Cashmere Stream Baseline Aquatic Ecology Survey

August 2021

Prepared for:
Christchurch City Council

Instream Consulting Limited
PO Box 1200
Christchurch 8140

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report describes results of an aquatic ecology survey undertaken in Cashmere Stream, its tributaries, and nearby ponds. The purpose of the survey was to provide baseline data to compare against data collected after planned restoration and realignment activities.

The reaches of Cashmere Stream and tributary drains sampled are artificially straight and steep-sided, and bank erosion is common. Riparian vegetation is dominated by exotic pasture grass and weeds, which help intercept overland flow, but provide little channel shading. Lack of shade is associated with high macrophyte cover and regular macrophyte removal is undertaken by council contractors to reduce water levels. Macrophyte communities are dominated by introduced weed species, although the native macrophyte *Nitella* occurs in well-shaded areas. *Nitella* is not associated with nuisance growths.

Bank and bed cover for fish was mainly restricted to overhanging grass, fine sediment deposits, and macrophytes. Regular waterway maintenance by council contractors limits the amount of overhanging vegetation and root mats available as fish habitat. However, natural banks provide habitat for wai kōura (freshwater crayfish) and eels to burrow into.

Most of the waterways surveyed have good coverage with recent Christchurch River Environment Assessment Survey (CREAS) data. These data can be used to compare against surveys undertaken after waterway restoration.

Invertebrate communities are dominated by pollution-tolerant crustaceans and snails. This reflects the lack of suitable stony bed sediments, diverse habitats, lack of riparian trees and shrubs for adult stages of aquatic insects, and possibly also poor water quality. The presence of wai kōura in Cashmere Stream is ecologically significant and they are worthy of protection, due to their At Risk conservation status and their susceptibility to urbanisation. Freshwater mussels (kākahi) are found in the lower reaches of Cashmere Stream, but they have only been found downstream of Dunbar Waterway, which is beyond the downstream extent of proposed restoration activities.

Six native fish species were caught during sampling, with shortfin eel being the most widespread, and sometimes very abundant. The presence of At Risk longfin eel, inanga, and giant bully is notable. The relatively large numbers of inanga caught from Farm Drain (Site H) was also noteworthy, given the highly modified appearance of the waterway. Electric fishing was strongly biased towards catching large numbers of smaller shortfin eels, as well as upland bully and wai kōura. Trapping methods caught more longfin eels and inanga, and larger eels overall.

Recommendations include: finalise waterway restoration goals; plant trees and shrubs to shade waterways; avoid trimming bank vegetation; retain natural banks; avoid bank armouring; encourage natural development of a meandering channel alignment; no net loss of aquatic habitat; retain equivalent or better quality pond habitat; create a mix of pool and run habitat; add tethered logs, root-wads and boulders to provide habitat; protect the Bunz Drain springs; provide for fish passage at stormwater basins, where required; relocate fish and wai kōura prior to channel works and realignment; and ecological monitoring to evaluate success of the restoration works.

1. INTRODUCTION

Cashmere Stream is a spring-fed tributary of the Ōpāwaho / Heathcote River, that arises as springs near the Christchurch suburb of Halswell. The Cashmere Stream catchment is undergoing rapid change from rural to urban residential landuse. Christchurch City Council (CCC) is therefore developing a large network of stormwater wetlands and basins to treat new and existing urban stormwater in the catchment. Part of the stormwater development involves realigning and enhancing habitats associated with Cashmere Stream.

CCC has developed a draft restoration plan for Cashmere Stream[1]. Restoration goals and objectives that directly relate to aquatic ecology include: increased abundance of threatened species; increased abundance of pollution-sensitive invertebrate species; increased fish diversity and abundance; and reduced need for aquatic weed clearance. Proposed mechanisms to achieve these outcomes include: enhanced habitat diversity; maintain natural bank habitat; riparian planting; reduced sediment inputs; and re-introduction of species following enhancement.

This report describes results of an aquatic ecology survey undertaken in Cashmere Stream, its tributaries, and nearby ponds. The purpose of the survey was to provide baseline data that can be used to compare against data collected after restoration and realignment activities. This report supersedes the previous baseline report (Instream Consulting 2016), through the addition of extra sampling locations and methods, and also by including the knowledge gained from waterway realignments conducted in the area to date.

2. METHODS

Aquatic habitat, invertebrate, and fish communities were sampled at eight locations. The sampling locations included six in Cashmere Stream, one in Quarry Road Drain, and one in an unnamed tributary referred to here as Farm Drain (Figure 1, Table 1). Sampling sites include locations where different restoration techniques are proposed by CCC, as well as locations of previous sampling by Instream Consulting (2016). Monitoring sites 2 and 6 from Instream Consulting (2016) were not sampled, to avoid construction works. In addition, fish communities were sampled in two ponds beside Cashmere Stream, referred to here as Pond 1 and Pond 2 (or P1 and P2). All fieldwork was conducted over 20–28 April 2021, under baseflow conditions.

Stream and drain habitats were sampled using standard ecology sampling methods outlined in the Environmental Monitoring Plan of the council's Comprehensive Stormwater Network Discharge consent (CRC190445). The standard methods were supplemented with additional methods to provide more detailed information of relevance to monitoring restoration activities. The additional methods are as follows:

- Both electric fishing and fish trapping was undertaken at all sites where it was considered practical. Usually only one method is used for CCC monitoring.
    - Each fishing method has sampling biases, so using two methods provides a better indication of fish diversity and abundance.

[1] Draft version dated 19 June 2020.

- For each sampling site, fish cover was measured as follows:
    - Total length of left and right bank with the following fish cover attributes: undercuts, overhanging vegetation, other cover attributes (e.g., emergent macrophytes), or no cover.
    - Percentage of the bed with the following fish cover: root mats, macrophytes, fine sediment, leaf litter, cobbles/boulders, woody debris, and algae.

- Riparian buffer width was measured at each transect (each bank separately).

- Five velocity measurements were taken per transect, rather than the single measurement used in the standard methods.
    - Velocity provides a measure of flow habitat variation, so it would be useful having more detailed measurements for pre- and post-restoration comparison.

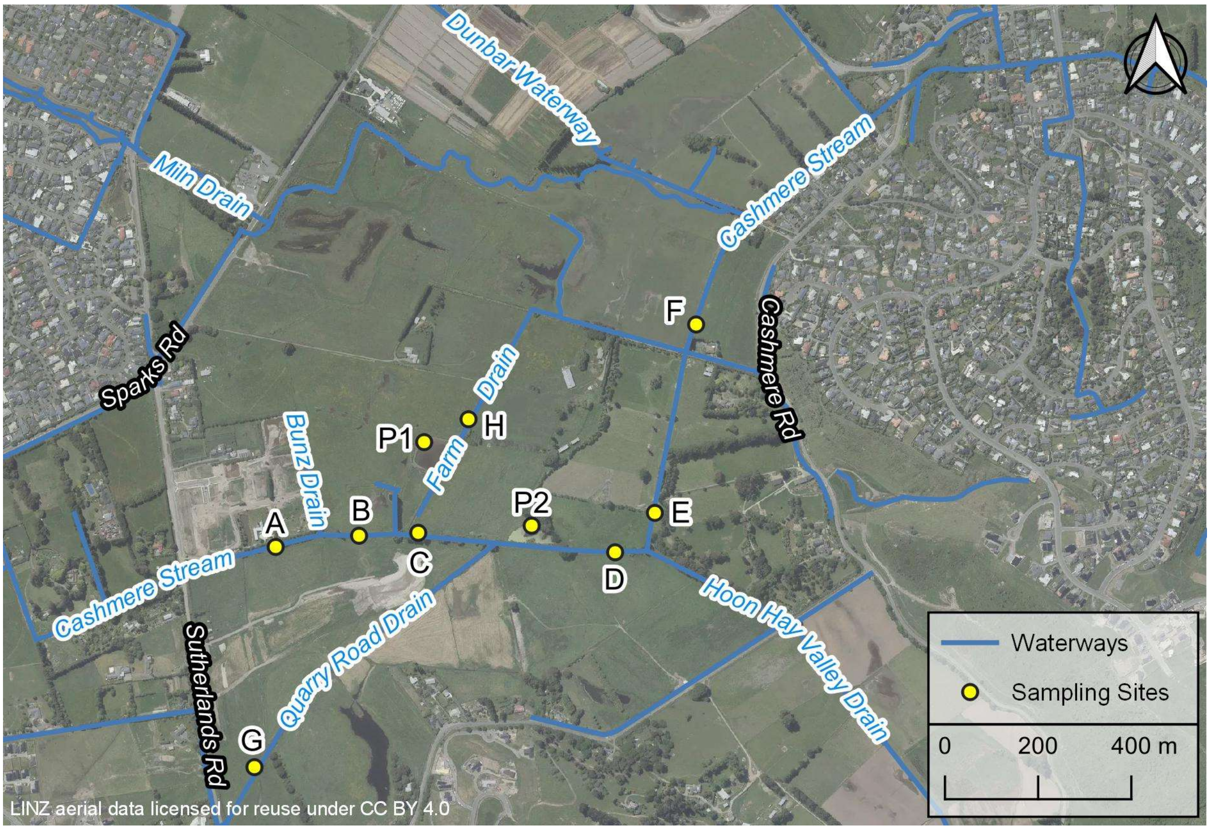

Figure 1: Sampling site locations in the Cashmere Stream catchment.

For pond sites P1 and P2, CCC only wished to know if fish were present, so only fish sampling was undertaken. This involved placing five unbaited fine mesh fyke nets around the banks of each pond, leaving them overnight, and then checking the catch the next morning.

Field data were compared to relevant guidelines and standards. Relevant guidelines and Attribute Target Levels from the Environmental Monitoring Programme for the council's Comprehensive Stormwater Network Discharge consent include: dissolved oxygen ≥90% saturation, water temperature <20 °C, pH 6.5–8.5; Quantitative Macroinvertebrate Community Index (QMCI) score ≥5; bed cover with fine sediment of <2 mm diameter ≤20%; bed cover with macrophytes ≤30%; bed cover with filamentous algae >2 cm long ≤20%. National Policy Statement for Freshwater Management 2020 national bottom line values were used for the Macroinvertebrate Community Index (MCI), with a bottom line MCI value of 90, and the Average Score Per Metric (ASPM), with a bottom line value of 0.3.

Table 1: Locations of sampling sites in the Cashmere Stream catchment.

Site	Waterway	Easting (NZTM)	Northing (NZTM)
A	Cashmere Stream	1566302	5174052
B	Cashmere Stream	1566481	5174076
C	Cashmere Stream	1566608	5174082
D	Cashmere Stream	1567031	5174041
E	Cashmere Stream	1567116	5174125
F	Cashmere Stream	1567205	5174529
G	Quarry Road Drain	1566256	5173580
H	Farm Drain	1566716	5174326
P1	Unnamed pond	1566679	5174275
P2	Unnamed pond	1566870	5714093

Note: Coordinates are taken at the downstream end of the stream and drain sites. Coordinates are the northern extent of sampling at the two pond sites.

In addition to the field measurements, Christchurch River Environment Assessment Survey (CREAS) data was collated for Cashmere Stream and its tributaries. The CREAS method involves making habitat measurements every 50 m along wadeable waterways (McMurtrie and Suren 2008). These regular habitat measurements include bank attributes (e.g., bank height, angle, and undercutting), channel attributes (e.g., water depth, velocity, and silt coverage), shading, and riparian vegetation type and cover. Any notable weeds, fish obstructions, and springs are also recorded. The data is briefly summarised here, to provide an indication of the spatial extent of data available. More detailed analysis may be undertaken as part of post-restoration assessments.

3. RESULTS AND DISCUSSION

3.1. Overview

The waterways sampled were once part of an extensive wetland that was drained for farming. The area is now in rural landuse, much of which has been purchased by CCC for stormwater management. The headwaters of Cashmere Stream arise as springs in rural land west of Sutherlands Road. The section of Cashmere Stream upstream of Sutherlands Road has been progressively naturalised and planted with native trees. Downstream of Sutherlands Road, Cashmere Stream is artificially straight and steep-sided, and it is dominated by uniform run habitat. Macrophyte removal typically occurs around twice per year, to reduce water levels and flood risk. Until recently, macrophyte removal was done with an excavator, removing a mixture of sediment and plants, but it is now done by hand, using rakes and scythes, to reduce environmental impacts.

Several tributaries of varying size join Cashmere Stream along the length of waterway studied. Bunz Drain is a major tributary that joins Cashmere Stream between Sites A and B. Quarry Road Drain is a small tributary that joins Cashmere Stream between Sites C and D. Hoon Hay Valley Drain flows intermittently and it joins Cashmere Stream between Sites D and E. The old alignment of Miln Drain enters Cashmere Stream between Sites E and F. The old Miln Drain alignment carries minimal flow, as it was recently redirected and it now flows into Dunbar Waterway, which enters Cashmere Stream approximately 200 m downstream of Site F.

The only potential barrier to fish passage near the area surveyed is the pipe culvert under Sutherlands Road. The culvert is steep, with shallow water depths, and it is perched during low flows. Since the previous baseline survey was conducted, the culvert has been assessed using the Fish Passage Assessment Tool (Franklin 2018), and the culvert was assessed as presenting a very high risk to fish passage. However, the culvert appears to prevent trout from swimming upstream, which means upstream native fish communities are protected from trout predation and competition (Instream Consulting 2016).

3.2. Water Quality and Habitat

Dissolved oxygen levels were moderate to relatively high, but below the guideline value of 90% saturation, at all sites (Table 2). Oxygen levels decline markedly between Sites A and B, reflecting the influence the large springs in Bunz Drain that carry oxygen-depleted groundwater. This is a natural phenomenon that has been observed previously (Instream Consulting 2016), and it is not associated with any discharge from local subdivisions or stormwater. Dissolved oxygen levels increase with distance downstream of Bunz Drain, due to the addition of oxygen via diffusion from the air and photosynthesis from plants and algae. Water temperatures were cool and pH was around neutral, and both were within guideline values. Conductivity varied within a relatively narrow band. Values for all measured water quality parameters were typical for Christchurch urban and rural waterways.

Water clarity was high at all sites, except for Farm Drain (Site H), which was slightly turbid and had a brown, tannin-stained appearance.

Table 2: Field measured water quality. Red values do not meet guidelines.

Site	Dissolved oxygen (%)	Temperature (°C)	pH	Conductivity (µS/cm)
A	**89.1**	12.4	7.76	242
B	**55.4**	13.0	7.42	235
C	**56.3**	14.1	7.45	213
D	**62.7**	13.9	7.41	197
E	**71.2**	14.3	7.61	197
F	**71.3**	14.1	7.64	201
G	**84.6**	15.3	7.76	185
H	**89.9**	14.4	7.62	151
Guideline	**≥90**	**<20**	**6.5–8.5**	**–**

Note: Guidelines are from the council's Comprehensive Stormwater Network Discharge consent.

Representative photographs of sampling sites are shown in Figure 2 to Figure 4, while photographs of all sampling sites are provided in Appendix 1.

Riparian vegetation throughout the length of the waterways sampled was dominated by long pasture grass and pasture weeds. Consequently, most sites were poorly shaded, with an average of 32% shade across Sites A to H. Sites with greater levels of shading included Site A (64% shade), which was bordered by a mix of tall native and exotic trees along half the sampling reach, and Site C (77% shade), which was bordered by tall exotic trees (Table 3). Bank cover with low "ground cover" vegetation was on average 86% across all sites. This high level of cover with ground vegetation would both help prevent bank erosion and intercept overland flow. The average riparian buffer width was 4.3 m across all sites sampled.

Figure 2: Representative photographs of Cashmere Stream sampling sites.

Figure 3: Tributary sampling sites.

Waterway banks were mainly comprised of natural earth, but they were steep and bank erosion was widespread, with an average of 42% bank erosion across the sites. Mean channel width ranged from a minimum of 0.59 m at Site G on Quarry Road Drain up to 4.83 m at Site C on Cashmere Stream (Table 3). Mean water depth ranged from 0.08 m at Site A on Cashmere Stream to 0.48 m at Site D on Cashmere Stream. Mean water velocity ranged from 0 m/s at Site H on Farm Drain to 0.14 m/s at Site E in Cashmere Stream. Mean values for the six Cashmere Stream sites were 3.0 m for wetted width, 0.32 m for water depth, and 0.11 m/s for velocity.

Figure 4: Pond sampling sites.

The two ponds were shallow, with average water depths of approximately 0.15 m for P1 and 0.25 m for P2. There was a narrow, deeper section at the northern end of P1, where the water depth was approximately 0.5 m. The beds of both ponds were comprised of fine sediment (<2 mm diameter) that varied from a hard pan to deeper deposits.

Inflows from Bunz Drain have a marked impact on water depths and channel width in Cashmere Stream, with mean width increasing from 0.99 m upstream (Site A) to 2.66 m downstream (Site B). Water depths are also greatly impacted by macrophyte growth and clearance by CCC contractors. Our sampling occurred several weeks after weed clearance and water levels had dropped in the order of 0.5 m.

Table 3: Average values of selected physical habitat parameters at each of the ecology sampling sites.

Site	Wetted width (m)	Water depth (m)	Velocity (m/s)	Shade (%)
A	0.99	0.08	0.04	64
B	2.66	0.23	0.14	9
C	4.83	0.39	0.10	77
D	2.93	0.48	0.11	32
E	3.33	0.36	0.14	12
F	3.18	0.40	0.11	17
G	0.59	0.14	0.02	49
H	3.55	0.44	0.00	0

The amount of bank cover available for fish was highly variable amongst sites (Figure 5). Where bank cover was present, it was mainly in the form of overhanging exotic grass, with bank undercuts also present at some sites. Where overhanging vegetation was present, the mean length of overhanging vegetation was 18 cm (taken from transect level measurements). The short length of overhanging vegetation reflected the impacts of recent cutting of bank vegetation by CCC waterway maintenance crews. Root mats were present at some sites, although they too had been trimmed back.

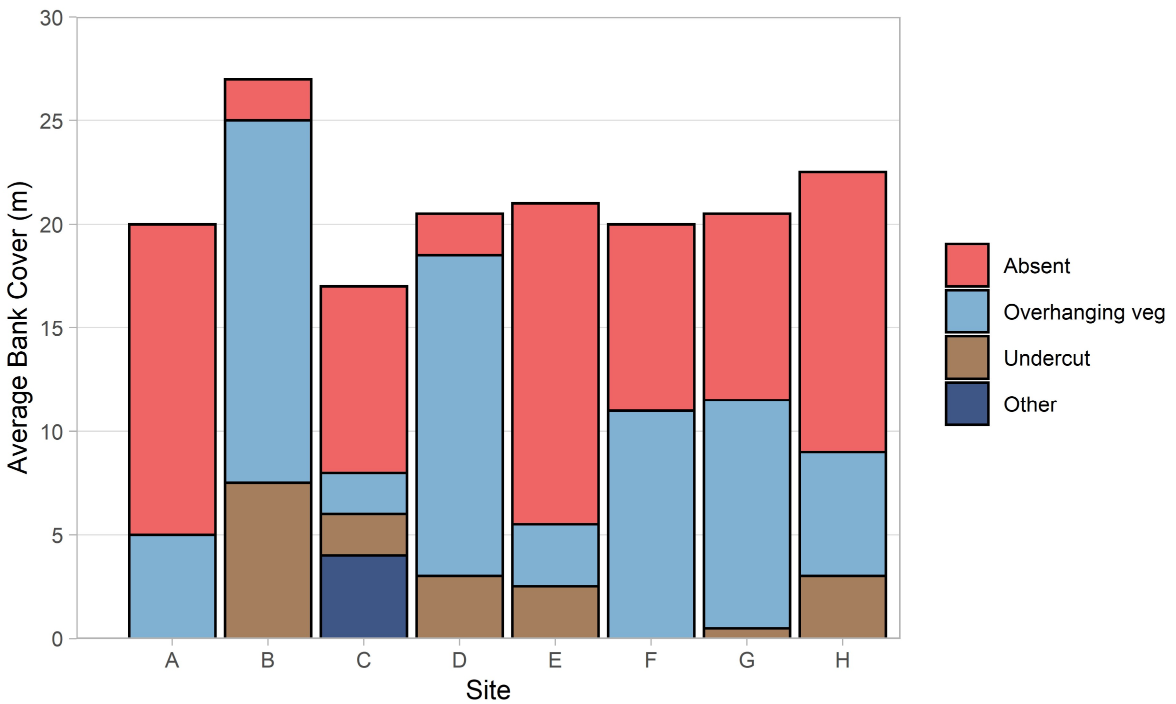

Figure 5: Length of bank cover available for fish at each site, averaged across the two banks. Note that total cover longer than the 20 m sampling reach indicates cover classes overlapping spatially.

Bed cover with different fish cover classes was also highly variable, although all sites had 100% bed cover with fine sediment (<2 mm diameter). Macrophytes provided the second most abundant bed cover class, while all other fish cover classes were uncommon (Figure 6). Overall, there was a lack of diversity of bed cover classes available as fish habitat across all sites sampled.

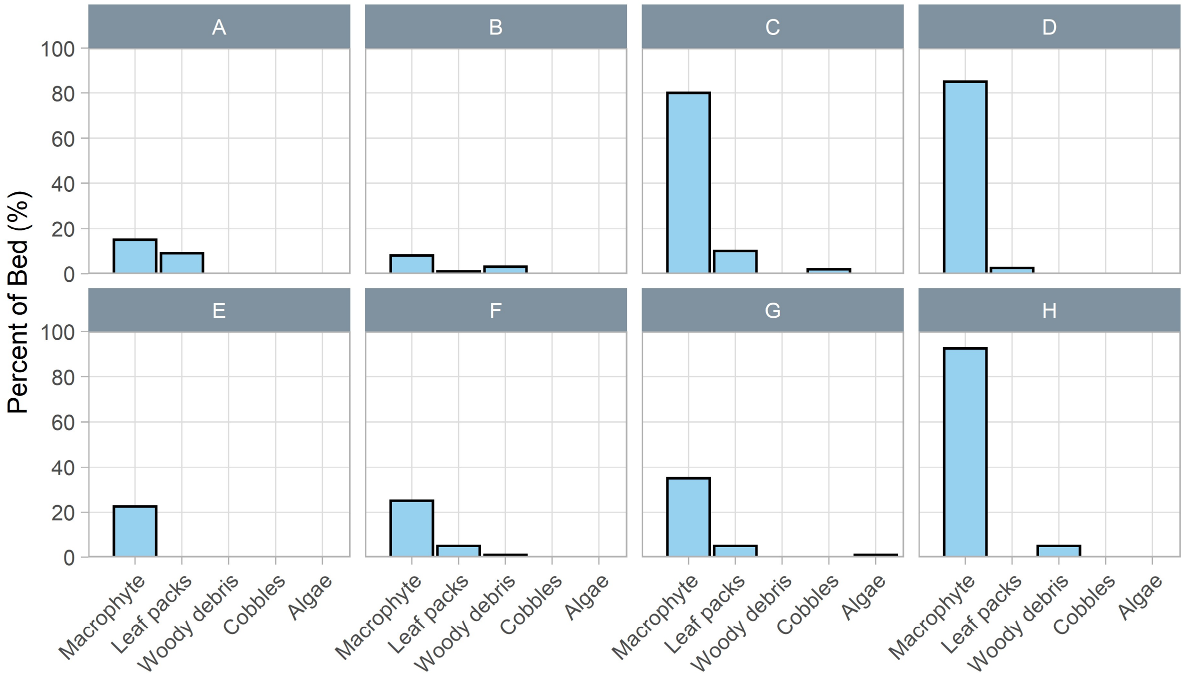

Figure 6: Amount and class of fish cover available on the bed at each of the ecology sampling sites. Note that cover classes may overlap, thus the sum of all cover classes may exceed 100% at any site. Fine sediment cover has been excluded as all sites had 100% cover of this habitat class. Macrophyte cover differs from estimates based on transect data, due to different sampling methods.

Macrophyte clearance had occurred several weeks prior to the survey, so macrophyte cover was overall lower than usual. Despite this, half the sites exceeded the 30% guideline for total macrophyte cover. However, average macrophyte depth across all sites was only 5 cm, indicating minimal growth. In contrast, mean macrophyte depth was 30 cm and mean cover was 87% at two nearby Cashmere Stream sites sampled one month earlier, prior to macrophyte clearance (Instream Consulting 2021). The macrophyte community was dominated by the introduced submerged macrophytes *Elodea canadensis* and *Potamogeton crispus*, which are widespread weed species in Christchurch waterways with little shade. The native macrophyte *Nitella* was moderately abundant at Site H (Farm Drain) and Site A (Cashmere Stream). *Nitella* has a delicate growth form, which means it does not tend to clog up waterways, unlike introduced species such as *E. canadensis* and *P. crispus*. It is therefore unsurprising that *Nitella* was relatively abundant at Site H, where light penetration is limited by the turbid and tannin-stained water, and at Site A, which was well shaded by trees.

3.3. CREAS Data

Much of the Cashmere Stream catchment was surveyed using the CREAS method in 2020 (Figure 7). Of the waterways sampled in this report, only Farm Drain (Site F) was not covered by the recent CREAS survey. Figure 8 illustrates the potential utility of CREAS data for the Cashmere Stream restoration project, as it compares CREAS measurements made before (2017–18) and after (2020) realignment and naturalisation of Miln Drain. For example, the CREAS data indicate that the new alignment generally has greater water depths than the old alignment, while water velocities remain low. Macrophyte cover remains high in the new alignment of Miln Drain, due to a lack of shading from new native plantings.

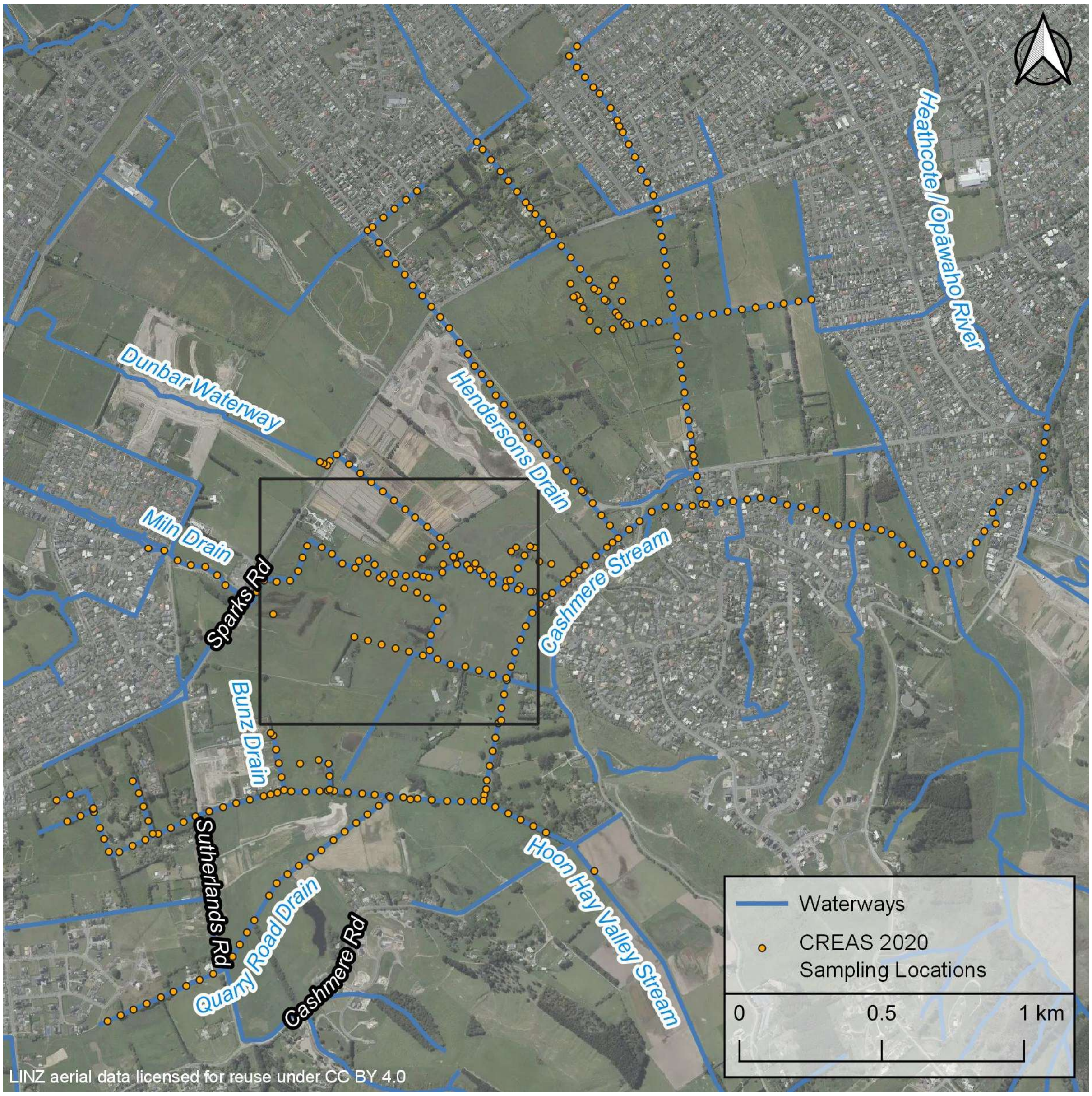

Figure 7: Extent of the 2020 CREAS sampling in the Cashmere Stream catchment. The black square indicates the extent of the Miln Drain realignment discussed in text.

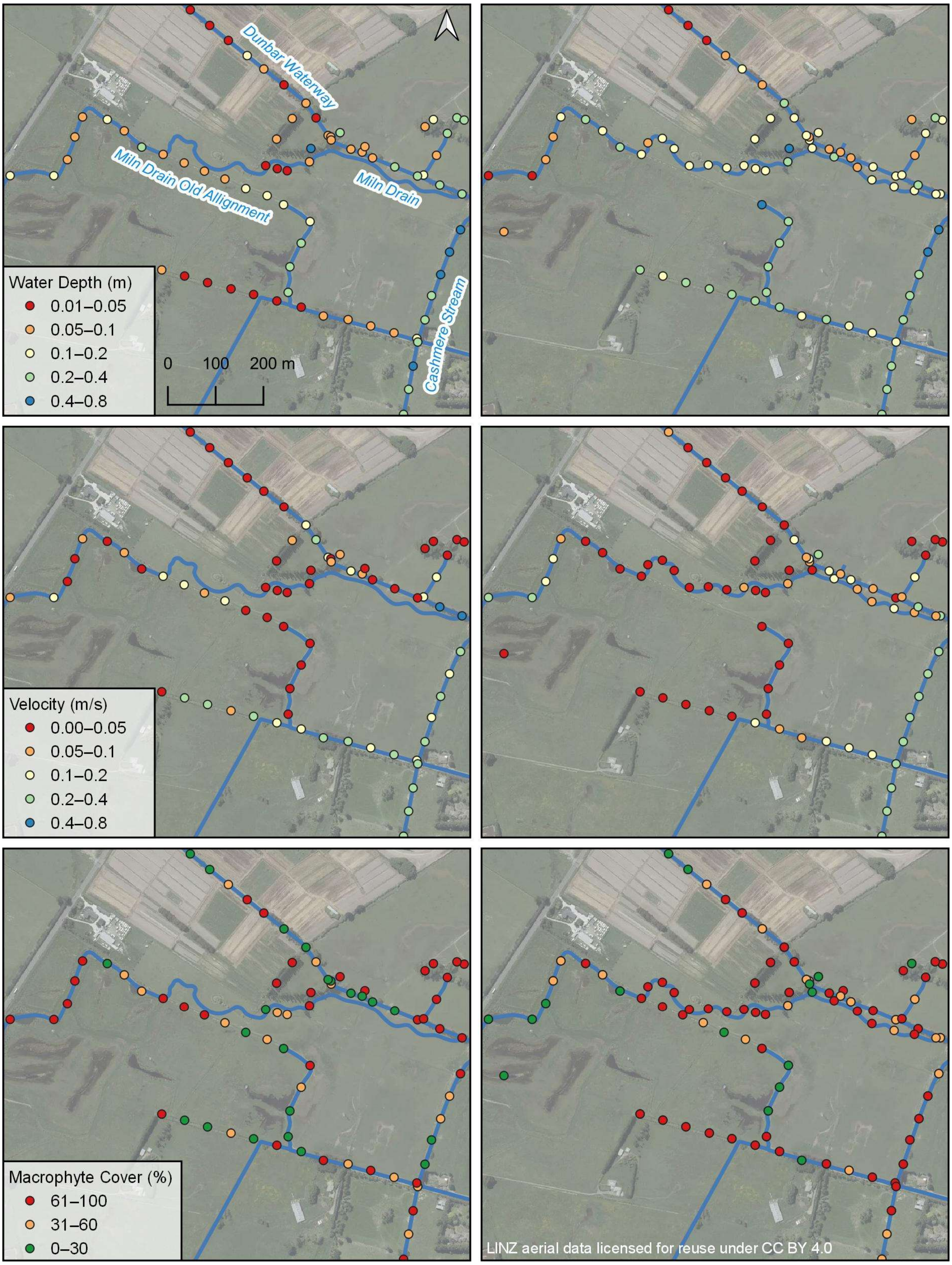

Figure 8: Water depth (top), velocity (middle), and macrophyte cover (bottom), in the vicinity of the Miln Drain realignment, including the years 2016–17 (left) and 2020 (right). All data sourced from the CREAS database. Map context can be seen in Figure 7 above.

A Waterway Impact Score was developed using 13 of the CREAS parameters (Suren and McMurtrie 2006). However, Waterway Impact Scores have not yet been compared with other biological data, such as invertebrate community metrics or fish community composition. We therefore recommend comparing CREAS data against ecological monitoring data before using CREAS to assess impacts of restoration activities on ecosystem health.

3.4. Invertebrates

The invertebrate community at all sites was dominated by pollution-tolerant taxa, particularly the common mud snail *Potamopyrgus antipodarum* (Mollusca), which comprised 59% of all invertebrates counted. The common amphipod crustacean *Paracalliope fluviatilis* was the second most abundant taxon, comprising 17% of all invertebrates. Ostracod crustaceans were also common and widespread, comprising 7% of total abundance. Cladoceran crustaceans comprised 9% of total abundance, but they were only recorded at Site H (Farm Drain), where they dominated the sample. Overall, the combination of molluscs and crustaceans accounted for 96% of all invertebrates caught across all sites (Figure 9).

The only pollution-sensitive invertebrate taxon[2] found was restricted to a single individual of the free-living caddisfly (Trichoptera) *Polyplectropus* (MCI=8). No mayflies (Ephemeroptera) or stoneflies (Plecoptera) were found at any of the sites. All three indices of invertebrate community health, the MCI, QMCI, and ASPM, fell below guidelines at all sites (Figure 10).

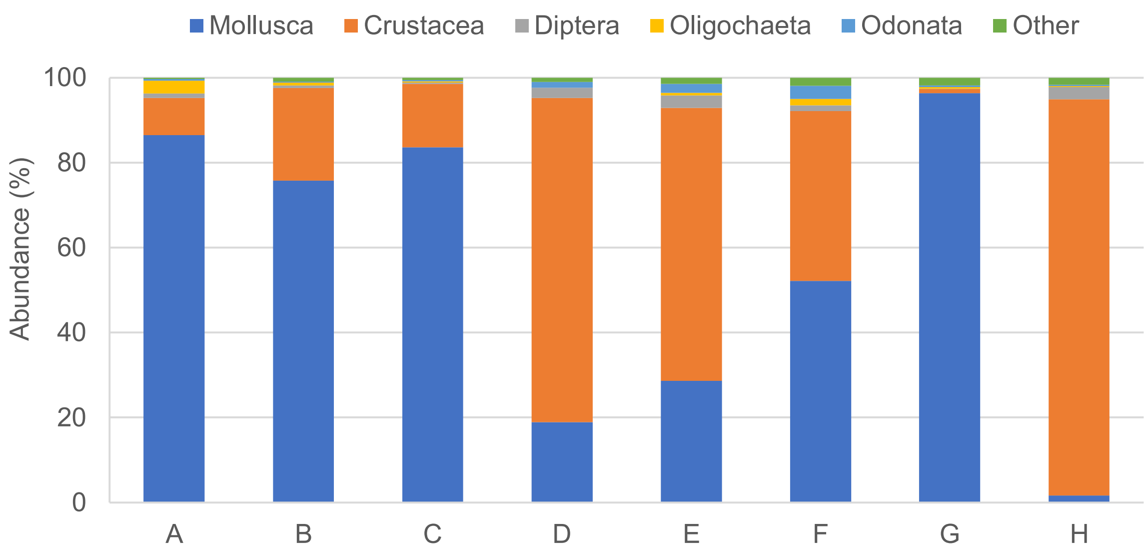

Figure 9: Invertebrate community composition at the Cashmere Stream and drain sampling sites.

Freshwater crayfish, also known as wai kōura (*Parenephrops zealandicus*), were caught during electric fishing at Sites D, E, and F on Cashmere Stream. Wai kōura burrows were also observed at Sites C to F on Cashmere Stream, although the burrows at Site C were 30–

[2] Pollution-sensitive taxa are defined here as species with hard-bottomed Macroinvertebrate Community Index (MCI) scores ≥7.

40 cm above the water line, due to recent macrophyte clearance dropping water levels (Figure 11). Although only low numbers of wai kōura were caught, the abundance of wai kōura burrows at Sites D to F suggests their numbers are much higher than indicated by electric fishing. Wai kōura have a Declining – At Risk conservation status (Grainger *et al.* 2018) and they are uncommon in urban waterways. Previous surveys have found freshwater mussels, or kākahi (*Echyridella menziesii*), from the Heathcote River confluence up to just downstream of Dunbar Waterway (Instream Consulting 2020b). However, kākahi have not been found in the reaches of Cashmere Stream upstream of Dunbar Waterway, which includes the sites sampled for this report.

Overall, invertebrate communities were degraded, reflecting the lack of suitable stony bed sediments, diverse habitats, lack of riparian vegetation for adult stages of aquatic insects, and possibly also poor water quality. However, the presence of wai kōura in Cashmere Stream is ecologically significant and they are worthy of protection, given their At Risk conservation status and their susceptibility to urbanisation.

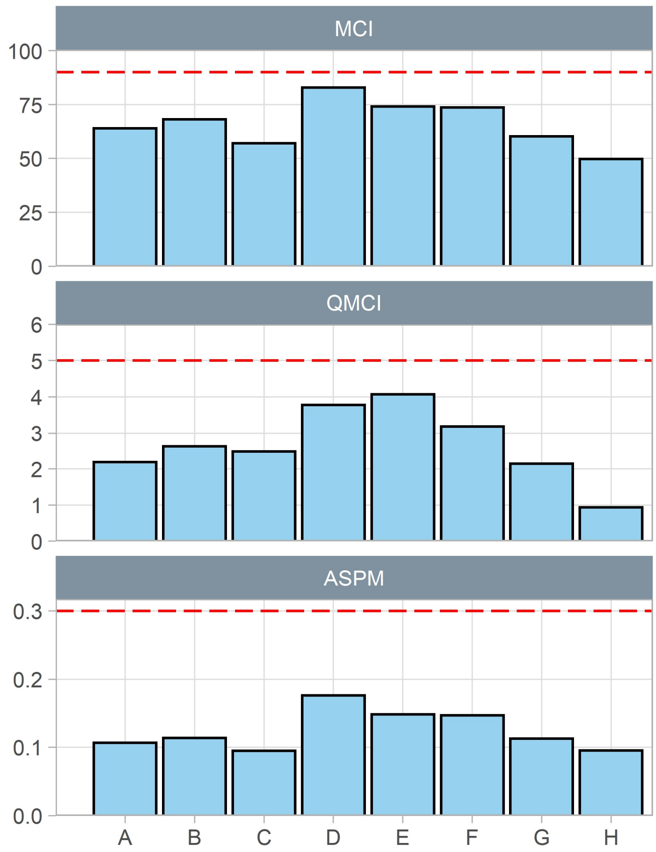

Figure 10: Macroinvertebrate Community Index (MCI), Quantitative Macroinvertebrate Community Index (QMCI), and Average Score Per Metric (ASPM) at each of the ecology sampling sites. Red dashed lines indicate the National Policy Statement for Freshwater Management 2020 national bottom line values for MCI and ASPM, and the Consent Attribute Target level for QMCI.

3.5. Fish

A total of six native fish species were caught across the ten sites sampled. No introduced or pest fish species were caught. Shortfin eel (*Anguilla australis*) was the most abundant species caught and it was found at all ten sites. Upland bully (*Gobiomorphus breviceps*) was the second most abundant species and it was found at Sites A to H. Inanga (*Galaxias maculatus*) and longfin eel (*A. dieffenbachii*) were common, but less abundant species. Common bully (*Gobiomorphus cotidianus*) was caught in low numbers at Sites B to F, while a single giant bully (*G. gobioides*) was caught at Site E. As noted in the previous section, wai kōura were also caught during electric fishing at Sites D, E, and F. Brown trout (*Salmo trutta*) are known to occur in Cashmere Stream in the vicinity of Sites A to H (personal observation), but they were not caught during this survey. Examples of fish and wai kōura caught during the survey are shown in Figure 11, while the total number of fish and wai kōura caught and their size ranges are summarised in Appendix 2.

Figure 11: Fish and wai kōura caught from Cashmere Stream.

The total number of fish species caught at each of the Cashmere Stream and drain sites ranged from a minimum of two species at Site G on Quarry Road Drain, to a maximum of six species at Site F on Cashmere Stream. Only one species, shortfin eel, was caught at the two pond sites. Fish abundance was also low at the two pond sites, reflecting the predominantly shallow water and lack of habitat present. Nineteen of the 24 shortfin eels caught at Pond A were caught in a single fyke net that was placed in a 0.5 m deep section at the north end of the pond.

Longfin eel and inanga both have an At Risk – Declining conservation status, while giant bully has an At Risk – Naturally Uncommon conservation status (Dunn *et al.* 2018). Shortfin eel, common bully, and upland bully have a Not Threatened conservation status. Five of the six species caught are diadromous, which means they migrate between freshwater and the sea to complete their life history. Upland bully was the only non-diadromous fish caught. Juvenile inanga are known as whitebait and their annual spring migration into freshwater supports a valued recreational fishery. Inanga and both eel species are also valued mahinga kai and they support commercial fisheries.

At Sites B to F, where both fishing methods were used, the number of fish caught by electric fishing was nine times the total caught by trapping methods. Thus, a mean of 112 fish were caught per site by electric fishing, compared with 13 per site using traps (Figure 12, Figure 13). The large difference in the total number of fish caught was mainly due to electric fishing catching more shortfin eels. Thus, at Sites B to F, a mean of 87 shortfin eels were caught per site by electric fishing, compared to a mean of 1 shortfin eel caught per site by trapping. Electric fishing was also more efficient at catching upland bully and wai kōura. However, longfin eel were more frequently caught by trapping, with a mean of 6 eels caught per site, compared with electric fishing, with a mean of 1 caught per site. Inanga were also more frequently caught using trapping methods. Overall, electric fishing yielded a larger catch, but each method was biased towards sampling different species.

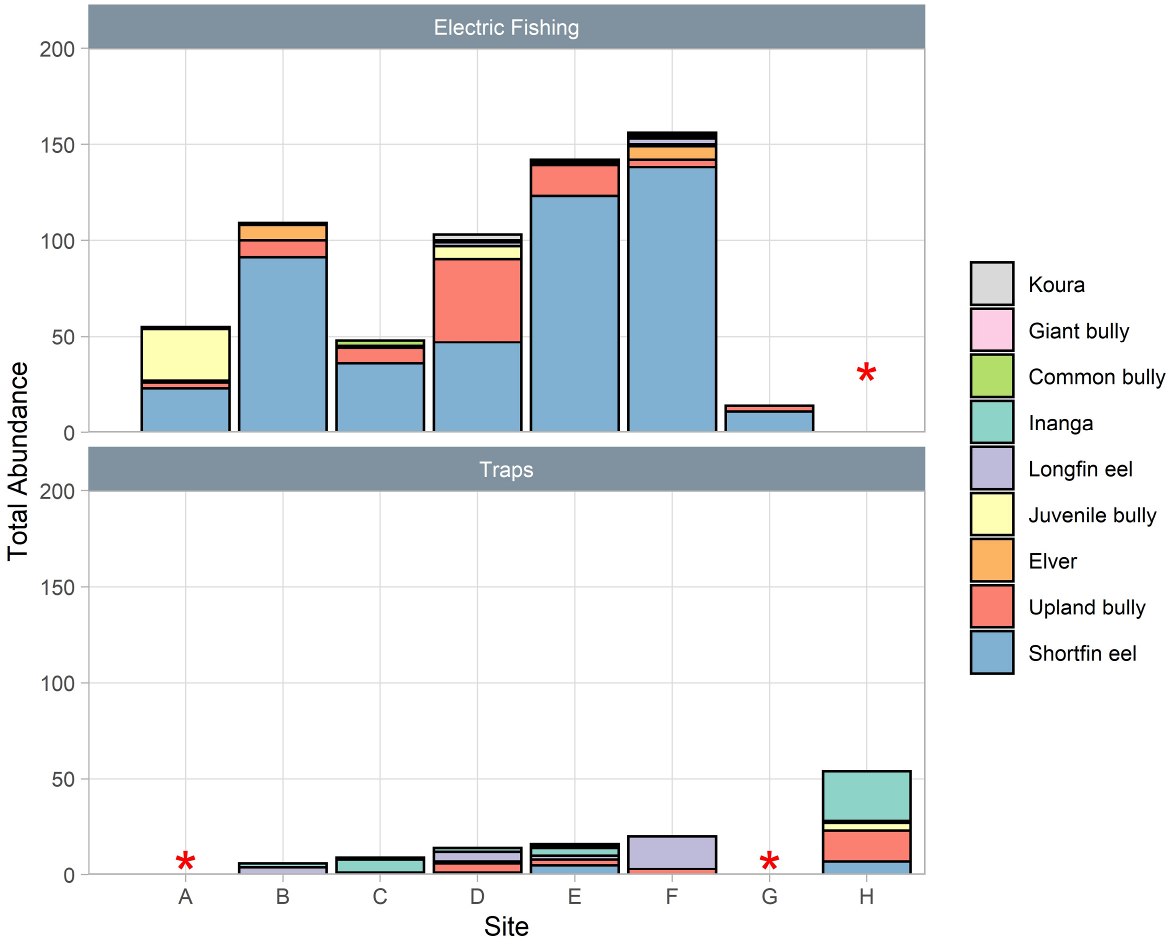

Figure 12: Total number of fish and kōura caught at Cashmere Stream and drain sites. Asterisks indicate the sample method was not used at that site.

The size distribution of eels caught varied with species, fishing method, and habitat sampled (Figure 14). Excluding pond sites, the mean length of fish caught by electric fishing was 220 mm for shortfin eels and 691 mm for longfin eels, whereas for trapping mean lengths were 421 mm for shortfin eels and 895 mm for longfin eels. Maximum lengths of longfin eels exceeded 1,000 mm at Sites A, D, and F, and the largest longfin eel was 1,318 mm, caught by a fyke net at Site B (Figure 11). In contrast, most shortfin eels caught were less than 700 mm long, with the longest shortfin measuring 878 mm, at Site G. As noted above, only shortfin eels were caught at the two pond sites, where the mean length of fish caught was 557 mm. In summary, trapping caught larger eels, the longfin eels caught were overall larger than the shortfin eels, and shortfin eels caught by trapping from the pond sites were larger than those caught by trapping from Cashmere Stream and the drain sites.

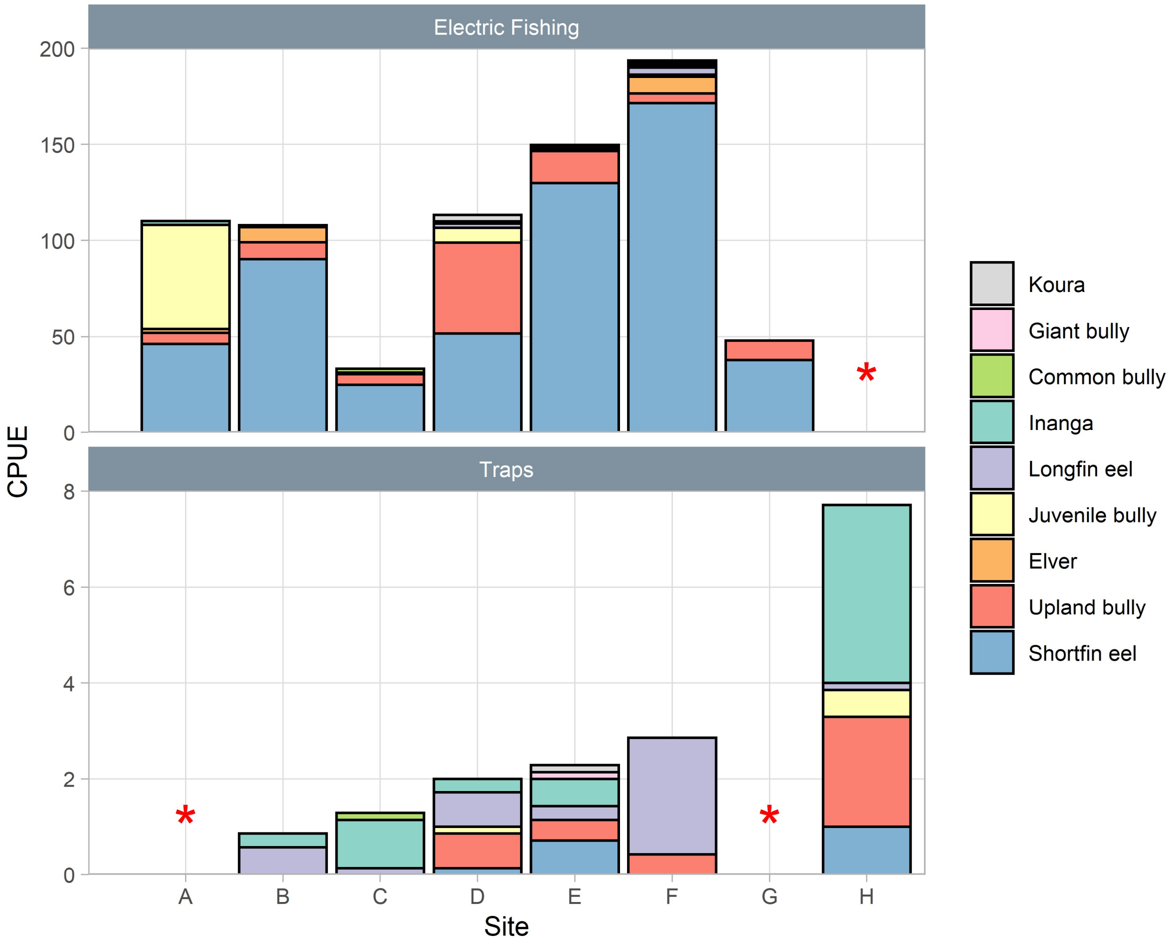

Figure 13: Fish and kōura caught at Cashmere Stream and drain sites, expressed as catchment per unit effort (CPUE; fish per 100 m² for electric fishing and fish per trap for trapping). Asterisks indicate method was not used at that site.

The range of fish species caught partly reflected the distance from the coast and lack of significant fish barriers downstream, as well as local habitat conditions. Fish diversity is typically greatest closer to the coast, because many of New Zealand's native fish species are diadromous. Of the species caught during this survey, giant bully are typically more abundant closer to the sea, while the remaining species are common at similar altitudes and distance from the sea. As noted in Section 3.2, all sampling sites lacked habitat diversity and cover for fish. Fine sediment deposits were the dominant form of fish cover at all sites. While fine sediment provides good cover for shortfin eels, additional cover attributes are generally required to encourage a range of other species. For example, juvenile longfin eels are typically found amongst stony beds with swifter velocities, and many native fish species prefer good bed and bank cover, in the form of wood, rocks, bank undercuts, and overhanging vegetation. Regular cutting back of bank vegetation, coupled with weed and sediment removal, greatly limits habitat available for native fish in the waterways sampled.

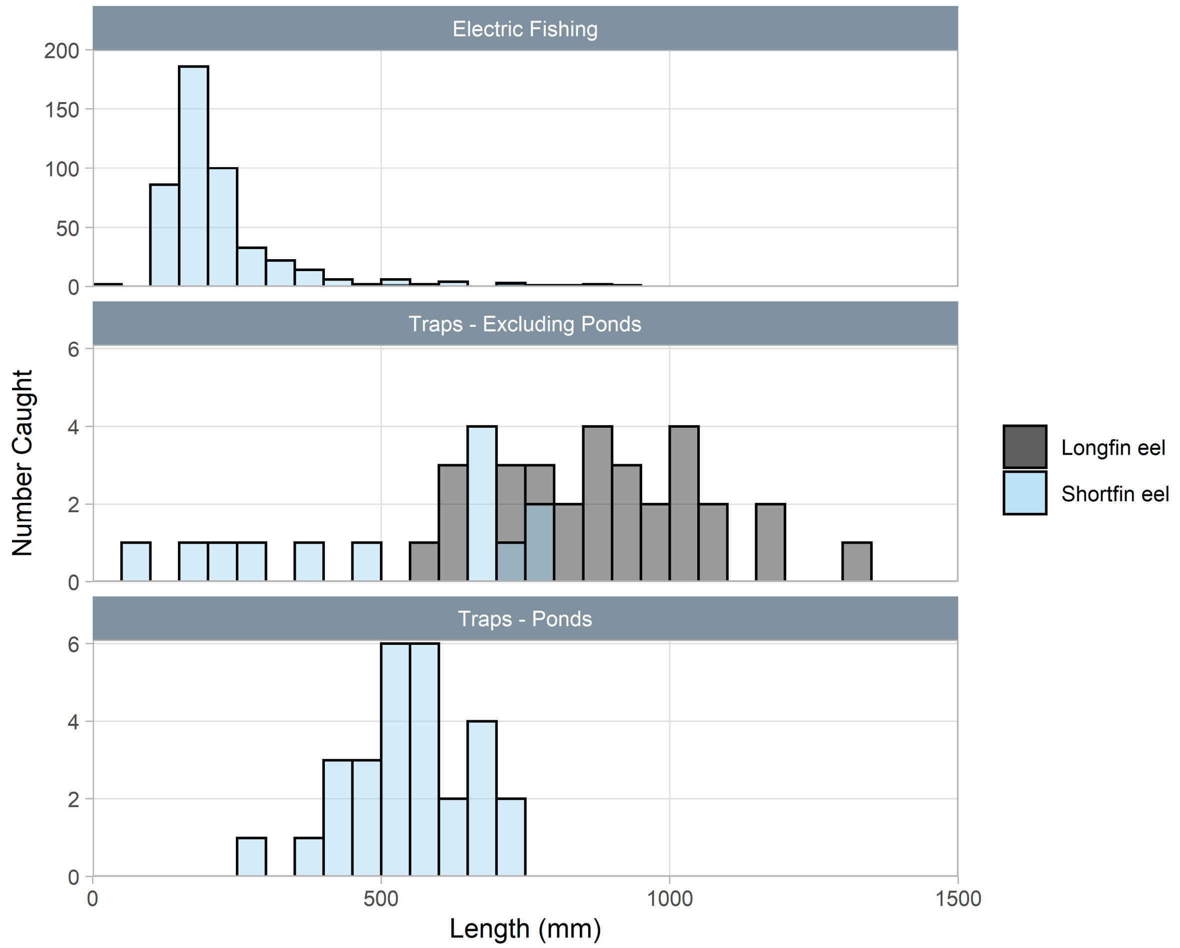

Figure 14: Size distributions of eels caught, categorised sampling method, species, and habitat type (i.e., ponds vs waterways)

Overall, fish diversity was typical for Christchurch urban and rural waterways. However, the total fish catch was relatively high at the Cashmere Stream sites, with large numbers of shortfin eels present. The presence of At Risk longfin eel, inanga, and giant bully is also notable. The relatively large numbers of inanga caught from Farm Drain (Site H) was also noteworthy, given the highly modified appearance of the waterway.

4. SUMMARY

- The reaches of Cashmere Stream and tributary drains sampled are artificially straight and steep-sided, and bank erosion is common.
- Riparian vegetation is dominated by exotic pasture grass and weeds, which help intercept overland flow, but provide little channel shading. Lack of shade is associated with high macrophyte cover and regular macrophyte removal is undertaken by CCC contractors to reduce water levels.
- Macrophyte communities are dominated by introduced weed species, although the native species *Nitella* occurs in well-shaded areas. *Nitella* is not associated with nuisance growths, due to its delicate growth form.

- Bank and bed cover for fish was mainly restricted to overhanging grass, fine sediment deposits, and macrophytes. Regular waterway maintenance by CCC limits the amount of overhanging vegetation and root mats available as fish habitat. However, natural banks provide habitat for wai kōura (freshwater crayfish) and eels to burrow into.
- Most of the waterways surveyed have good coverage with recent CREAS data. These data can be used to compare against surveys undertaken after waterway restoration.
- Invertebrate communities are dominated by pollution-tolerant crustaceans and snails. This reflects the lack of suitable stony bed sediments, diverse habitats, lack of riparian trees and shrubs for adult stages of aquatic insects, and possibly also poor water quality.
- The presence of wai kōura in Cashmere Stream is ecologically significant and they are worthy of protection, due to their At Risk conservation status and their susceptibility to urbanisation.
- Six native fish species were caught during sampling, with shortfin eel being the most widespread, and sometimes very abundant. The presence of At Risk longfin eel, inanga, and giant bully is notable. The relatively large numbers of inanga caught from Farm Drain (Site H) was also noteworthy, given the highly modified appearance of the waterway.
- Electric fishing was strongly biased towards catching large numbers of smaller shortfin eels, as well as upland bully and wai kōura. Trapping methods caught more longfin eels and inanga, and larger eels overall.

5. RECOMMENDATIONS

Restoration recommendations for Cashmere Stream were provided by Instream Consulting (2016). Since that report was produced, bank works in the catchment have revealed soft ground conditions that can make channel realignments problematic. Steep bank cuts on poorly supported soils, coupled with springs, have resulted in bank collapses and necessitated use of stabilising materials, including boulders and geotechnical fabric. While such bank stabilisation techniques may be necessary close to infrastructure such as roads and stormwater basins, they should be generally be avoided, because they can reduce habitat quality.

We therefore suggest CCC consider using modified waterway realignment methods to retain bank habitat. Rather than realigning the channel and armouring it with hard surfaces, consider leaving the baseflow channel in its current alignment, but grade the upper banks back, to reduce bank slumping, and add boulders and wood to the invert, to encourage natural erosion and deposition processes, and gradual evolution towards a meandering path. This approach takes more time to develop a sinuous channel form, but it would be less disruptive to species residing within the waterway. It would also avoid the need for harder engineering options such as rock lining to stabilise banks.

CCC propose realigning a section of Cashmere Stream that is currently on private land, in the vicinity of Site F. As noted above, we generally recommend against realigning the channel, to avoid potential bank slumping and the need for bank armouring. However, on balance, the potential environmental benefits of realigning this section of Cashmere Stream outweigh the costs. The benefits of realignment include[3]:

- Realigning stream onto CCC land will allow enhancement works outside of the current easement and provide a wider riparian buffer up to 30 m (15 m each bank) to be planted. Without realignment, planting would be limited to the current easement width of approximately 7.5 m
- A wider planted buffer will increase its inherent habitat and biodiversity value, as well as enhancing filtering of overland runoff and potentially also increasing channel shade.
- Relocation to CCC land will allow a recreational corridor including walking and cycling path to be continued adjacent to the stream.
- Relocation onto CCC land will allow space to the east of Cashmere Stream for stormwater treatment for the new Blencathra subdivision and retrofit of treatment for 11.5 ha of existing catchment in Westmorland. Should stream relocation not occur, stormwater from these areas will need to be siphoned under Cashmere Stream at additional cost and risk.
- Moving the stream onto Council land at 482a Cashmere Road will prevent right angles in the channel when the channel transitions from the realigned section on 564 Cashmere Road to the old alignment on 482 Cashmere Road. This would not perform well hydraulically
- Realignment will continue on from that planned at 564 Cashmere Road and provide a good comparison of the ecological benefit of realignment verses upstream sections that are planned to stay on their current alignment (as per the advice above).

Since completion of the previous baseline report by Instream Consulting (2016), it has become clear that creation of riffle habitat may be impractical, due to the low bed gradient across the site. If that is indeed the case, we suggest that it is most important to retain deeper water habitat, with a range of velocities, where possible. This is because deeper water provides habitat for larger eels and trout, and different fish species and life stages have differing depth and velocity preferences. For example, the largest number of At Risk inanga were caught in the highly modified habitat of Farm Drain (Site H), where the water was relatively deep and velocities were very low.

We recommend using a combination of electric fishing and trapping techniques for future monitoring and fish salvage, where practical. That is because each technique is biased towards catching certain fish species, so using both methods will ensure the full range of fish species present are caught. We also recommend conducting macrophyte removal prior to fish salvage. Electric fishing for this survey was only practicable at the Cashmere Stream sites due to recent weed clearance. Prior to weed clearance, electric fishing would have been impractical due to greater water depths, plus high macrophyte cover would have reduced catch efficiency. Electric fishing yielded much higher numbers of shortfin eel, which often dominate urban Christchurch waterways, but trapping was also needed to capture the full range of fish species and size classes present.

[3] Benefits are based on an email from Belinda Margetts, CCC Principal Waterways Ecologist, 19 August 2021.

The following recommendations summarise and build on previous recommendations made by Instream Consulting (2016):

- **Finalise and follow waterway restoration goals.** The draft goals summarised in Section 1 are a good start, but they should be finalised, so that they can guide ongoing design work and provide clear expectations for restoration outcomes.
- **Plant trees and shrubs to shade waterways.** This will reduce the need for regular weed removal, plus greater shade favours native macrophyte species over introduced species. Waterways with greater shade and lower macrophyte cover also provide better aquatic habitat for fish and invertebrates.
- **Avoid trimming bank vegetation.** Regular cutting back of bank vegetation, coupled with weed and sediment removal, greatly limits habitat available for native fish in the waterways sampled. This will require regular training of council contractors, coupled with community education of the ecological value of retaining overhanging vegetation.
- **Retain natural banks and avoid bank armouring.** Natural earth banks provide important habitat for wai kōura and eels. Where rocks are used for bank armouring (e.g., to protect critical infrastructure), preferably use larger boulders with no geotextile backing, to provide crevices and maintain access to the soft banks behind. Avoid using plastic-based geotextiles, such as Bidim, as they pollute waterways as they degrade.
- **Encourage natural development of a meandering channel alignment.** Over time, this will create instream flow diversity and aquatic habitat for invertebrates and fish to colonise. Grade back the upper banks, to reduce slumping, and add boulders and wood to the channel invert, to provide habitat and encourage natural erosion and deposition processes.
- **Not net loss of aquatic habitat.** The aim of the restoration should be to improve habitat quality and avoid any loss of aquatic habitat. Waterways such as Farm Drain could be realigned, but it would be important to retain an equivalent length of waterway, or longer, with similar water depths, to provide habitat for species such as inanga. Stormwater ponds should not be included in the "no net loss" calculation, as they are designed to trap stormwater contaminants.
- **Pond habitats – retain equivalent or better.** The two ponds sampled covered a large area, but they were dominated by shallow water and lacked good quality fish habitat. Creating a greater variety of depths, as well as the addition of habitat features (e.g., logs and boulders), and riparian planting, would greatly enhance fish habitat.
- **Fish passage in stormwater basins.** Upstream and downstream fish passage is required through any stormwater basins that are built "online", with the waterway flowing through them. Offline stormwater basins still need to provide for downstream fish passage, and they need to avoid fish stranding, as fish often find their way into stormwater ponds as juveniles and their downstream passage as adults may be blocked.
- **Fish passage at Sutherlands Road.** If the existing Sutherlands Road culvert is upgraded, the design should consider excluding brown trout, while maintaining or enhancing upstream access for native fish species. Cashmere Stream Care Group should be consulted regarding culvert design, as they have undertaken restoration work upstream and they are interested in keeping the upper reaches trout-free.
- **Create a mix of pool and run habitat.** This will create habitat diversity that is now lacking. Deeper, slow-flowing pools would be used by larger eels, trout, and inanga, while shallower, swifter run habitat would be used by bullies and juvenile eels. Riffle

sections would also provide valuable habitat diversity, but there may be insufficient gradient to create riffle habitat in this location.

- **Snags and boulders.** The addition of tethered logs, root-wads, and boulders to the channel would provide cover and habitat for a range of native fish and wai kōura.
- **Protect Bunz Drain springs.** These impressive springs are the major source of baseflow in Cashmere Stream below Bunz Drain, so it is important that any channel realignment captures the springs' flow. The springs should also be protected because of their biodiversity and cultural value.
- **Fish and wai kōura salvage.** Fish and wai kōura should be removed from the affected length of Cashmere Stream and its tributaries prior to flow being diverted to any new channel alignment. As noted above, macrophyte clearance should occur prior to salvage, to facilitate electric fishing. Separate salvage of kākahi is unnecessary, as they do not occur within the area covered by this report.
- **Monitor success.** Ecological monitoring should be undertaken following completion of the realignment and enhancement works, to evaluate the success of the restoration works. Monitoring will need to occur over a number of years, to allow an adequate length of time for biological communities to colonise and establish in the new habitat.

6. REFERENCES

Dunn, N. R., Allibone, R. M., Closs, G. P., Crow, S. K., David, B. O., Goodman, J. M., Griffiths, M., Jack, D. C., Ling, N., Waters, J. M., and Rolfe, J. R. (2018). 'Conservation status of New Zealand freshwater fishes, 2017'. (Department of Conservation: Wellington.)

Franklin, P. (2018). Fish Passage Assessment Protocol Mobile Application User Guide. *Report prepared by NIWA for Envirolink Tools, NIWA Client Report Number 2018349HN*, 75. Available at: https://niwa.co.nz/sites/niwa.co.nz/files/User guide v1.3 FINAL.pdf

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

Instream Consulting (2016). Cashmere Stream baseline aquatic survey. *Report prepared for Christchurch City Council, July 2016.*

Instream Consulting (2021). Christchurch Aquatic Ecology Monitoring 2021. *Report prepared for Christchurch City Council, July 2021*.

Instream Consulting (2020a). Heathcote River, Linwood Canal, and Banks Peninsula aquatic ecology 2020. *Report prepared for Christchurch City Council, September 2020*.

Instream Consulting (2020b). Kākahi in Cashmere Stream: Distribution and Current State of the Population. *Report prepared for Christchurch City Council, June 2020*.

McMurtrie, S., and Suren, A. (2008). Field Methodology for the Christchurch River Environment Assessment Survey (CREAS). *Report prepared by EOS Ecology for Christchurch City Council, June 2008*.

Suren, A., and McMurtrie, S. (2006). Development of a Waterway Impact Score. *EOS Ecology Report No. 05007-CCC02-01, prepared for Christchurch City Council by EOS Ecology and NIWA*.

APPENDIX 1: SITE PHOTOGRAPHS

Figure 1: Site A – downstream looking upstream.

Figure 2: Site B – upstream looking downstream.

Figure 3: Site C – downstream looking upstream.

Figure 4: Site D – downstream looking upstream.

Figure 5: Site E – downstream looking upstream.

Figure 6: Site F – downstream looking upstream.

Figure 7: Site G – downstream looking upstream.

Figure 8: Site H – upstream looking downstream.

Figure 9: Site P1 – looking south from the northern bank.

Figure 10: Site P2 – looking east, across the northern bank.

APPENDIX 2: FISH AND WAI KŌURA SUMMARY TABLE

Table 1: Fish and wai kōura caught electric fishing and trapping during the current study. Data are number of fish caught, with the size range (in mm) in brackets.

Site	Shortfin eel	Longfin eel	Elver	Inanga	Upland bully	Common bully	Giant bully	Juvenile bully	Wai kōura
A	23 (130–358)		1 (116)	1 (71)	3 (48–67)			27 (21–40)	
B	91 (112–595)	4 (645–1318)	8 (111–136)	2 (65–79)	9 (46–74)	1 (50)			
C	36 (134–549)	1 (1191)		8 (54–74)	8 (41–65)	4 (40–59)			
D	48 (167–864)	7 (502–1175)		2 (70–71)	48 (39–78)	1 (64)		8 (32–37)	3 (34–38)
E	128 (120–712)	2 (560–736)	1 (98)	5 (52–65)	19 (40–70)	1 (69)	1 (116)		1 (29)
F	138 (112–713)	20 (497–1092)	7 (105–136)	1 (81)	7 (53–66)	1 (69)		1 (35)	1 (31)
G	11 (158–878)				3 (60–66)				
H	7 (596–767)	1 (1036)		26 (51–96)	16 (41–62)			4 (31–36)	
Pond 1	24 (384–739)								
Pond 2	4 (282–679)								

Note: Data include combined results from both fishing methods for Sites B to F.