fish length by taxon from passive fishing methods (i.e., netting/trapping) pre-impact (2022 – red boxes) and post-impact (2024 – blue boxes).

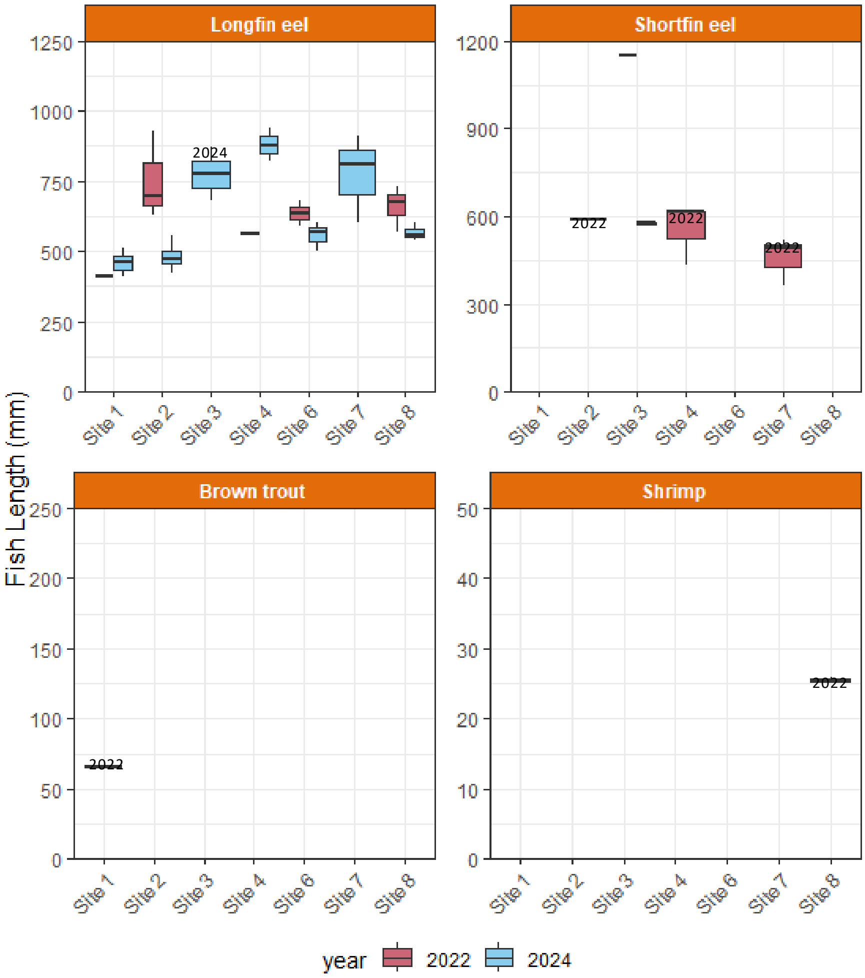

Figure 21: Fish length by taxon from passive fishing methods (i.e., netting/trapping) pre-impact (2022 – red boxes) and post-impact (2024 – blue boxes).

4.0 Discussion

Weir A, located on Ōtākaro - Avon River in Mona Vale, Christchurch, underwent fish passage remedial works in the form of a constructed rock riffle in May 2023. These works were designed to improve migratory fish passage to and from suitable habitat present within the upper catchment of Ōtākaro - Avon River. PDP were engaged to determine both the baseline and Year 1 post-remediation ecological conditions at sites within Ōtākaro - Avon River and its tributaries upstream, downstream and within the constructed rock riffle. This report represents the Year One assessment and considers relevant findings from both studies to assess the overall project objective of improving fish passage into the upper catchment.

Surface water quality and habitat assessments were completed to characterise the suitability of the physicochemical conditions and physical habitat for fish colonisation, as well as to determine any confounding effects on freshwater fish community composition (i.e., outside of limitations to fish passage due to Weir A/constructed rock riffle). Collection of fish data included both active and passive fishing at all sites where the methods could be used (e.g., nets were not set in the constructed rock riffle).

4.1 Ecological communities

4.1.1 Fish population structure

In 2024, īnanga, giant bully and common bully were caught upstream of the remediated reach for the first time. Further, bluegill bullies were found within the constructed riffle, making it the most upstream location known for their distribution in the Ōtākaro – Avon River catchment. Statistical tests showed that in 2022, migratory species were significantly less common upstream of the weir compared to downstream, but that there was no difference between the two locations in 2024. This suggests that the constructed rock riffle is improving fish passage to the upper catchment.

In contrast, the density of the overall migratory fish community upstream of the remediated reach did not change over time. Specifically, the 2024 upstream migratory fish population was similar to that present downstream of the rock riffle, the latter of which showed a decline in population density since baseline surveys were conducted in 2022. The similarity between 2024 migratory fish densities upstream and downstream of the rock riffle may, therefore, be more reflective of a decline over time in downstream reaches, rather than any marked improvement upstream. Notably, shortfin eels were significantly less abundant across all sites in 2024 compared to 2022.

Incidental to the above findings was that the non-migratory fish population density was significantly lower both upstream and downstream of the rock riffle in 2024 than that recorded in 2022. As most of the fish species in Ōtākaro – Avon River catchment are migratory, this is essentially representative of a temporal change in upland bully abundance between the survey periods. Taxon-specific analyses support these findings, where upland bullies were significantly less abundant across all sites in 2024 compared to the 2022 baseline.

The decline in shortfin eel and upland bully abundances merit further consideration. Using active (electric fishing) fishing methods, shortfin eels were found to be abundant and the most dominant species at Site 6 in 2022, but were completely absent from this site in 2024. They were present at all other sites in the same, or lower, abundances in 2024. When looking at passive (trapping) fishing results, shortfin eels were present at three upstream and one downstream site in 2022, but only one upstream site in 2024. Upland bullies are a food source for many larger fish species and were also notably absent (or present in lower numbers) from some sites in 2024. These results are of interest given the upland bully is a typically ubiquitous species.

With regards to migratory fish diversity, the same patterns were seen through the use of both active and passive fishing methods. That is, taxonomic richness downstream of the remediated reach was lower post-remediation, while richness was higher upstream. This shows that despite the decrease in mean taxonomic richness downstream, upstream richness still increased owing to presence of newly caught species (e.g., īnanga, giant bully and common bully).

The comparison of species-specific fish lengths can provide a useful insight to determine fish population structure. A size (and thus age) skewed population may indicate that migration or habitat barriers remain present and are restricting upstream recruitment. However, there were generally no clear patterns in species-specific fish length distributions either between survey years, or upstream and downstream of the remediated reach. Many fish species also lacked presence in high enough abundances for any meaningful interpretation of fish length distributions. Of potential note was that all but one īnanga across the entirety of the November studies were small (< 60 mm). The November surveys were timed to follow the whitebait run, such that īnanga would be known to be present in the system (Smith, 2014). It is possible that at this size/age they may still be too small for most individuals to navigate the weir. If the year 3 post-remediation survey shows low abundance of īnanga upstream, but high abundance downstream, there may be merit in completing a targeted īnanga survey upstream in January/early February to determine if larger īnanga migrate up later in the season.

4.1.2 Macroinvertebrate population structure

Macroinvertebrate sampling was completed within the rock riffle footprint pre- and post-remediation. As such, the 2022 sample was collected primarily from macrophytes, where the 2024 sample was collected from hard substrates. Despite the differing methodologies, comparison was considered appropriate as pre-remediation conditions represented a degraded hard bottom site. Investigation of metrics showed a mixed response, with some macroinvertebrate metrics improving and others declining. Total taxonomic richness was notably higher in 2024. This skewed the %EPT taxa richness scores, as a comparable number of EPT taxa were present in both years, thus they formed a smaller proportion of the richness in 2024. Both MCI and QMCI scores declined notably between years. This is largely due to an increase in low scoring taxa in 2024 and low colonisation of high scoring taxa. It is possible that this represents a limited/absent source population for high scoring hard bottom taxa due to historic habitat degradation in the catchment, rather than a decline in microhabitat conditions. This is supported by the higher taxonomic richness recorded in 2024, as well as the comparable number of EPT taxa. However, the community is also likely impacted by urban contaminants (e.g., via stormwater inputs) which may also restrict the macroinvertebrate community. Despite the decline in QMCI, the site met the CSDNC guideline but not the national bottom line or LWRP Outcome.

None of the salvaged kākahi were found at the relocation site. This indicates that either they relocated outside of the release site, or they did not survive. A search buffer was applied to the surveyed zone to control for localised movement, so either the kākahi were very mobile or the relocation was unsuccessful, either due to predation or stress from being salvaged.

4.2 Fish recruitment

Compared to 2022 baseline survey results, four native obligate sea-migratory fish species have been newly detected upstream of/within the constructed rock riffle (giant bully, bluegill bully, common bully and īnanga). Further, there was no statistically significant difference in overall migratory fish abundance upstream and downstream of the constructed rock riffle post-remediation. Despite these findings, migratory fish population density did not increase significantly upstream pre- and post-remediation, indicating the overall fish community response to weir remediation was not strong enough for statistical detection.

These patterns observed in the data could be driven by a variety of factors. For example, the decline in shortfin eel abundance (irrespective of location) or limited recruitment of species upstream, which could in-turn be the result of poor habitat quality at the upstream sites, low population abundances downstream (i.e., a lack of source population to facilitate recruitment), or the constructed rock riffle is still challenging for many fish individuals to navigate. Some observations of these factors are described in further detail below:

- Although there is no November 2022 data for comparison, 2024 data shows that some physical habitat metrics differed upstream and downstream of the rock riffle. For example, water velocity was typically higher downstream, which may mean that fast water species, such as bluegill bullies, may not be found upstream in comparable numbers due to habitat preferences (Jowett & Richardson, 1995). This lower velocity may be more suitable for īnanga, which prefer slower waters (Jowett, 2002). However, fish refuge in the form of bank undercuts and overhanging vegetation were also more prevalent downstream, which could result in fish abundance being greater downstream. While submerged macrophytes were also higher downstream, this could be a result of weed clearing upstream, but not downstream, so this may not be an enduring factor.
- The effects of weir remediation on the upstream passage of migratory fish species were complicated by a decrease in population density of migratory species (primarily shortfin eels) downstream. As such, it is possible that when migratory fish population density increases downstream, we will see a stronger upstream response.
- Water velocities through the constructed rock riffle were high in most places with a mean of 0.95 m/s (range: 0.26-1.58 m/s). This was reflected by a high proportion (50%) of fast flowing rapid mesohabitats. It is possible that velocities are excessive, or at least challenging, for many individuals to navigate, particularly the pelagic species that may be less likely to use the slower, shallower margins. This could reduce the number of fish that can migrate through the constructed rock riffle and increase energy expenditure for those that do, which may reduce long-term survivability and fecundity (Newton et al., 2018).

Differences in upstream/downstream physicochemical water quality could impact fish diversity. However, results were comparable either side of the remediated site, therefore water quality is not expected to be a driver of the observed population densities. Urban contaminants, such as dissolved metals, are not generally of ecological concern at these sites and also should not be driving any changes in population density (Noakes & Marshall, 2024). Therefore, it is not expected that water quality will impact on migratory fish diversity (i.e., richness and abundance).

5.0 Summary

Weir A presented a significant barrier to upstream migration for several fish taxa recorded within Ōtākaro – Avon River catchment, with baseline surveys showing the structure may have excluded several native species of high conservation value from favourable upstream habitat. Remediation of the site has improved passage enough so that new migratory fish species have been found upstream, or within, the constructed rock riffle. Notably, these were īnanga, common bully, giant bully, and bluegill bully.

Despite this, a statistically significant increase in the overall migratory fish abundance upstream of the remediated structure has not been detected. It is possible that a year-to-year decrease in migratory fish abundance downstream of the rock riffle could be impacting on abundance upstream due to a limited population source and therefore recruitment into upper reaches. Conversely, downstream sites might favour higher population densities of certain species due to sites having higher velocities, greater fish refuge, and greater macrophyte cover and depth. As such, these features may be preferable habitat for fish and continue to support higher population densities downstream of the remediated reach, although the 2022 and 2024 data shows little evidence of this to date.

Further post-remediation surveys are required to document changes in population dynamics resulting from the Weir A remediation works. They should follow the same methodology as outlined in this report to enable comparative analysis over time. It is recommended that post-remediation monitoring continues at three-, five- and ten-year intervals post construction. If the year three post-impact survey shows low abundance of īnanga upstream but high abundance downstream, a targeted īnanga survey upstream in January/early February may be required to determine if the timing of the survey is impacting on observed īnanga abundance.

Under the CSNDC EMP, this catchment is due for ecological monitoring in 2025. The update should specifically address upland bully and shortfin eel abundance to determine if this is a continuing or cyclical trend as indicated by the 2022 and 2024 datasets obtained during this investigation.

Macroinvertebrate kicknet results showed mixed results. Overall, it is considered that microhabitat has improved but that there are potential issues with source populations of pollution sensitive EPT taxa. None of the relocated kākahi were found, indicating either high mobility or mortality.

Overall, weir remediation has increased migratory fish passage to the upper catchment. However, the response is not yet strong enough for statistical detection. eDNA sampling upstream and downstream of the constructed rock ramp would be a useful addition to complement physical sampling of the fish and macroinvertebrates.

6.0 References

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Appendix A: Data collection summary

Table A1: Comparison of data collected in Ōtākaro - Avon River at Mona Vale (Weir A) during the baseline (2022) and Year 1 (2024) studies.

Site	Year	Month	Samples	Rational for change/retention in 2022/2024
Sites 1-4, 6-8	2022	April/May	Water quality, habitat, kākahi, fish	A single fish survey in November ensured that all migratory species are present, therefore autumn (April/May) sampling was not considered necessary post-remediation (2024). Water/habitat data was collected to support fish findings, as such collection was also moved to November 2024. Kākahi surveys were not completed in 2024 as these will be covered as part of the Council's CSNDC monitoring program.
		November	Fish	
	2024	November	Water quality, habitat, fish	
Site 5	2022	April/May	Macroinvertebrates	Data collected in the same month to ensure accurate temporal comparison.
	2024	April		
		November	Water quality, habitat, fish	Data collected in line with all other water quality, habitat and fish samples in 2024.
Site 10	2022	August	Brown trout spawning	Not completed in 2024 as this will be covered in routine Council surveys.
	2024	-	-	
Site 11	2022	February	Kākahi	Resurveyed to determine if translocated kākahi still present
	2024	December		

Appendix B: Photographs

Photograph 1: Site 1 – Looking upstream from the downstream extent of the assessment reach.

Photograph 2: Site 1 – Looking downstream at the assessment reach.

Photograph 3: Site 2 – looking upstream at the assessment reach.

Photograph 4: Site 2 – looking downstream from the upstream extent of the assessment reach.

Photograph 5: Site 3 looking downstream from the upstream extent of the assessment reach.

Photograph 6: Site 3 Looking upstream from the downstream extent of the assessment reach.

Photograph 7: Site 4 – Looking upstream from the downstream end of the assessment reach.

Photograph 8: Site 4 – Looking downstream to Weir A, from the downstream end of the reach.

Photograph 9: Looking upstream at Site 5 (remediated Weir A at Mona Vale)

Photograph 10: Looking downstream at Site 5 (remediated Weir A at Mona Vale)

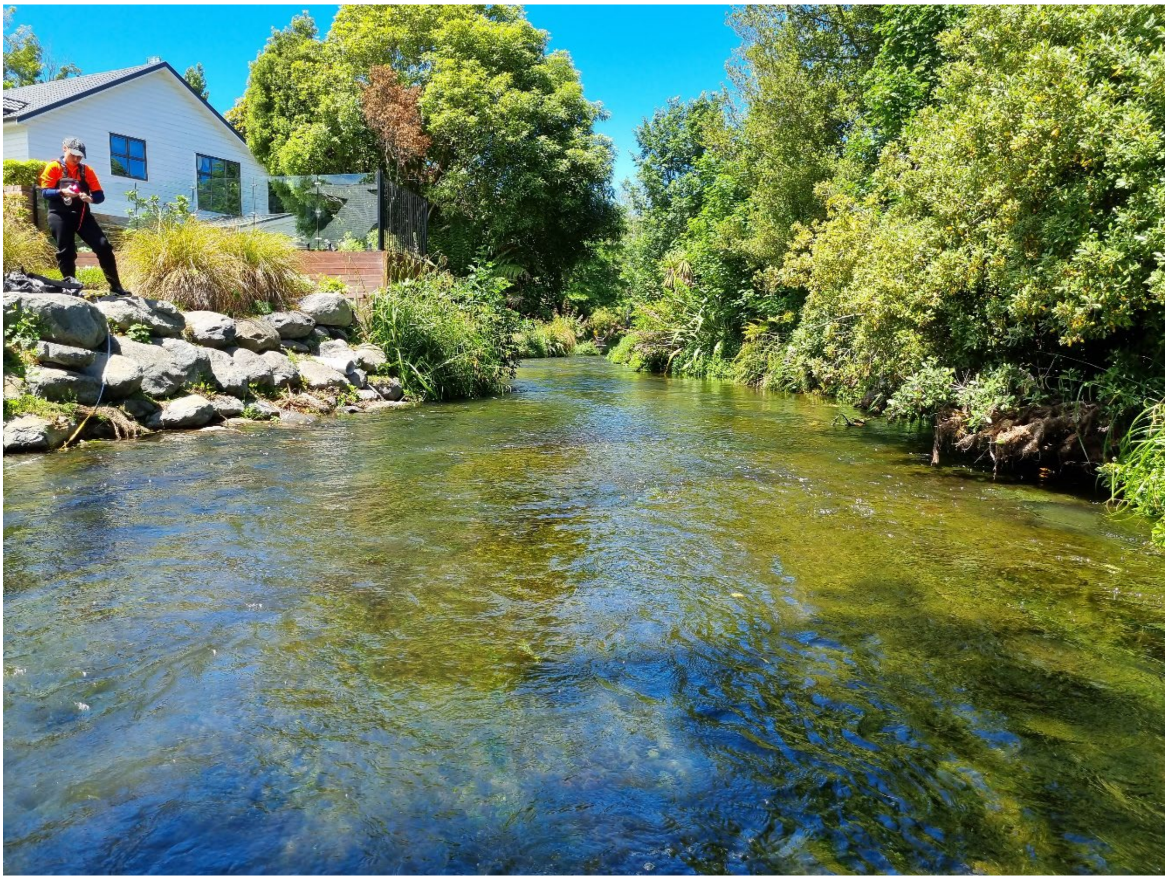
Photograph 11: Site 6 – Looking downstream from the upstream extent of the assessment reach.

Photograph 12: Site 6 – looking upstream from the downstream extent of the assessment reach.

Photograph 13: Inanga (*Galaxias maculatus*; 'whitebait') caught in the reach at Site 6

Photograph 14: Bluegill bully (*Gobiomorphus hubbsi*) recorded from Site 5.

Photograph 15: Site 7 – looking upstream from the downstream extent of the assessment reach.



Photograph 16: Site 7 – looking downstream from the upstream end of the assessment reach.

Photograph 17: Site 8 – looking upstream from the downstream extent of the assessment reach.

Photograph 18: Site 8 – looking downstream from the upstream extent of the assessment reach.

Appendix C: Stream habitat tables

Table C1: Summary of stream habitat data collected for the Mona Vale fish passage remediation project (November 2024)									
Habitat features		**Ōtākaro - Avon River**	**Waimairi Stream**	**Wairarapa Stream**	**Ōtākaro - Avon River**				
		Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**
Flow permanence		Permanent	Permanent	Permanent	Permanent	Permanent	Permanent	Permanent	Permanent
Surrounding land use		Urban/Residential	Urban Park/Residential	Urban Park/Residential	Urban Park	Urban Park	Urban	Urban/Residential	Urban Park
Bank material		Wooden retainer and earth	Wooden retainer and soil/rocks	Wooden retainer	Wooden retainer, earth and boulders	Earth and rock	Earth and rock	Rock and wood	Earth and concrete
Wetted width (m)		3.79	5.13	12.23	16.47	7.03	7.01	9.27	15.33
Water depth (cm)		38.1	29.9	33.8	35.0	24.0	52.0	50.0	32.1
Terrestrial vegetation	Riparian cover	TLB: Mix of natives (e.g., ferns, *Carex*) and exotics TRB: Mix of natives (e.g., ferns, *Carex*) and exotics	TLB: Mix of natives (e.g., ferns, *Carex*) and exotics (e.g., grass) TRB: Mix of natives (e.g., ferns, flax) and exotics (e.g., grass, lilies)	TLB and TRB: Exotics (e.g., grass, lilies)	TLB and TRB: Mix of natives (e.g., *Carex*) and exotics (e.g., grass)	TLB and TRB: Natives (e.g., *Carex*)	TLB and TRB: Predominantly grass with some weeds	TLB: Bare earth and exotics (e.g., grasses) TRB: Exotics	TLB: Mix of natives (e.g., ferns, flax) and exotics (e.g., grass) TRB: Mix of natives (e.g., trees, flax) and exotics (e.g., grass)

Table C1: Summary of stream habitat data collected for the Mona Vale fish passage remediation project (November 2024)

Habitat features		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
	Canopy cover (%)	33	14	33	0	0	4	10	10.5
Instream vegetation	Emergent macrophytes (composition and % cover)	0%	0%	0%	0%	0%	6.7% (watercress, mint)	0%	0%
	Total macrophytes (composition and % cover)[1]	7% Canadian PW; starwort; glyceria; macroalgae	74% Canadian PW; curly PW; starwort; monkey musk; glyceria; macroalgae	8% Canadian PW; starwort	23% Canadian PW; milfolis	9% Canadian PW; curly PW; glyceria; milfoils	87% Canadian PW; curly PW; milfolis; glyceria; macroalgae; watercress; mint	85% Canadian PW; curly PW; milfolis	54% Curly pondweed; milfoils
	Periphyton (composition and % cover)[2]	Thin (10%); Medium (2%)	Thin (16%); long (12%)	Thin (2%)	0%	Thin (38%); Medium (6%); Thick (11%); short (5%); long (18%)	Thin (2%); short (8%); long (22%)	Thin (8%); Medium (0.33%); Thick (0.67%); long (2%)	Thin (18%); Medium (5%); Thick (0.67%); short (3%); Long (23%)
Substrate	Bedrock/artificial hard substrate (%)	3	0.0	0.0	0.0	10	0.7	0	0
	Boulders (%)	0.0	0.0	0.0	0.0	21	0.0	0.0	0
	Large Cobbles (%)	0.0	0.0	0.0	0.0	28	0.0	7	0
	Small Cobbles (%)	5	11	0	0	13	0.67	0.67	2
	Pebbles (%)	15	4	0	0	7	1	2	17
	Gravels (%)	23	6	7	0	7	4	4	12
	Silt/Sand (%)	54	79	93	100	15	94	86	62

Table C1: Summary of stream habitat data collected for the Mona Vale fish passage remediation project (November 2024)									
Habitat features		**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**
	Fine sediment depth (mm)[3]	27	181+	204	759+	3	69	53	14
	Organic matter (composition and % cover)	CPOM (3%) leaves, wood		FPOM (41%); CPOM (5%) wood	FPOM (6%); CPOM (2%) leaves, wood		CPOM (1%) leaves		
Instream conditions	Bank undercut (cm) (TLB/TRB)	9/30	0	0	0	0	13/3	29/29	0/29
	Overhanging vegetation (cm) (TLB/TRB)	13/31	33/47	7/0	34/70	8/4	30/29	27/92	148/335
Mesohabitat types (%)	Pool	0	0	0	0	5	0	0	0
	Run	100	70	100	100	10	100	100	100
	Riffle	0	30	0	0	30	0	0	0
	Rapid	0	0	0	0	55	0	0	0

Notes:

1. *PW = pond weed*
2. ***thin/medium/thick refers to mat thickness. Short/long refers to filament length***
3. ***'+' refers to sites where some depths were recorded as >1000mm***

Mean values presented where multiple observations/measurements were taken per parameter (i.e., per transect/point)

Appendix D: Macroinvertebrate tables

Table D1: Macroinvertebrate sample results from Site 5 pre- (April 2022) and post- (April 2024) weir remediation.

Group	Taxa	MCI_{hb} Score	Abundance	
			2022	2024
Amphipoda	Paracalliope	5	119	27
Arachnida	Acarina	5		1
Diptera	Empididae	3		6
	Orthocladiinae	2		4
	Tanytarsini	3		10
	Polypedilum	3		1
Gastropoda	Ferrissia	3		4
	Gyraulus	3	1	
	Physa	3	42	6
	Potamopyrgus	4	48	142
Hirudinea	Alboglossiphonia sp.	3		1
Nemertea	Nemertea	3		1
Oligochaeta	Oligochaeta	1		33
Ostracoda	Ostracoda	3	1	32
Platyhelminthes	Platyhelminthes	3		5
Trichoptera	Triplectides	5	3	
	Edpercivalia	9	1	
	Hydrobiosidae sp.	6		2
	Hudsonema	6	6	11
	Hydrobiosis	5	3	2
	Oxyethira	2		7
	Psilochorema	8	1	3
	Pycnocentrodes	5	1	1

Appendix E: Fish tables

Table E1: Fish abundance by species for sites sampled as part of the Mona Vale Fish Passage Remediation Project. Sites presented are those located upstream of the original weir (Weir A) and in the original weir footprint which now forms the rock riffle. Data includes both electric fishing and netting/trapping. Size range is given in brackets (mm).

	Upstream								Constructed rock riffle	
Site	**1**		**2**		**3**		**4**		**5**	
Year	**2022**	**2024**	**2022**	**2024**	**2022**	**2024**	**2022**	**2024**	**2022**	**2024**
Longfin eel[1] (*Anguilla dieffenbachii*)	4 (410-1,000)	6 (310-630)	5 (360-930)	7 (420-990)	1 (1,040)	7 (150-870)	1 (565)	2 (820-940)	N/A	1 (280)
Shortfin eel (*Anguilla australis*)	7 (180-600)	7 (135-405)	8 (120-590)	2 (200-580)	10 (190-1,150)	5 (415-580)	3 (430-620)		N/A	
'Unidentified eel'[2.] (*Anguilla* sp.)			2 (100-120)						N/A	4 (90-180)
Upland bully (*Gobiomorphus breviceps*)	27 (40-58)	6 (40-67)	14 (40-56)	3 (40-45)	12 (40-56)	11 (35-75)	13 (35-57)	6 (35-55)	N/A	27 (38-70)
Giant bully[1] (*Gobiomorphus gobioides*)				1 (100)					N/A	
Common bully (*Gobiomorphus cotidianus*)	1 (52)	6 (80-95)				2 (25-37)			N/A	1 (83)
Bluegill bully[1] (*Gobiomorphus hubbsi*)									N/A	26 (41-57)
'Unidentified bully'[2.] (*Gobiomorphus* sp.)			1 (31)	1 (10)	5 (15-38)		1 (19)	21 (6-15)	N/A	
Inanga[1] (*Galaxias maculatus*)				1 (47)					N/A	1 (48)
Brown trout[3] (*Salmo trutta*)		1 (48)		2 (50-55)					N/A	

Notes:

1. *At Risk species (Dunn et al., 2018)*
2. *Fish that were too small to confidently identify were recorded as unidentified eel or unidentified bully*
3. *Introduced and naturalised (Dunn et al., 2018)*

Table E2: Fish abundance by species for sites sampled as part of the Mona Vale Fish Passage Remediation Project. Sites presented are those located downstream of the original weir (Weir A). Data includes both electric fishing and netting/trapping. Size range is given in brackets (mm).						
Site	**6**		**7**		**8**	
Year	**2022**	**2024**	**2022**	**2024**	**2022**	**2024**
Longfin eel[1] (*Anguilla dieffenbachii*)	6 (140-680)	7 (210-1,240)	19 (120-1,070)	10 (140-1,200)	4 (570-730)	9 (470-900)
Shortfin eel (*Anguilla australis*)	73 (110-570)		2 (57-520)	2 (220-270)	8 (135-290)	10 (130-560)
'Unidentified eel'[2.] (*Anguilla* spp.)			2 (105-140)			7 (100-260)
Lamprey[3] (*Geotria australis*)			1 (360)			
Upland bully (*Gobiomorphus breviceps*)	14 (42-65)	25 (33-97)	49 (31-85)	14 (38-55)	62 (31-116)	25 (35-60)
Giant bully[1] (*Gobiomorphus gobioides*)		1 (102)				
Common bully (*Gobiomorphus cotidianus*)	4 (60-100)	3 (93-112)	3 (44-97)		5 (52-81)	3 (38-47)
Bluegill bully[1] (*Gobiomorphus hubbsi*)			2 (45-52)			
'Unidentified bully'[2.] (*Gobiomorphus* sp.)		1 (15)	5 (22-44)			4 (15-35)
Inanga[1]	1	3			13	32

Table E2: Fish abundance by species for sites sampled as part of the Mona Vale Fish Passage Remediation Project. Sites presented are those located downstream of the original weir (Weir A). Data includes both electric fishing and netting/trapping. Size range is given in brackets (mm).						
Site	**6**		**7**		**8**	
Year	**2022**	**2024**	**2022**	**2024**	**2022**	**2024**
(*Galaxias maculatus*)	(55)	(54-60)			(47-55)	(30-80)
Brown trout[4] (*Salmo trutta*)		1 (206)				
Shrimp (*Paratya* sp.)					3 (25-26)	

Notes:

1. *At Risk species (Dunn et al., 2018)*
2. *Fish that were too small to confidently identify were recorded as unidentified eel or unidentified bully*
3. *Threatened species (Dunn et al., 2018). 4. Introduced and naturalised (Dunn et al., 2018)*

Table E3: Negative binomial generalised linear model results for all fish, migratory fish, and non-migratory fish catch per unit effort using electric fishing. Models compare results upstream and downstream from the constructed rock riffle and pre- and post-remediation (i.e., between years). Note that Site 5 has not been included in these models as there is no pre-impact data.

Fish Community	Coefficients	Effect[1]	Standard Error	Z-Value	p-Value
All Fish	Intercept	-2.3	0.27	-8.42	<2e-16***
	Location: Downstream	0.72	0.38	1.93	0.054
	Year: 2024	-0.58	0.38	-1.47	0.14
	Downstream x 2024	-0.73	0.55	-1.34	0.18
Migratory Fish	Intercept	-3.19	0.38	-8.32	<2e-16 ***
	Location: Downstream	1.15	0.52	2.21	0.03*
	Year: 2024	-0.10	0.54	-0.19	0.85
	Downstream x 2024	-1.34	0.75	-1.80	0.07
Non-Migratory Fish	Intercept	-2.93	0.23	-12.55	<2e-16 ***
	Location: Downstream	0.35	0.31	1.13	0.26
	Year: 2024	-1.15	0.38	-3.00	0.003**
	Downstream x 2024	-0.01	0.50	-0.02	0.98

Notes:

1. *Model coefficient effects defined as follows:*
   - ***'Intercept'*** *– log density when* ***Location = Upstream*** *and Year* ***= 2022***
   - ***'Location: Downstream'*** *– the log value by which reference population density (Intercept) is multiplied when Location = Downstream and Year = 2022 (Intercept)*
   - ***'Year: 2024*** *– the log value by which reference population density (Intercept) is multiplied when Location = Upstream (Intercept) and Year = 2024*

   'Downstream*2024 *– Interactive effect – the log value by which the log effects of* ***'Location: Downstream'*** *and* ***'Year: 2024*** *on population density (at Intercept) are multiplied when these effects are applied in combination.*

   ** Indicates statistical significance (P<0.05), ** Indicates statistical significance (p<0.01), *** Indicates statistical significance (p<0.001)*

Table E4: Summary output of negative binomial generalised linear model results for all fish, migratory fish, and non-migratory fish catch per unit effort using electric fishing using the R package 'emmeans'. Models compare results upstream and downstream from the constructed rock riffle and pre- and post-remediation (i.e., between years). Note that Site 5 has not been included in these models as there is no pre-impact data.

Fish Community	Coefficients	Response	Standard Error	Lower confidence level	Upper confidence level
All Fish	Upstream: 2022	40.5	11.07	23.7	69.2
	Downstream: 2022	83.5	21.50	50.4	138.3
	Upstream: 2024	22.6	6.49	12.8	39.7
	Downstream: 2024	22.4	6.13	13.1	38.3
	Coefficients	**Ratio**	**Standard Error**	**Z-Ratio**	**P-Value**
	Contrast: Upstream 2022 / 2024	1.79	0.71	1.47	0.14
	Contrast: Downstream 2022 / 2024	3.73	1.40	3.50	0.0005
	Contrast: 2022 Upstream / Downstream	0.49	0.18	-1.93	0.054
	Contrast: 2024 Upstream / Downstream	1.01	0.40	0.02	0.99
Migratory Fish	**Coefficients**	**Response**	**Standard Error**	**Lower confidence level**	**Upper confidence level**
	Upstream: 2022	16.6	6.39	7.85	35.3
	Downstream: 2022	52.5	18.43	26.35	104.4
	Upstream: 2024	15.1	5.79	7.08	32.0
	Downstream: 2024	12.4	4.63	5.96	25.8
	Coefficients	**Ratio**	**Standard Error**	**Z-Ratio**	**P-Value**
	Contrast: Upstream 2022 / 2024	11.1	0.60	0.19	0.85
	Contrast: Downstream 2022 / 2024	4.23	2.17	2.81	0.005
	Contrast: 2022 Upstream / Downstream	0.32	0.17	-2.21	0.03
	Contrast: 2024 Upstream / Downstream	1.22	0.65	0.37	0.72

Table E4: Summary output of negative binomial generalised linear model results for all fish, migratory fish, and non-migratory fish catch per unit effort using electric fishing using the R package 'emmeans'. Models compare results upstream and downstream from the constructed rock riffle and pre- and post-remediation (i.e., between years). Note that Site 5 has not been included in these models as there is no pre-impact data.					
Fish Community	**Coefficients**	**Response**	**Standard Error**	**Lower confidence level**	**Upper confidence level**
Non Migratory Fish	**Coefficients**	**Response**	**Standard Error**	**Lower confidence level**	**Upper confidence level**
	Upstream: 2022	21.59	5.04	13.66	34.1
	Downstream: 2022	30.67	6.30	20.51	45.9
	Upstream: 2024	6.82	2.08	3.75	12.4
	Downstream: 2024	9.58	2.35	5.93	15.5
	Coefficients	**Ratio**	**Standard Error**	**Z-Ratio**	**P-Value**
	Contrast: Upstream 2022 / 2024	3.17	1.22	3.0	0.003
	Contrast: Downstream 2022 / 2024	3.20	1.02	3.64	0.0003
	Contrast: 2022 Upstream / Downstream	0.704	0.22	-1.13	0.26
	Contrast: 2024 Upstream / Downstream	0.71	0.28	-0.87	0.39

Table E5: Generalised linear model results for taxon-specific fish catch per unit effort using electric fishing. Models compare results upstream and downstream from the constructed rock riffle and pre- and post-remediation but does not include an interactive effect due to data limitations. Note that Site 5 has not been included in these models as there is no pre-impact data.

Fish Community	Coefficients	Effect	Standard Error	Z-Value	p-Value
Common bully	Intercept	-6.05	0.89	-6.76	1.39e-11***
	Location: Downstream	0.70	0.95	0.74	0.46
	Year: 2024	0.82	0.95	0.87	0.39
Longfin eel	Intercept	-4.58	0.44	-10.40	<2e16***
	Location: Downstream	0.43	0.49	0.89	0.38
	Year: 2024	-0.13	0.49	-0.28	0.78
Shortfin eel	Intercept	-2.98	0.53	-5.62	1.98e-08
	Location: Downstream	0.25	0.63	0.41	0.69
	Year: 2024	-1.71	0.63	-2.72	0.00652**
Unidentified bully	Intercept	-5.82	0.60	-9.71	<2e-16***
	Location: Downstream	-0.16	0.76	-0.21	0.83
	Year: 2024	-1.97	1.08	-1.82	0.07
Unidentified eel	Intercept	-5.78	0.98	-5.93	3.06e-09***
	Location: Downstream	0.33	1.13	0.30	0.77
	Year: 2024	-0.78	1.13	-0.70	0.49
Upland bully	Intercept	-2.97	0.20	-14.80	<2e-16***
	Location: Downstream	0.43	0.24	1.79	0.07
	Year: 2024	-1.27	0.24	-5.29	1.26e-07***

Notes:

** Indicates statistical significance (P<0.05), ** Indicates statistical significance (p<0.01), *** Indicates statistical significance (p<0.001)*

Table E6: Non-metric Multidimensional Scaling (NMDS) results tested as fish catch per unit effort from electric fishing.

Location	R statistic	p-Value	Number of permutations
Upstream	0.48	0.24	719
Downstream	0.63	0.12	719

Table E7: Poisson and Negative binomial generalised linear model results for migratory and non-migratory fish abundance (from fyke netting and Gee minnow trapping) upstream and downstream of the constructed rock riffle in 2022 and 2024.					
Fish Community	**Coefficient**	**Effect[1]**	**Standard Error**	**Z-Value**	**p-Value**
All Fish	Intercept	0.27	0.39	0.69	0.49
	Location: Downstream	0.10	0.59	0.17	0.86
	Year: 2024	0.10	0.55	0.19	0.85
	Downstream x 2024	0.45	0.82	0.55	0.58
Migratory Fish	Intercept	0.92	0.43	2.12	0.03*
	Location: Downstream	0.93	0.60	1.56	0.12
	Year: 2024	0.53	0.58	0.92	0.36
	Downstream x 2024	0.08	0.80	0.1	0.92
Non-Migratory Fish	Intercept	2.08	0.31	6.71	2e-11 ***
	Location: Downstream	-0.29	0.49	-0.59	0.56
	Year: 2024	-0.9	0.49	-1.85	0.06
	Downstream x 2024	1.38	0.71	1.95	0.052

Notes:

1. *Model coefficient effects defined as follows:*
   *- **'Intercept'** – log population abundance when **Location = Upstream** and **year = 2022***
   *- **'Location: Downstream'** – the log value by which reference population abundance (Intercept) is multiplied when Location = Downstream and year = 2022 (Intercept)*
   *- **'Year: 2024'** – the log value by which reference population abundance (Intercept) is multiplied when Location = Upstream (Intercept) and Year = 2024*
   ***'Downstream*year'** – Interactive effect – the log value by which the log effects of **'Location: Downstream'** and **'Year: 2024** on population abundance (at Intercept) are multiplied when these effects are applied in combination.*
   ** Indicates statistical significance (P<0.05), ** Indicates statistical significance (p<0.01)*

Table E8: Summary output of poisson and negative binomial generalised linear model results for migratory and non-migratory fish abundance (from fyke netting and Gee minnow trapping) upstream and downstream of the constructed rock riffle in 2022 and 2024 using the R package 'emmeans'.					
Fish Community	**Coefficients**	**Response**	**Standard Error**	**Lower confidence level**	**Upper confidence level**
All Fish	Upstream: 2022	1.31	0.51	0.61	2.79
	Downstream: 2022	1.44	0.64	0.61	3.45
	Upstream: 2024	1.44	0.56	0.68	3.07
	Downstream: 2024	2.52	1.09	1.08	5.86
	Coefficients	**Ratio**	**Standard Error**	**Z-Ratio**	**P-Value**
	Contrast: Upstream 2022 / 2024	0.90	0.49	-0.19	0.85
	Contrast: Downstream 2022 / 2024	0.57	0.36	-0.90	0.37
	Contrast: 2022 Upstream / Downstream	0.90	0.53	-0.17	0.86
	Contrast: 2024 Upstream / Downstream	0.57	0.33	-0.96	0.34
Migratory Fish	**Coefficients**	**Response**	**Standard Error**	**Lower confidence level**	**Upper confidence level**
	Upstream: 2022	2.50	1.08	1.07	5.83
	Downstream: 2022	6.33	2.60	2.83	14.16
	Upstream: 2024	4.25	1.62	2.01	8.98
	Downstream: 2024	11.67	4.44	5.54	24.58
	Coefficients	**Ratio**	**Standard Error**	**Z-Ratio**	**P-Value**
	Contrast: Upstream 2022 / 2024	0.59	0.34	-0.92	0.36
	Contrast: Downstream 2022 / 2024	0.54	0.30	-1.09	0.28
	Contrast: 2022 Upstream / Downstream	0.40	0.24	-1.06	0.12
	Contrast: 2024 Upstream / Downstream	0.36	0.20	-1.87	0.06

Table E8: Summary output of poisson and negative binomial generalised linear model results for migratory and non-migratory fish abundance (from fyke netting and Gee minnow trapping) upstream and downstream of the constructed rock riffle in 2022 and 2024 using the R package 'emmeans'.

	Coefficients	Response	Standard Error	Lower confidence level	Upper confidence level
Non-Migratory Fish	Upstream: 2022	8.00	2.48	4.36	14.7
	Downstream: 2022	6.00	2.26	2.87	12.6
	Upstream: 2024	3.25	1.22	1.55	6.8
	Downstream: 2024	9.67	3.36	4.89	19.1
	Coefficients	**Ratio**	**Standard Error**	**Z-Ratio**	**P-Value**
	Contrast: Upstream 2022 / 2024	2.46	1.20	1.85	0.06
	Contrast: Downstream 2022 / 2024	0.62	0.32	-0.93	0.35
	Contrast: 2022 Upstream / Downstream	1.33	0.65	0.59	0.56
	Contrast: 2024 Upstream / Downstream	0.34	0.17	-2.13	0.03

Table E9: Generalised linear model results for taxon-specific fish catch (from fyke netting and Gee minnow trapping) upstream and downstream of the constructed rock riffle pre- and post-remediation but does not include an interactive effect due to data limitations.					
Fish Community	**Coefficient**	**Effect**	**Standard Error**	**Z-Value**	**p-Value**
Inanga	Intercept	-3.36	1.72	-1.95	0.05
	Location: Downstream	3.90	1.57	2.49	0.013*
	Year: 2024	1.74	1.43	1.22	0.22
Longfin eel	Intercept	0.35	0.35	1.01	0.31
	Location: Downstream	0.22	0.36	0.62	0.54
	Year: 2024	0.60	0.38	1.60	0.11
Shortfin eel	Intercept	0.51	0.66	0.77	0.44
	Location: Downstream	-0.90	0.98	-0.92	0.36
	Year: 2024	-1.14	0.95	-1.20	0.23
Unidentified bully	Intercept	0.40	0.80	0.50	0.62
	Location: Downstream	-1.06	0.99	-1.07	0.29
	Year: 2024	1.18	0.97	1.23	0.22
Upland bully	Intercept	1.80	0.34	5.27	1.39e-07***
	Location: Downstream	0.41	0.41	1.00	0.32
	Year: 2024	-0.25	0.41	-0.62	0.54

Notes:
** Indicates statistical significance (P<0.05), ** Indicates statistical significance (p<0.01)*

Table E10: Non-metric Multidimensional Scaling (NMDS) results tested as fish catch per unit effort from passive fishing methods.			
Test location	**R statistic**	**p-Value**	**Number of permutations**
Upstream (2022 vs 2024)	0.14	0.13	100
Downstream (2022 vs 2024)	-0.15	0.91	719