Paparua Water Race Scheme: 2022 Ecological Surveys

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Prepared for Christchurch City Council and Selwyn District Council

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SCIENCE + ENGAGEMENT

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EXECUTIVE SUMMARY

The Paparua Water Race Scheme is operated under the joint jurisdiction of Selwyn District Council (SDC) and Christchurch City Council (CCC). To inform future management decisions, EOS Ecology was contracted by Christchurch City Council and Selwyn District Council to undertake surveys to provide an overview of ecological health in the Paparua Water Race Scheme. The focus of these surveys was to assess the biotic communities present, with particular emphasis on determining the presence of sensitive or otherwise notable native species.

The riparian vegetation communities throughout the Scheme were highly modified, with generally low native plant diversity. A small number of sites had diversity of native rushes, ferns, and sedges; the most diverse of these sites consisted of a mix of native and introduced species planted near residences or in public parks. The majority of surveyed sections were moderately fast flowing with predominantly coarse substrate, although most sites had at least some degree of fine sediment accumulation. The aquatic pest plant *Lagarosiphon major* was found at a single site and the riparian pest plant *Salix cinerea*/grey willow was found at six sites.

The macroinvertebrate communities at all sites were characterised by taxa that tolerate degraded habitat and/or water quality conditions. Kākahi/freshwater mussels, which have a threat classification of "At Risk – Declining" were detected via eDNA at two sites and are known to be present from past observations in two additional locations within the Paparua Water Race Scheme. Two other taxa found (the freshwater snails *Glyptophysa variabilis* and *Austropeplea tomentosa*) have threat classifications of "Data Deficient", and thus their presence may be of some conservation interest. There are also three invasive macroinvertebrate species present within the scheme: the introduced freshwater snails *Physa acuta* and *Radix auricularia*, and the freshwater jellyfish *Craspedacusta sowerbii.*

Eight fish species were found, four of which require access to the ocean to complete their life cycle (shortfin eels, longfin eels, torrentfish and bluegill bullies). Water races are generally a "dead end" for these migratory species, since migrating downstream leads them to the terminal end of the water race, rather than to the ocean. One species (common bully) is usually migratory, but can form landlocked populations if they are unable to access the ocean. Common bullies, along with the remaining three species (upland bullies, brown trout, rainbow trout) which are potentially able to establish self-sustaining populations within the water race scheme are all widespread, and do not have threat classifications which would make them of note from a conservation perspective. The threatened kōwaro/Canterbury mudfish was not found at any of the survey sites.

Based on a set of criteria devised for the assessment of water races, eight sites of ecological interest were identified. Four of these were of note because they were located in the vicinity of kākahi populations and one site ranked particularly high in the ecological values of diversity and uniqueness. Management of the water race scheme should prioritise retention of these four kākahi sites and one site with other high ecological values (and the branches from which the water is provided). If this is not possible, removal and relocation of sensitive/threatened species should be undertaken. The remaining three sites did not have high ecological values as such, but are located on branches of water race which constitute the headwaters or contribute flow to streams under Christchurch City Council management, and thus may support the ecological values of these streams. Further investigation should be carried out as to the actual contribution of water from the water race scheme to the headwaters of these streams in order to determine whether it is necessary for these branches to be retained.

1 INTRODUCTION

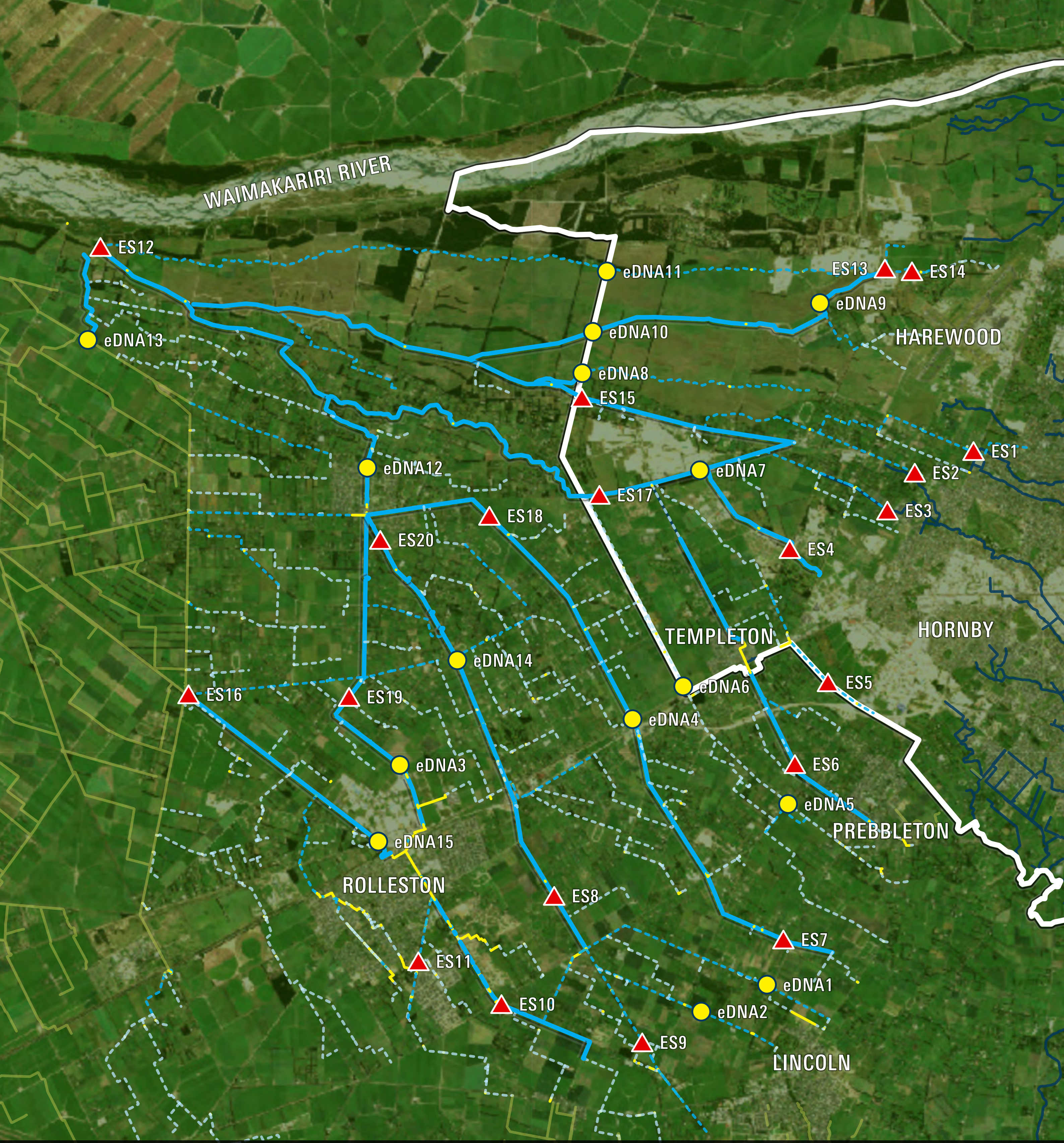
The Paparua Water Race Scheme is one of three water race schemes operated by Selwyn District Council. The Paparua Water Race receives water from the Waimakariri River, with the intake at Intake Road. A portion of the Scheme also lies within the boundaries of Christchurch City Council, and thus management of the system is shared between the two councils. In addition to connections with other water races in the Selwyn District (namely the Malvern Water Race Scheme), the Paparua Water Race Scheme connects to several streams within the Christchurch City Council boundaries (Figure 1), and thus management of the water races must also consider impacts on these natural waterways.

The last known comprehensive survey of the Paparua Water Race Scheme was undertaken by McMurtrie *et al.* in 1997, although Sinton (2008) also surveyed a number of sites within the Scheme, as part of a comparison of water races and natural streams on the Canterbury Plains. EOS Ecology was contracted by Christchurch City Council and Selwyn District Council to undertake surveys to provide an updated overview of ecological health in the Paparua Water Race Scheme.

Surveys were conducted in the neighbouring Malvern and Ellesmere Water Race Schemes in 2011 to identify sites of ecological significance (James, 2011b). The methodologies developed for the surveys of the Malvern and Ellesmere provided a means for assigning ecological values to water race systems. Such methods differ from the valuation of natural waterways in that water races have no natural or unmodified state to be compared with, and thus the focus is on the biotic communities that have colonised and are supported by these systems. During the surveys of the Malvern and Ellesmere water races, several species of note were found, chiefly the “Threatened” kōwaro/Canterbury mudfish, as well as the “At-Risk” kākahi/freshwater mussel. Some sites were also found to have diversity of native fish, native macroinvertebrates, and native vegetation (both riparian and aquatic).

The findings of prior studies in the Malvern and Ellesmere Water Race Schemes, as well as historical data from the Paparua Water Race Scheme, indicate that water races of the Canterbury Plains provide habitat for native species. This underscores the value of understanding which areas have sensitive or otherwise notable native species or diverse biotic communities. Information from these 2022 Paparua Water Race scheme surveys was used to identify sites of ecological significance and the upstream branches of water race that provide flow to these sites. This information will inform future management decisions for these water races and their downstream waterways, particularly in relation to closing branches of the Scheme.

Figure 1 …*figure over page*… **Overview map of sites within the Paparua Water Race Scheme surveyed by EOS Ecology in February and March 2022.**



Paparua Water Race (PWR) Survey Sites

SURVEY TYPE
- eDNA
- Ecological survey

PWR WATERWAY TYPE
- Culvert/piped
- Lateral
- Local
- Main

- Christchurch City Council boundary
- Christchurch City waterways
- Other water race schemes

0 0.5 1 2 km

N

Layer source: Sites monitored by EOS Ecology, waterways: Christchurch City Council, Selwyn District Council.

Image source: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors

2 METHODS

2.1 Surveys

2.1.1 Site Selection

A total of 35 sites were surveyed for ecological values (Figure 2, Figure 3). Potential sites were selected via means of a desktop analysis. Criterion used to select sites included: positioning on a "main" or otherwise significant branch of the water race scheme, even coverage of the water race network, and accessibility by public roads. In addition, three sites were positioned on branches of waterways which form the headwaters to streams within Christchurch, as these are of particular management interest to the Christchurch City Council. Aerial imaging was used to inform selection of sites representative of a variety of different riparian habitat types. Actual site locations were then modified if necessary during the field visits based on site accessibility and safety, and also to ensure as much as possible the full range of riparian and instream habitat types present in the Paparua Water Race Scheme were sampled.

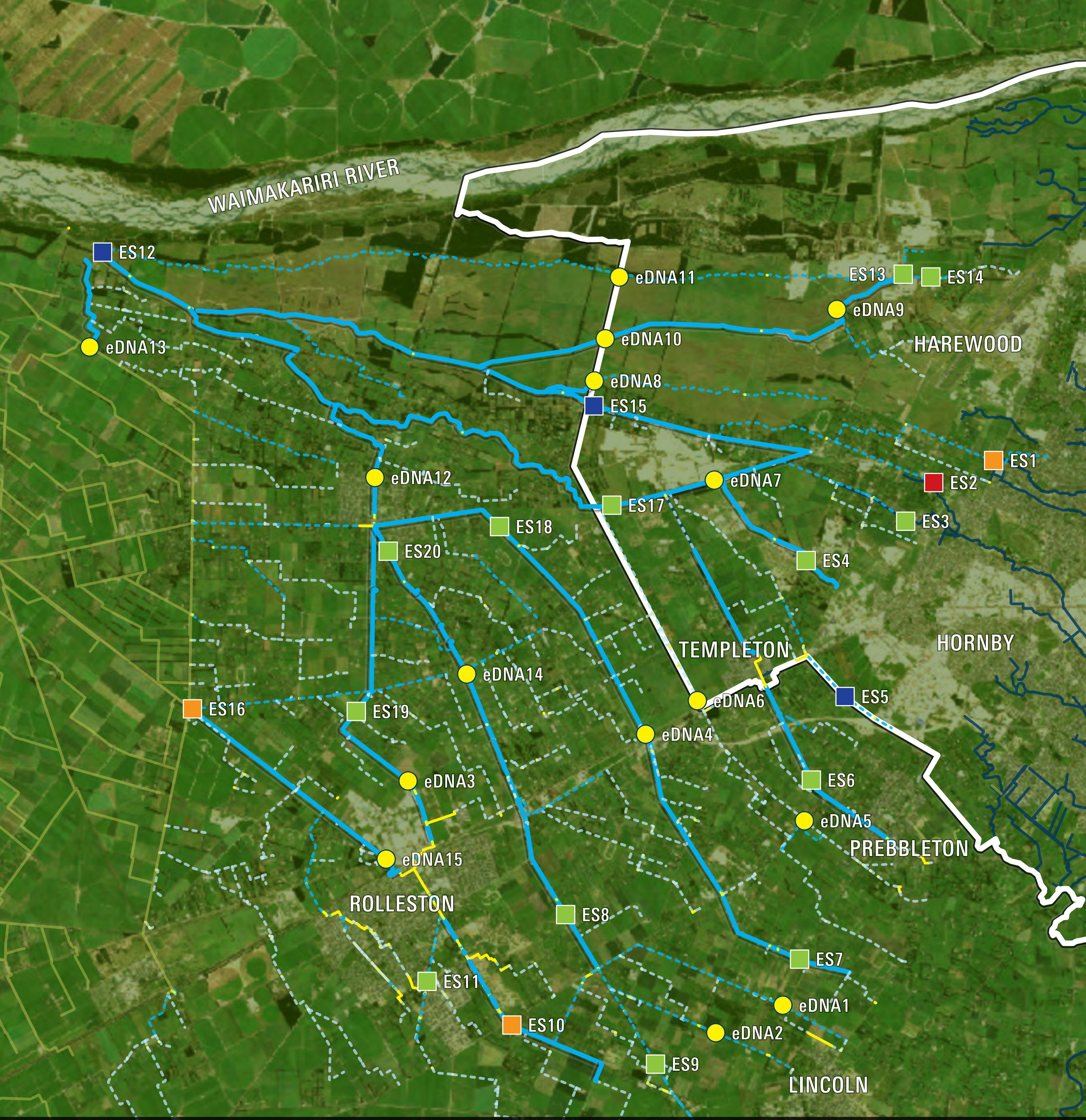
Twenty of these sites underwent full ecological surveys consisting of a rapid habitat assessment, invertebrate sample collection, kākahi/freshwater mussels search (where relevant), and fish sampling via electrofishing, with the addition of Gee minnow trapping at sites with potential habitat for kōwaro/Canterbury mudfish. The remaining 15 sites were sampled for eDNA, and a rapid habitat assessment was conducted at each. Methods for each of these survey components are detailed below.

An eDNA sampler *in situ.*

Undertaking a visual search for kākahi/freshwater mussels.

Figure 2 Photos of some of the survey methods used during surveys conducted by EOS Ecology in February and March 2022.

Figure 3 *…figure over page…*Map of sites within the Paparua Water Race Scheme surveyed by EOS Ecology in February and March 2022 and the survey methods used at each site.



Paparua Water Race (PWR) Survey Methods

SURVEY METHOD

- eDNA sampling
- Electrofishing, Gee minnow trapping, kicknet sampling
- Electrofishing, Gee minnow trapping, kicknet sampling, kākahi search
- Electrofishing, kicknet sampling, kākahi search
- Electrofishing, kicknet sampling

PWR WATERWAY TYPE

- Culvert/piped
- Lateral
- Local
- Main

- Christchurch City Council boundary
- Christchurch City waterways
- Other water race schemes

0 0.5 1 2 km

N

Map © EOS Ecology, 2022 / www.eosecology.co.nz

Layer source: Sites monitored by EOS Ecology, waterways: Christchurch City Council, Selwyn District Council.

Image source: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors

2.1.2 Rapid Habitat Assessment

All 35 sites were visually assessed for riparian (dominant vegetation and level of shading) and instream (flow and substrate type) habitat and classified according to the rapid habitat assessment categories initially developed by Dr Colin Meurk for use in the Malvern Water Race Scheme and described in James (2011a).

Each site was assigned to one of 12 possible riparian habitat classifications. Classifications are notated by a letter (A–F) to indicate vegetation type, and a number (1 or 2) to indicate level of shading. Vegetation type ranged from Class A (scorched earth, >25% bare ground) to Class F (densely planted native trees, shrubs, and tussocks), with an increase in native plant coverage from A to F. Sites given a "1" for shading had <20% overhead canopy cover, whilst sites given a "2" had >20% overhead canopy cover. Sites with greater native plant coverage and those with higher shading are generally considered to have higher ecological value (i.e., "A1" has the lowest ecological value, "F2" has the highest).

Each site was assigned to one of 8 possible instream habitat classifications. Classifications are notated by a letter (G–J) to indicate flow type, and a number (3 or 4) to indicate substrate. Flow type ranged from Class G (swift velocity, approximately ≥0.8 m/s) to Class J (no detectable water flow), with a decrease in flow from G to J. Sites given a "3" for substrate had coarse substrate (dominated by cobble/gravel), whilst sites given a "4" had soft substrate (dominated by sand/mud). Sites with greater flow and those with coarse substrate are generally considered to have higher ecological value (i.e., "G3 has the highest ecological value, "J4" has the lowest).

2.1.3 Macroinvertebrates – Full Ecological Survey Sites

A single macroinvertebrate sample was collected from each of the 20 sites which underwent full ecological surveys. Each sample was made up of a composite of six individual kicknets, in accordance with the 0.6 m^2 minimum sample size prescribed under the new NEMS Macroinvertebrate guidelines (Milne *et al.*, 2020), and covering all microhabitats present (e.g., where present, macrophytes, woody debris, stony substrate). Samples were taken within the same 30 m reach which was sampled for fish. Each invertebrate sample was kept in a separate container, preserved in 70% isopropyl alcohol, and taken to the laboratory for identification following the NEMS Fixed Count 200 with Subsampling Option method, which supersedes the equivalent Stark *et al.* (2001) protocols.

A visual search for kākahi/freshwater mussels was also undertaken throughout the 30 m survey reach in areas where visibility was sufficient to allow for this. In areas with insufficient visibility, but which had potentially suitable habitat for kākahi, a quick hand search was conducted. Prior records of kākahi found by EOS Ecology in the Paparua Water Race Scheme in 2021 and records from the New Zealand Freshwater Fish Database (Crow, 2017) reported by Wildlands in 2019 have also been included when assessing ecological values in this report.

2.1.4 Fish – Full Ecological Survey Sites

Fish were sampled within each ecological survey site using electrofishing. Gee minnow traps were used at any sites deemed to have habitat which was potentially suitable for kōwaro/Canterbury mudfish (which are unlikely to be detected via electrofishing). The following describes the different fishing methods:

» **Electrofishing** is a method of fishing that passes an electric current through the water that serves to temporarily 'stun' fish, allowing for their capture in dip nets or handheld stop nets. At each site, a section of 30 m was fished via a single pass with the electrofishing machine, aiming to cover all habitat types within the reach. Some sites contained sections which were not amenable to electrofishing (e.g., thick macrophyte beds or very deep water/sediment), hence spot fishing at suitable locations was undertaken rather than fishing entire reaches – in such cases, it was ensured that the total length fished remained at 30 m.

» **Gee minnow traps** are designed to catch smaller fish by fish entering through the two funnel-shaped entrances at either end of a small mesh (3 mm mesh size) cylinder. To accommodate the breathing requirements of kōwaro/Canterbury mudfish, Gee minnow traps were set to allow an air gap above the entrance to the trap. At each site where Gee minnow traps were deployed, five traps were set along a reach of up to 200 m, targeting areas of most suitable habitat (e.g., dense cover provided by overhanging riparian vegetation or macrophytes). At each site, three of the traps were baited with Vegemite and the remaining two were un-baited. This was done in accordance with the suggestion in Ling *et al.* (2013) that mudfish are most likely to be caught incidentally during night-time foraging (rather than because of being actively attracted to bait), but that traps baited with Marmite/Vegemite may improve catch rates under some circumstances. The traps were set overnight and retrieved the following day.

All captured fish were retained in buckets (with air bubblers), identified, measured, and counted before being returned to the reach from which they were captured.

A search of the New Zealand Freshwater Fish Database (NZFFD, Crow, 2017) was also conducted to find any available past records of fish. The Department of Conservation, Environment Canterbury and Selwyn District Council were also contacted for any existing ecological records from the Paparua Water Race Scheme, but no relevant records were produced.

2.1.5 eDNA

eDNA is a method that measures the presence of organisms by detecting traces of genetic material these leave in the environment. A passive method for eDNA sampling was used, wherein a filter mounted on a stainless steel peg is secured to the substrate of the water race, within the flow of the water. The sampler is left *in situ* overnight; upon collection the filters are preserved and returned to the eDNA laboratory (Wilderlab, Wellington) for processing. For each sample, the laboratory completed a multi-species analysis by metabarcoding for fish, insects, birds, and mammals.

In order to maximise the coverage throughout the water race network, it was requested that a single eDNA sample be taken from each of the 20 eDNA sites (rather that the standard three or six replicates recommended by the eDNA laboratory). The collection of a single replicate may impact on the ability of the sampling to detect all taxa actually present within sampling range; however it still provides valuable presence information on the fish and invertebrate taxa upstream of the sampling point.

It is important to note that not all species within New Zealand waterways are within the scope of existing assays or have reference sequences available. All of New Zealand's extant freshwater fish species are within the scope of the assays available and have good detection rates. Approximately 70% of the macroinvertebrate species listed in Grainger *et al.* (2018) are able to be detected by current available assays and reference sequences. Of the two particularly noteworthy macroinvertebrate species in this report (due to their conservation status of "At Risk – Declining"), kākahi/freshwater mussels have good detection rates via current eDNA analysis, but waikōura/kēkēwai/freshwater crayfish have poor detection rates.

2.2 Data Analysis

eDNA data is provided as a species list with DNA barcode sequences and DNA sequence counts. While sequence counts have some relationship to abundance/biomass of taxa detected, they are also impacted by factors such as distance of the sampler from the taxa detected, whether the genetic material comes from a living or dead specimen, and also biases within a given assay. As such, this data cannot currently be used as an indicator of abundance/biomass, and thus was converted to presence/absences for the purposes of this study. The eDNA data received from the laboratory was also processed to remove terrestrial taxa and records which were identified to a high taxonomic level such that they did not contribute meaningfully to the data set.

For both fish and macroinvertebrate data, analysis of species presence/absence was done on both the physical catch data (electrofishing/Gee minnow trapping and kicknet sampling) and the eDNA data. It is important to note however, that physical catch data provides information on biotic communities localised to the sampling site, whilst eDNA provides data of all species present within a longer reach of waterway upstream of the sampling site. Metrics such as taxa richness should therefore be interpreted accordingly for each sampling method.

Fish data from electrofishing/Gee minnow trapping and eDNA sampling was summarised as presence/absence by site. The focus of these fish surveys was to determine the species present rather than densities, thus calculation of CPUE was not necessary.

Raw macroinvertebrate data from both kicknet and eDNA sampling was summarised by taxa richness. Invertebrate community metrics calculated were the number of Ephemeroptera-Plecoptera-Trichoptera taxa (EPT taxa richness), %EPT taxa richness, and the Macroinvertebrate Community Index (MCI). All macroinvertebrates were grouped to MCI level for analysis due to mixed resolution of identifications. The points below provide brief clarification of these metrics:

» **Taxa richness** is the number of different taxa identified in each sample. Taxa is generally a term for taxonomic groups, and in this case refers to the lowest level of classification that was obtained during the study. Taxa richness is a useful community metric related to habitat diversity, with sites with more diverse habitats often having greater richness. However, there are numerous aquatic invertebrate taxa that prefer or tolerate degraded instream conditions such that taxa richness on its own should not be used to infer stream health.

» **EPT** refers to three Orders of invertebrates that are generally regarded as 'cleanwater' taxa. These Orders are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies): forming the acronym EPT. These taxa are relatively intolerant of organic enrichment or other pollutants and habitat degradation. The exceptions to this are the hydroptilid caddisflies (e.g., Trichoptera: Hydroptilidae: *Oxyethira, Paroxyethira*), which are algal piercers and often found in high numbers in nutrient enriched waters with high algal content. In general, the disappearance and reappearance of EPT taxa can also provide evidence of whether a site is impacted or recovering from a disturbance. EPT taxa are generally more diverse in non-impacted stream systems, although there is a small set of EPT taxa able to persist in degraded waterways.

» **Macroinvertebrate Community Index (MCI):** In the mid-1980s the MCI was developed as an index of community integrity for use in stony riffles in New Zealand streams and rivers and can be used to determine the level of organic enrichment for these types of streams (Stark, 1985). Although developed to assess nutrient enrichment, the MCI will respond to any disturbance that alters macroinvertebrate community composition (Boothroyd & Stark, 2000), and as such is used widely to evaluate the general health of waterways in New Zealand. A variant for use in streams with a streambed of sand/silt/mud (i.e., soft-bottomed) was developed by Stark & Maxted (2007) and is referred to as the MCI-sb. Both the hard-bottomed (MCI-hb) and soft-bottomed (MCI-sb) versions calculate an overall score for each sample, which is based on pollution-tolerance values for each invertebrate taxon that range from 1 (very pollution tolerant) to 10 (pollution-sensitive). MCI-hb and MCI-sb are calculated using presence/absence data. MCI is included in the NPS-FM (2020), with a 'national bottom line' of 90 for MCI. The NPS-FM (2020) uses the following bands and descriptions:

   – MCI ≥130, A band – "Macroinvertebrate community, indicative of pristine conditions with almost no organic pollution or nutrient enrichment."

- MCI ≥110 and <130, B band – “Macroinvertebrate community indicative of mild organic pollution or nutrient enrichment. Largely composed of taxa sensitive to organic pollution/nutrient enrichment.”
- MCI ≥90 and <110, C band – “Macroinvertebrate community indicative of moderate organic pollution or nutrient enrichment. There is a mix of taxa sensitive and insensitive to organic pollution/nutrient enrichment.”
- MCI <90, D band – “Macroinvertebrate community indicative of severe organic pollution or nutrient enrichment. Communities are largely composed of taxa insensitive to inorganic pollution/nutrient enrichment.”

Non-metric multidimensional scaling (NMS) is statistical technique that condenses sample data (in this case macroinvertebrate community data) to a single point in low-dimensional ordination space using some measure of community dissimilarity (Bray-Curtis metric in this instance). Interpretation is straightforward such that points on an x-y plot that are close together represent samples that are more similar in community composition than those further apart (Clarke & Gorley, 2015). To aid statistical analysis, the qualitative habitat information recorded were split into four habitat variables (riparian vegetation, substrate, water velocity, canopy cover). Riparian vegetation had four categories (dense weeds, dense exotic grasses, scorched earth, and dense native rushes/sedges/ferns), as did water velocity (swift, moderate, slow, none). Substrate (hard and soft) had two categories, as did canopy cover (open and shaded).

The 20 sites where kick net macroinvertebrate samples were collected were coded using these categories to allow the ANOSIM procedure to be undertaken in PRIMER v7 (Clarke & Gorley, 2015). ANOSIM is an approximate analogue of the standard ANOVA (analysis of variance) and compares the similarity between groups (in this instance upstream control and downstream impact) using the R test statistic. R=0 where there is no difference in macroinvertebrate community between groups, while R=1 where the groups have completely different communities. Where ANOSIM results showed significant or near-significant differences in macroinvertebrate community compositions, the similarity percentages (SIMPER) procedure was used to determine which taxa where responsible.

3 STATE OF THE EXISTING ENVIRONMENT

3.1 Habitat

3.1.1 Riparian Rapid Habitat Assessment

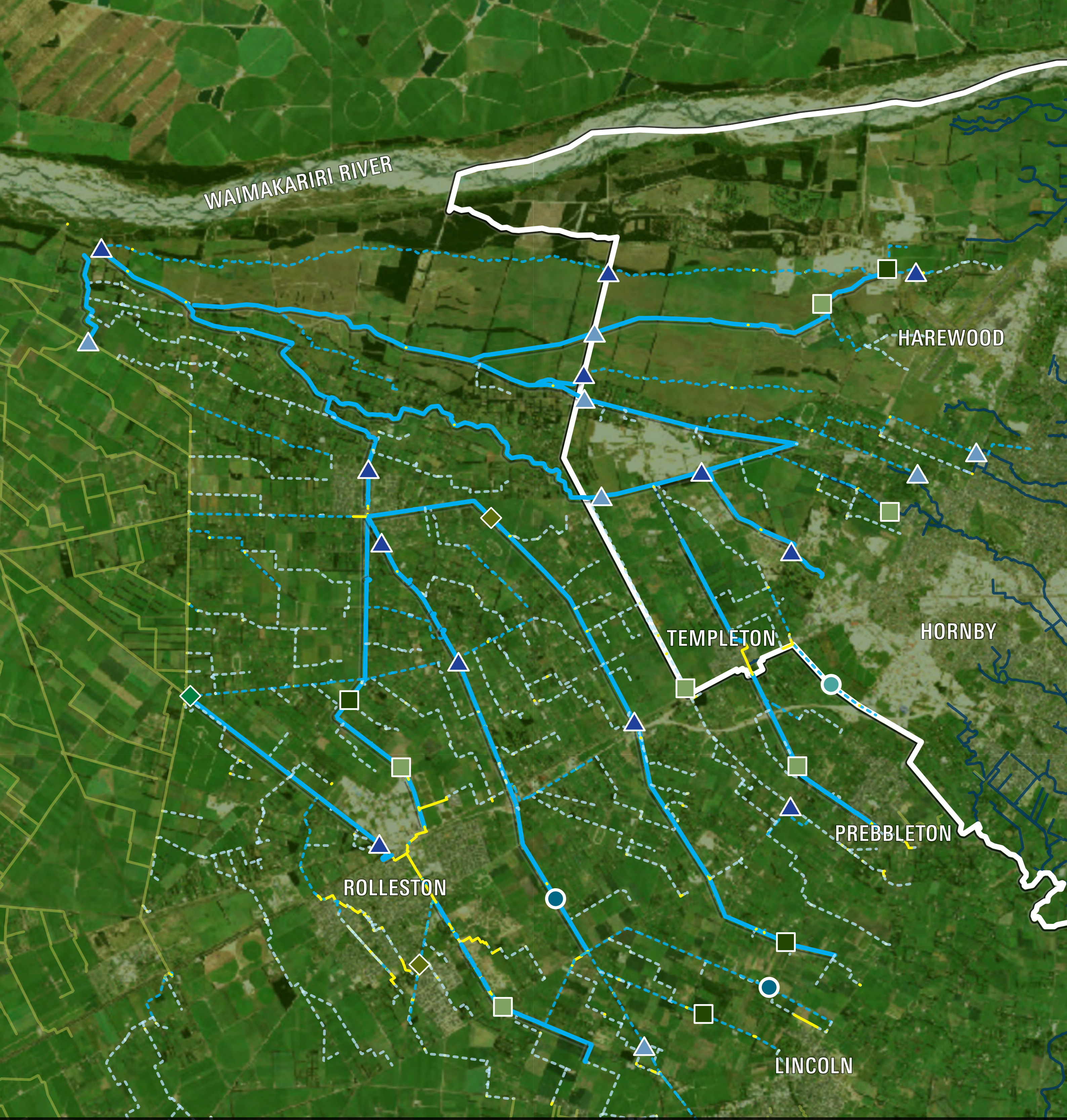
Seven riparian habitat types were found across the 35 survey sites (Table 1, Figure 4, Figure 5). 54% of the areas surveyed were predominantly in open canopy; the remaining 46% of sites had at least 20% overhead shading. Exotic grasses were the dominant vegetation type throughout the water race scheme, with dense exotic weeds (gorse, broom, blackberry) also common. Native vegetation present included *Blechnum minus* (swamp kiokio), *Carex maorica*, *Carex secta*, *Cordyline australis* (cabbage tree/tī kōuka), *Juncus sarophorus*, *Phormium tenax* (flax/harakeke), *Pteridium esculentum*, and *Typha orientalis* which all have a conservation status of "Not Threatened" (de Lange *et al.*, 2017).

Table 1 Riparian categories (number of sites within each category and the percentage of overall sites) found during the rapid habitat assessment at all sites by EOS Ecology in February and March 2022.

RHA Category	Number of Sites in Category	Percentage of Overall Sites	Composition of Vegetation
A1: Scorched earth (open canopy)	2	6%	Primarily bare earth; exotic grasses, harakeke[1], *Juncus articulatus*[2]
A1: Scorched earth (shaded)	1	3%	Primarily bare earth, exotic grasses, poplar
B1: Dense weeds (open canopy)	4	11%	Gorse, broom, blackberry, exotic grasses, *Salix cinerea*[3], *Blechnum minus*[1], *Carex maorica*[1], *Carex secta*[1], raupō[1]
B2: Dense weeds (shaded)	6	17%	Gorse, broom, blackberry, exotic grasses, exotic shrubs, *Eucalyptus*, exotic conifers, *Salix cinerea*[3]
C1: Dense exotic grass (open canopy)	12	34%	Primarily exotic grasses; gorse, harakeke[1]
C2: Dense exotic grass (shaded)	7	20%	Exotic grasses, gorse, willow, poplar, exotic conifers, harakeke[1], *Blechnum minus*[1], *Carex maorica*[1], *Carex secta*[1], *Cordyline australis*[1], *Juncus articulatus*[2], *Juncus sarophorus*[1], *Juncus effusus*, *Pteridium esculentum*[1], male fern, *Salix cinerea*[3]
D1: Dense native rushes, sedges or ferns (open canopy)	1	3%	*Pteridium esculentum*[1], exotic grasses, *Blechnum minus*[1]
D2: Dense native rushes, sedges or ferns (shaded)	2	6%	*Pteridium esculentum*[1], *Blechnum minus*[1], *Carex maorica*[1], *Carex secta*[1], harakeke[1], *Eucalyptus*, exotic conifers, exotic grasses, *Cordyline australis*[1]

[1]Native Vegetation, [2]Naturalised, [3]Listed in the National Pest Plant Accord.

Figure 4 *…figure over page…* Map of survey sites that fit within each of the riparian vegetation classifications initially developed by Dr Colin Meurk for use in the Malvern Water Race Scheme (James, 2011a).



Paparua Water Race (PWR)
Rapid Habitat Assessment (RHA): RIPARIAN

RHA CATEGORY:
Dominant Vegetation

OPEN CANOPY
- A1: Scorched earth
- B1: Weeds
- C1: Exotic grass
- D1: Native rushes, sedges, ferns

SHADED
- A2: Scorched earth
- B2: Weeds
- C2: Exotic grass
- D2: Native rushes, sedges, ferns

PWR WATERWAY TYPE
- Culvert/piped
- Lateral
- Local
- Main

- Christchurch City Council boundary
- Christchurch City waterways
- Other water race schemes

0 0.5 1 2 km

N

Map © EOS Ecology, 2022 / www.eosecology.co.nz

Layer source: Sites monitored by EOS Ecology, waterways: Christchurch City Council, Selwyn District Council.

Image source: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors

CLASS A: SCORCHED EARTH: >25% bare ground (including those planted with *Agapanthus* and other

A1: Scorched earth (open canopy)

A2: Scorched earth (shaded)

CLASS B: DENSE WEEDS – blackberry, gorse, broom

B1: Dense weeds (open canopy)

Figure 5 Representative photos of survey sites that fit within each of the riparian vegetation classifications initially developed by Dr Colin Meurk for use in the Malvern Water Race Scheme (James, 2011a). Photos taken during ecological surveys of the Paparua Water Race Scheme by EOS Ecology in February and March 2022.

B2: Dense weeds (shaded)

CLASS C: DENSE EXOTIC GRASS – with minor native rushes and sedges (e.g., 25% cover of *Carex* spp., *Pteridium esculentum, Juncus sarophorus* and/or *Blechnum minus*)

C1: Dense exotic grass (open canopy)

C2: Dense exotic grass (shaded)

Figure 5 *…continued from previous page…*

CLASS D: DENSE NATIVE RUSHES, SEDGES OR FERNS (e.g., >25% cover of *Carex* spp., *Juncus sarophorus, Pteridium esculentum* and/or *Blechnum minus*)

D1: Dense native rushes, sedges or ferns (open canopy)


D2: Dense native rushes, sedges or ferns (shaded)


CLASS E: BIODIVERSE RICH – generally with >25% cover of *Juncus edgarae*, *Eleocharis acuta*, *Carex* spp., *Pteridium esculentum* and/or *Blechnum minus* but with larger quantities of *Blechnum minus* and other less common species such as *Blechnum penna-marina*, *Juncus planifolius* or *Histiopteris incisa* (total native plants >5).

No such site found

CLASS F: DENSELY PLANTED NATIVE TREES, SHRUBS AND TUSSOCKS

No such site found

Figure 5 *…continued from previous page.*

3.1.2 Instream Rapid Habitat Assessment

Six instream habitat types were found across the 35 survey sites (Table 2, Figure 6, Figure 7). Most of the sites (80%) had swift or moderate flow; only a single site appeared not to be flowing at all. Coarse substrate was the most common substrate type (dominant at 60% of all sites), particularly in areas of swift to moderate flow. As is to be expected, higher water velocity and coarse substrate were more prevalent at sites closer to the intake of the water race scheme.

Many of the areas with coarse substrate were overlayed with a thin layer of silt, and/or were heavily embedded with silt/sand. Water depths ranged from 8–55 cm throughout the sites surveyed, with soft sediment depths of up to 20 cm in sites with predominantly soft substrate.

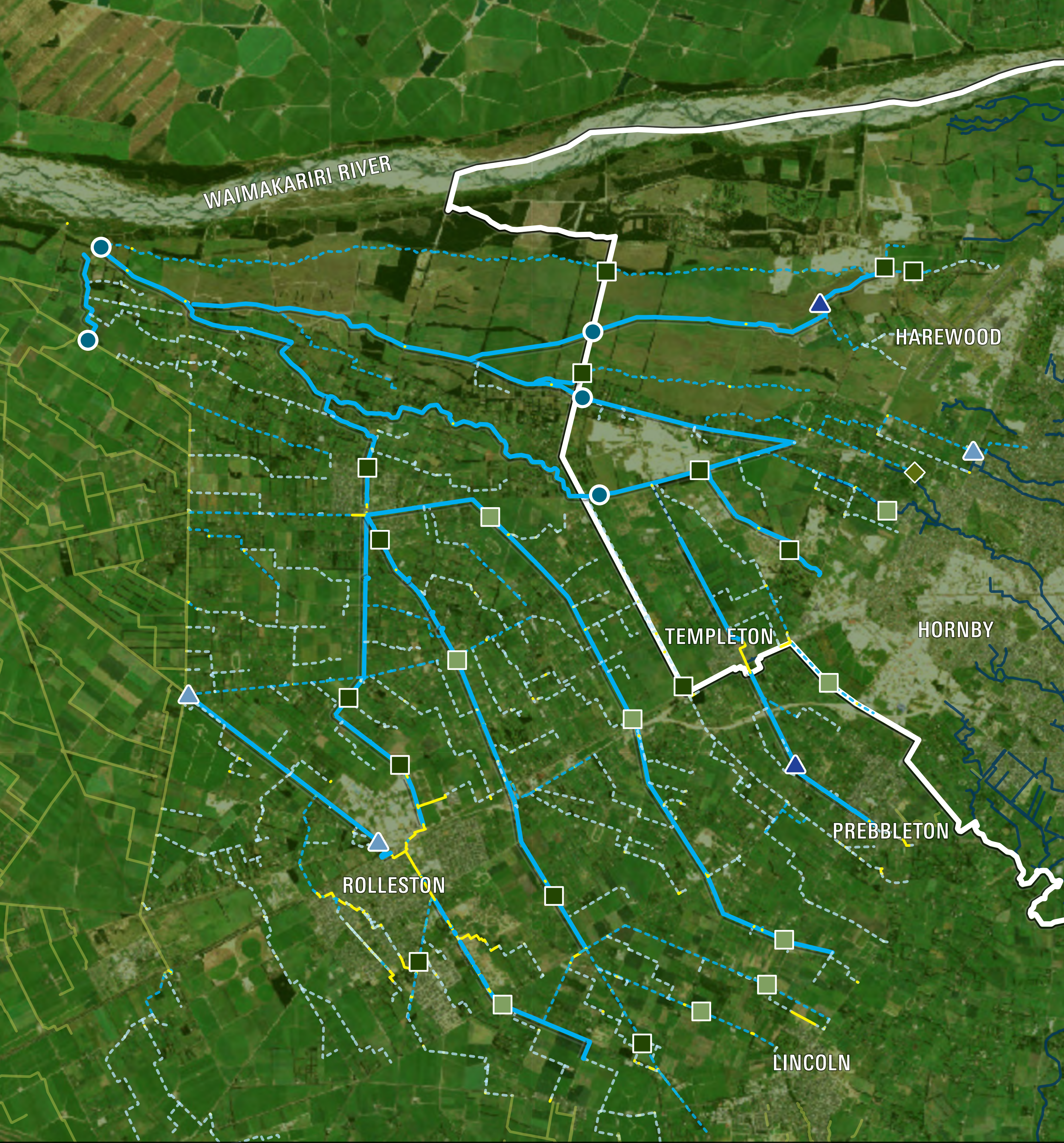
Native aquatic vegetation present included *Azolla rubra*, *Lemna minor*, *Myriophyllum triphyllum*, *Nitella*, and *Potamogeton cheesemanii,* all of which have a conservation status of "Not Threatened" (de Lange *et al*., 2017).

Table 2 Instream categories (number of sites within each category and the percentage of overall sites) found during the rapid habitat assessment at all sites by EOS Ecology in February and March 2022.

RHA Category	Number of Sites in Category	Percentage of Overall Sites	Aquatic Vegetation Composition
G3: Swift water velocity (coarse substratum)	5	14%	*Elodea canadensis,* Filamentous algae
H3: Moderate water velocity (coarse substratum)	14	40%	*Azolla rubra*[1], *Elodea canadensis*, filamentous algae, *Lemna minor*[1], *Myriophyllum triphyllum*[1], *Nitella*[1], *Potamogeton cheesemanii*[1]
H4: Moderate water velocity (soft substratum)	9	26%	*Elodea canadensis*, *Lemna minor*[1], *Mimulus guttatus,* mint, *Nitella*[1], *Potamogeton cheesemanii*[1], filamentous algae
I3: Slow water velocity (coarse substratum)	2	6%	*Elodea canadensis,* filamentous algae, *Mimulus guttatus*
I4: Slow water velocity (soft substratum)	4	11%	*Elodea canadensis,* filamentous algae, *Lagarosiphon major*[2]
J4: No detectable water flow (soft substratum)	1	3%	*Myosotis laxa, Lemna minor*[1], filamentous algae

[1]Native Vegetation, [2]Listed in the National Pest Plant Accord.

Figure 6 *…figure over page…* Map of survey sites that fit within each of the instream habitat classifications initially developed by Dr Colin Meurk for use in the Malvern Water Race Scheme (James, 2011a).



Paparua Water Race (PWR)
Rapid Habitat Assessment (RHA): INSTREAM

RHA CATEGORY:
Substratum (ss) & Water Velocity (wv)

ss = COARSE:
- G3: Swift wv
- H3: Moderate wv
- I3: Slow wv

ss = SOFT:
- H4: Moderate wv
- I4: Slow wv
- J4: No detectable flow

PWR WATERWAY TYPE
- Culvert/piped
- Lateral
- Local
- Main

- Christchurch City Council boundary
- Christchurch City waterways
- Other water race schemes

0 0.5 1 2 km

N

Map © EOS Ecology, 2022 / www.eosecology.co.nz

Layer source: Sites monitored by EOS Ecology, waterways: Christchurch City Council, Selwyn District Council.

Image source: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors

CLASS G: SWIFT WATER VELOCITY (approx. ≥0.8 m/s)

G3: Swift water velocity (coarse substratum)

G4: Swift water velocity (soft substratum)

No such site found

CLASS H: MODERATE WATER VELOCITY (approx. 0.2–0.79 m/s)

H3: Moderate water velocity (coarse substratum)

H4: Moderate water velocity (soft substratum)

Figure 7 Representative photos of survey sites that fit within each of the instream habitat classifications initially developed by EOS Ecology for use in the Malvern Water Race Scheme (James, 2011a). Photos taken during ecological surveys of the Paparua Water Race Scheme by EOS Ecology in February and March 2022.

CLASS I: SLOW WATER VELOCITY (<0.2m/s)

I3: Slow water velocity (coarse substratum)

I4: Slow water velocity (soft substratum)

CLASS J: NO DETECTABLE WATER FLOW

J3: No detectable water flow (coarse substratum)

No such site found

J4: No detectable water flow (soft substratum)

Figure 7 *…continued from previous page.*

3.2 Macroinvertebrates

A total of 68 invertebrate taxa (when considered at MCI taxonomic resolution) were recorded from the 20 representative kicknet samples and the 15 eDNA samples taken in the Paparua Water Race Network. Overall taxa richness at individual sites ranged from 6 to 34 taxa. The most diverse groups were the two-winged flies (Diptera) with 22 taxa, followed by caddisflies (Trichoptera: 15 taxa), molluscs (Mollusca: 8 taxa), beetles (Coleoptera: 4 taxa), crustaceans (Crustacea: 3 taxa), damselflies (Odonata: 2 taxa), cnidarians (Cnidaria: 2 taxa), and true bugs (Hemiptera: 2 taxa). Groups represented by one taxon included worms (Oligochaeta), flatworms (Platyhelminthes), leeches (Hirudinea), moths (Lepidoptera), spiders (Arachnida), stoneflies (Plecoptera), mayflies (Ephemeroptera), springtails (Collembola), nematodes (Nematoda), and proboscis worms (Nemertea).

The macroinvertebrate communities within the water race scheme were dominated by taxa that prefer or tolerate degraded habitat and/or water quality conditions (e.g., *Potamopyrgus* snails, *Physa acuta* snails, oligochaete worms). *Potamopyrgus* snails were by far the most common taxa and accounted for 47% of all individuals captured in kick net samples. MCI scores at 34 of the sites were in the lowest NPS-FM band ("D"); the one remaining site (ES18) was in the next bracket up ("C") (Table 3).

Of the three Orders of the cleanwater EPT group, all three (Ephemeroptera/mayflies, Plecoptera/stoneflies, Trichoptera/caddisflies) were present. Only a single mayfly genus (*Deleatidium*) and single stonefly genus (*Zelandobius*) were found. When the pollution-tolerant hydroptilid caddisflies are excluded (*Oxyethira* and *Paroxyethira*), 13 caddisfly genera remain (*Costachorema, Hudsonema, Hydrobiosis, Hydropsyche (Aoteapsyche), Neurochorema, Oecetis, Oeconesus, Polyplectropus, Psilochorema, Pycnocentria, Pycnocentrodes, Triplectides, Triplectidina*). EPT taxa richness ranged from 0 to 11 taxa, with a median taxa richness of 6 taxa across all sites (both eDNA and kicknet samples) (Table 3).

One-way ANOSIM of riparian vegetation and of canopy cover found no significant differences among the kick net sampling sites with p-values of 0.92 and 0.27, respectively. One-way ANOSIM of substrate detected a significant difference between mud/silt and stony bottomed sites (p=0.009), although this was relatively weak (R=0.23). SIMPER analysis indicated this was primarily the result of higher abundances of *Potamopyrgus* snails, oligochaete worms, sphaeriid pea clams, and ostracod seed-shrimps at mud/silt bottomed sites, and higher abundances of *Hudsonema* and *Pycnocentrodes* cased-caddisflies, and elmid riffle beetles at stony bottomed sites. One-way ANOSIM of velocity also showed a significant difference among the velocity categories (p=0.034), although this was relatively weak (R=0.30). Of the four water velocity categories, the "swift" sites were most distinct to all the others as clearly illustrated in the non-metric multidimensional scaling ordination (Figure 8). SIMPER analysis indicated this was largely the result of higher abundances of taxa such as *Pycnocentrodes* cased-caddisflies, *Hydropsyche* net-spinning caddisflies, tanytarsini midge larvae, and *Deleatidium* mayflies at the swift sites, and higher abundances of *Potamopyrgus* snails, oligochaete worms, sphaeriid pea clams, ostracod seed-shrimps, and *Xanthocnemis* damselfly larvae at sites without such swift water velocities. Based on the measured habitat variables, the composition of the macroinvertebrate community was related to the key habitat characteristics of substrate size and water velocity. A breakdown of the five most abundant taxa in kick net samples collected in sections with swift water velocities compared to all other sites is given in Figure 9. In spite of the differences between these communities, *Potamopyrgus* snails were the most abundant taxa at all flow types.

Assessment of conservation status is based on species-level identifications, and thus only those individuals identified to species in either the kicknet or eDNA samples can be considered in regards to their conservation status. Of the 35 macroinvertebrates identified to species, 28 have a conservation status (Grainger *et al.*, 2018). Of these 28 species, two are classified as "Data Deficient" (the aquatic snails *Austropeplea tomentosa* and *Glyptophysa variabilis*), one is classified as "At Risk – Declining" (the freshwater mussel/kākahi, *Echyridella menziesii*), and the remaining 25 are classified as “Not Threatened”. Both of the “Data Deficient” taxa are endemic snails with poorly understood distribution, and which may to be subject to competition pressure from introduced snail species. Only one specimen of *Glyptophysa variabilis* was found, and this was an empty shell found via kicknet sampling. However, the presence of an empty shell suggests that live individuals may be present or have recently be present.

No kākahi/freshwater mussel were found from the quick visual searches carried out during the ecological surveys, but their presence was detected in two eDNA samples. Kākahi are also known to be present approximately 1.5 km upstream of site eDNA05 (Culhane, 2021); this record was allocated to site eDNA05 to ensure that the presence of kākahi in this area was accounted for. Likewise, a 2019 record by Wildlands in the NZFFD indicates that kākahi have been found approximately 1.8 km upstream of site ES6; this record was accordingly allocated to site ES6.

In addition to kākahi, other native macroinvertebrate taxa found only in the eDNA samples included three species of caddisfly (*Hydrobiosis frater, Hydropsyche catherinae,* and *Triplectides cephalotes*). All three of these caddisflies are possible to identify to species level if present in a kicknet sample, and thus their detection in the eDNA samples alone is not an artefact of different identification levels possible via different methods. Two introduced species were also detected by eDNA alone: one snail (in the genus *Radix,* the only known species of which in New Zealand is *Radix auricularia*), and the introduced freshwater jellyfish *Craspedacusta sowerbii*. Given the soft-bodied and delicate nature of the freshwater jellyfish, it is unlikely to ever be detected in medusa form via processing of kicknet samples. While it may be detectable at the polyp stage, it is unclear how well this would be preserved in kicknet samples, and prior records indicate that despite being more prevalent the polyp stage is more rarely recorded than the medusa stage (Dumont, 1994). Thus, eDNA provides a valuable tool for detecting the presence of this species.

Prior eDNA sampling at three sites in the vicinity of site ES14 found similar species composition to that found via kicknet sampling at this site, with detection of 9 additional taxa: three caddisflies (*Paroxyethira, Triplectides, Triplectidina*), two Diptera (*Culex*, Chironomidae), two micro-crustaceans (*Chydoridae, Simocephalus*), one snail (*Radix*), and one cnidarian (Hydra) (Demchick, 2021). This supports the findings that this section of water race has macroinvertebrate communities characterised by taxa that prefer or tolerate degraded habitat and/or water quality conditions.

Table 3 Macroinvertebrate community metrics for the 20 ecological survey sites and 15 eDNA sites. For MCI the relevant value was used depending on substrate type as indicated in the site column (HB=hard bottom, SB=soft bottom). The MCI NPS-FM (2020) interpretation band is shown in parentheses.

Site		Metric					
		Taxa Richness	MCI	EPT Taxa Richness	EPT Taxa Richness (excl. Hydroptilidae)	%EPT Richness	%EPT Richness (excl. Hydroptilidae)
ES1	Ryans Rd (SB)	11	67 (D)	2	2	18.18	18.18
ES2	Yaldhurst Rd (SB)	15	49 (D)	1	1	6.67	6.67
ES3	Buchanans Rd (SB)	17	73 (D)	4	3	23.53	17.65
ES4	Hasketts Rd (HB)	18	89 (D)	6	6	33.33	33.33
ES5	Marshs Rd (SB)	18	71 (D)	3	2	16.67	11.11
ES6	Trents Rd (HB)	26	74 (D)	6	3	23.08	11.54
ES7	Robinsons Rd (SB)	22	59 (D)	3	2	13.64	9.09
ES8	Weedons Rd (HB)	16	88 (D)	6	5	37.50	31.25
ES9	Weedons Rd (HB)	19	75 (D)	4	3	21.05	15.79
ES10	Springston Rolleston Rd (SB)	22	71 (D)	5	4	22.73	18.18
ES11	Goulds Rd (HB)	25	77 (D)	4	4	16.00	16.00
ES12	Intake below sediment ponds (HB)	17	86 (D)	6	6	35.29	35.29
ES13	McLeans Island Rd (HB)	20	78 (D)	6	4	30.00	20.00
ES14	McLeans Island Rd (HB)	24	82 (D)	7	4	29.17	16.67
ES15	Old West Coast Rd (HB)	18	82 (D)	8	7	44.44	38.89
ES16	Newtons Rd (SB)	34	72 (D)	8	6	23.53	17.65
ES17	West Coast Rd (HB)	18	84 (D)	6	6	33.33	33.33
ES18	Curraghs Rd (SB)	22	92 (C)	11	10	50.00	45.45
ES19	West Melton Rd (HB)	21	80 (D)	6	5	28.57	23.81
ES20	Weedons Ross Rd (HB)	21	88 (D)	8	8	38.10	38.10
eDNA1	Tancreds Rd (SB)	11	54 (D)	2	0	18.18	0.00
eDNA2	Boundary Rd (SB)	9	59 (D)	3	2	33.33	22.22
eDNA3	Hoskyns Rd (HB)	12	58 (D)	1	1	8.33	8.33
eDNA4	Curraghs Rd (SB)	24	71 (D)	11	8	45.83	33.33
eDNA5	Hamptons Rd (SB)	20	62 (D)	6	4	30.00	20.00
eDNA6	Dawsons Rd (HB)	17	89 (D)	9	8	52.94	47.06
eDNA7	West Coast Rd (HB)	18	82 (D)	9	8	50.00	44.44
eDNA8	Chattertons Rd (HB)	7	54 (D)	1	1	14.29	14.29
eDNA9	Conservators Rd (HB)	6	50 (D)	0	0	0.00	0.00
eDNA10	Chattertons Rd (HB)	21	84 (D)	10	8	47.62	38.10
eDNA11	Chattertons Rd (HB)	15	83 (D)	8	6	53.33	40.00
eDNA12	Weedons Ross Rd (HB)	17	77 (D)	8	6	47.06	35.29
eDNA13	Halkett Rd (HB)	21	82 (D)	9	8	47.83	43.48
eDNA14	Weedons Ross Rd (SB)	19	69 (D)	8	7	42.11	36.84
eDNA15	Railway Rd (SB)	8	46 (D)	1	1	12.50	12.50

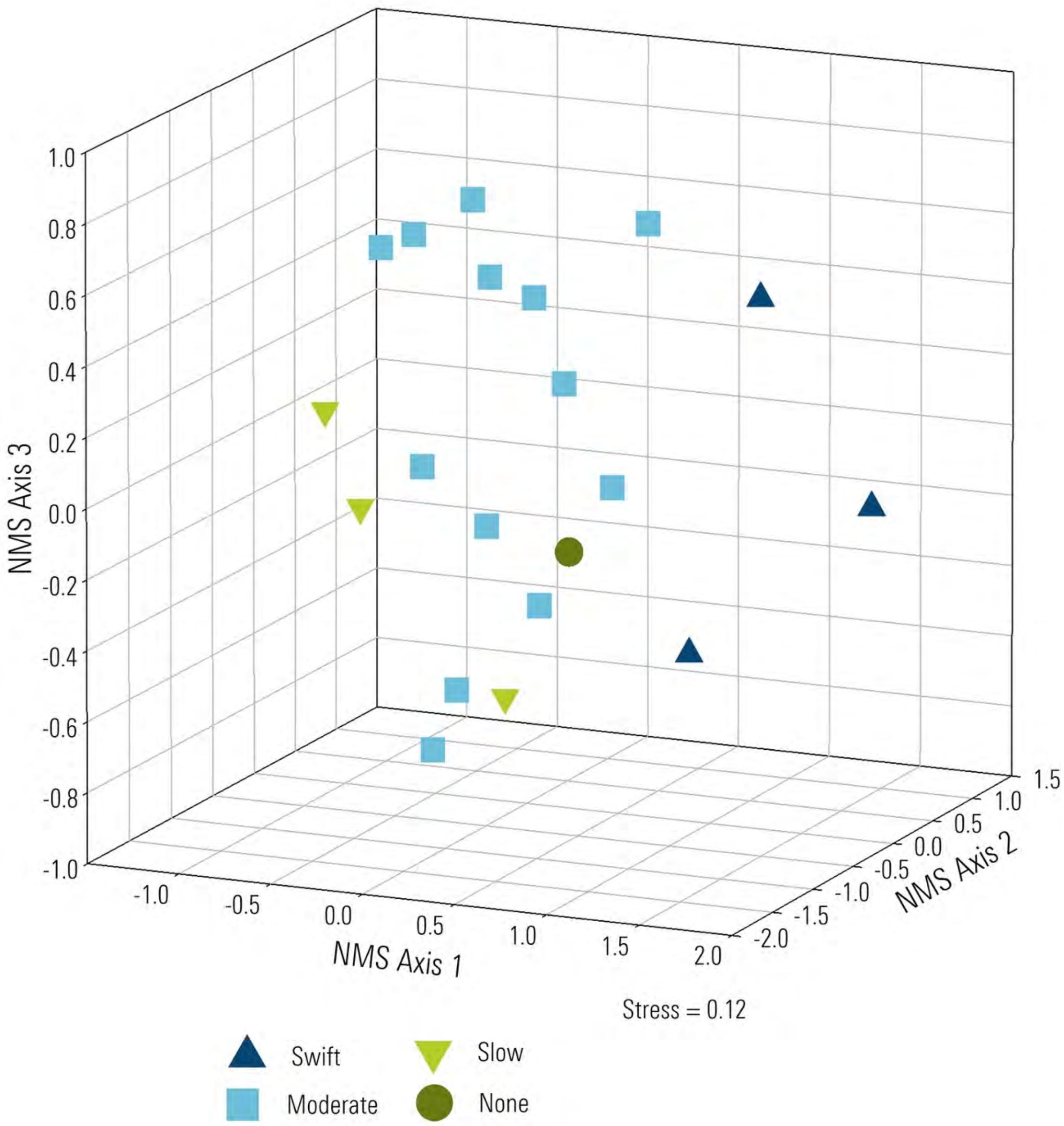


Figure 8 Non-metric multidimensional scaling ordination of benthic macroinvertebrate kick net samples collected by EOS Ecology from the Paparua Water Race Scheme in February and March 2022, coded by water velocity. A stress value of 0.12 is indicative of an ordination that can still correspond to a usable picture, but too much reliance should not be placed on the details of the plot.

Figure 9 **Images of the most abundant aquatic macroinvertebrates by velocity type. Percentage abundance for each taxon is provided in brackets.** All photos © EOS Ecology.

3.3 Fish

A total of eight species of fish were found during the ecological surveys and eDNA sampling carried out by EOS Ecology in February and March 2022 (Figure 10, Table 4). Six of these species are native or endemic and three (longfin eel, torrentfish, bluegill bully) have an 'At Risk – Declining' conservation status according to the threat classification of Dunn *et al.* (2018). Two of the species (brown trout and rainbow trout) are introduced.

Seven of the eight total species recorded were captured during the ecological surveys (electrofishing and Gee minnow trapping). In order of abundance, these were upland bully, shortfin eel, brown trout, longfin eel, common bully, bluegill bully and torrentfish (Table 4). Upland bullies were captured at 19 of the 20 sites, making them the most prevalent species detected. Bluegill bullies and torrentfish were the least common, having been captured at a single site each.

Seven of the eight total species recorded were detected via eDNA sampling. In order of frequency encountered, these were upland bully (in 14 samples), shortfin eel (in 11 samples), brown trout (in 10 samples), shortfin eel (in 9 samples), torrentfish, common bully, rainbow trout (one sample each).

Of the native species found, shortfin eels, longfin eels, torrentfish and bluegill bullies are obligate migratory species and require access to the ocean to complete their life cycle. Adult eels migrate to the ocean to spawn off the shores of Tonga, with the juvenile "glass eels" returning to freshwater to mature. Adult torrentfish and bluegill bullies spawn in freshwater and the hatched larvae wash out to sea before returning to freshwater environments to mature. Water races act as a "dead end" for these species, since migrating downstream leads them to the terminal end of the water race, rather than to the ocean. Some of these fish may be able to migrate if they make their way into one of the branches of water race connected to natural streams, but this is likely to be a very small proportion of the total fish population in the Scheme. Therefore, while the Scheme may provide habitat for these individuals to live, it does not provide the opportunity for them to reproduce and thus contribute to the abundance and genetic diversity of their wider metapopulations. Thus, it is preferable to prevent these species of fish from entering the water race network. We understand that fish screens are present at the intake to the Paparua Water Race Scheme, but these screens may not be sufficient to prevent smaller individuals from being washed into the Scheme.

Upland bullies are a non-migratory native species that spends its entire life cycle in freshwater; and was the only non-migratory species detected within this section of water race. A further species, common bully, is considered to be "facultatively amphidromous" (i.e., their larvae spend time at sea or in estuaries), but may form non-migratory populations if movement is restricted (McQueen, 2013). Upland bullies, and also possibly common bullies, will be able to establish self-sustaining populations within this area, although it seems that common bully numbers are low throughout the Scheme. Both introduced species found (brown trout and rainbow trout) are generally non-migratory in New Zealand, and thus may also be able to establish self-sustaining populations.

Past electrofishing/trapping records from the New Zealand Freshwater Fish Database (NZFFD) include seven of the eight species found in this survey; no rainbow trout have been recorded from previous surveys. One additional species, Chinook salmon (*Oncorhynchus tshawytscha*), was recorded from two sites (near the water race intake on Halkett Road, and in the Kirk Road water race) by NIWA in 1983 and 1987 respectively. Given the time elapsed since these records, as well as the fact that Chinook salmon generally require access to the ocean to complete their life cycle, it is unlikely that there is an established population of this species within the Paparua Water Race Scheme.

Prior eDNA data from the vicinity of site ES14 detected the presence of shortfin eel (upstream and downstream of ES14), longfin eel (downstream of ES14), bluegill bully (downstream of ES14), torrentfish (upstream of ES14), and upland bully (upstream and downstream of ES14) (Demchick, 2021). The signals for both longfin eel and torrentfish were weak, suggesting that the DNA was from a significant distance upstream, that it was from a single or small number of individuals, or that it was from decaying tissue of a deceased individual. This data does not shed light on any additional non-migratory fish species found in this area that were not detected via electrofishing (Table 4).

Shortfin eel/*Anguilla australis*
(Not Threatened; requires access to the ocean)

Longfin eel/*Anguilla dieffenbachia*
(At Risk – Declining; requires access to the ocean)

Torrentfish/panoko/*Cheimarrichthys fosteri*
(At Risk – Declining; requires access to the ocean)

Upland bully/*Gobiomorphus breviceps*
(Not Threatened; does not require access to the ocean)

Common bully/*Gobiomorphus cotidianus*
(Not Threatened; usually requires access to the ocean, but can form landlocked populations)

Bluegill bully/*Gobiomorphus hubbsi*
(At Risk – Declining; requires access to the ocean)

Brown trout/*Salmo trutta*
(Introduced and Naturalised; does not require access to the ocean)

Rainbow trout/*Oncorhynchus mykiss*
(Introduced and Naturalised; does not require access to the ocean)

Figure 10 **Images of the 8 fish species recorded during EOS Ecology ecological surveys and eDNA sampling in the Paparua Water Race Scheme in February and March 2022. The conservation status from Dunn *et al.* (2018) is shown in brackets, along with information about whether the species requires access to the ocean to complete its life cycle.** All photos © EOS Ecology

Table 4 Abundance data of fish captured from the 20 ecological survey sites in February and March 2022. Unidentified juvenile bullies were excluded on the basis that these are likely to be one of the species already recorded, and thus their inclusion would artificially inflate species richness.

		Fish Species Counts							
Site		Shortfin eel/ *Anguilla australis*	Longfin eel/ *Anguilla dieffenbachii*	Torrentfish/ *Cheimarrichthys fosteri*	Upland bully/ *Gobiomorphus breviceps*	Common bully/ *Gobiomorphus cotidianus*	Bluegill bully/ *Gobiomorphus hubbsi*	Brown trout/ *Salmo trutta*	Total
ES1	Ryans Rd	0	0	0	35	0	0	0	**35**
ES2	Yaldhurst Rd	0	0	0	1	0	0	0	**1**
ES3	Buchanans Rd	0	0	0	11	0	0	0	**11**
ES4	Hasketts Rd	0	0	0	13	2	0	1	**16**
ES5	Marshs Rd	0	0	0	28	0	0	0	**28**
ES6	Trents Rd	0	0	0	2	2	0	7	**11**
ES7	Robinsons Rd	0	0	0	4	0	0	0	**4**
ES8	Weedons Rd	0	0	0	3	0	0	0	**3**
ES9	Weedons Rd	1	0	0	1	0	0	0	**2**
ES10	Springston Rolleston Rd	0	0	0	33	0	0	0	**33**
ES11	Goulds Rd	0	0	0	27	0	3	0	**30**
ES12	Intake below sediment ponds	8	3	2	10	0	0	0	**23**
ES13	McLeans Island Rd	0	0	0	14	0	0	0	**14**
ES14	McLeans Island Rd	0	0	0	21	0	0	0	**21**
ES15	Old West Coast Rd	0	0	0	21	0	0	1	**22**
ES16	Newtons Rd	0	0	0	109	1	0	0	**110**
ES17	West Coast Rd	0	1	0	2	0	0	0	**3**
ES18	Curraghs Rd	0	0	0	6	0	0	0	**6**
ES19	West Melton Rd	0	0	0	11	0	0	2	**13**
ES20	Weedons Ross Rd	2	0	0	0	0	0	0	**2**
Total		**11**	**4**	**2**	**352**	**5**	**3**	**11**	**388**

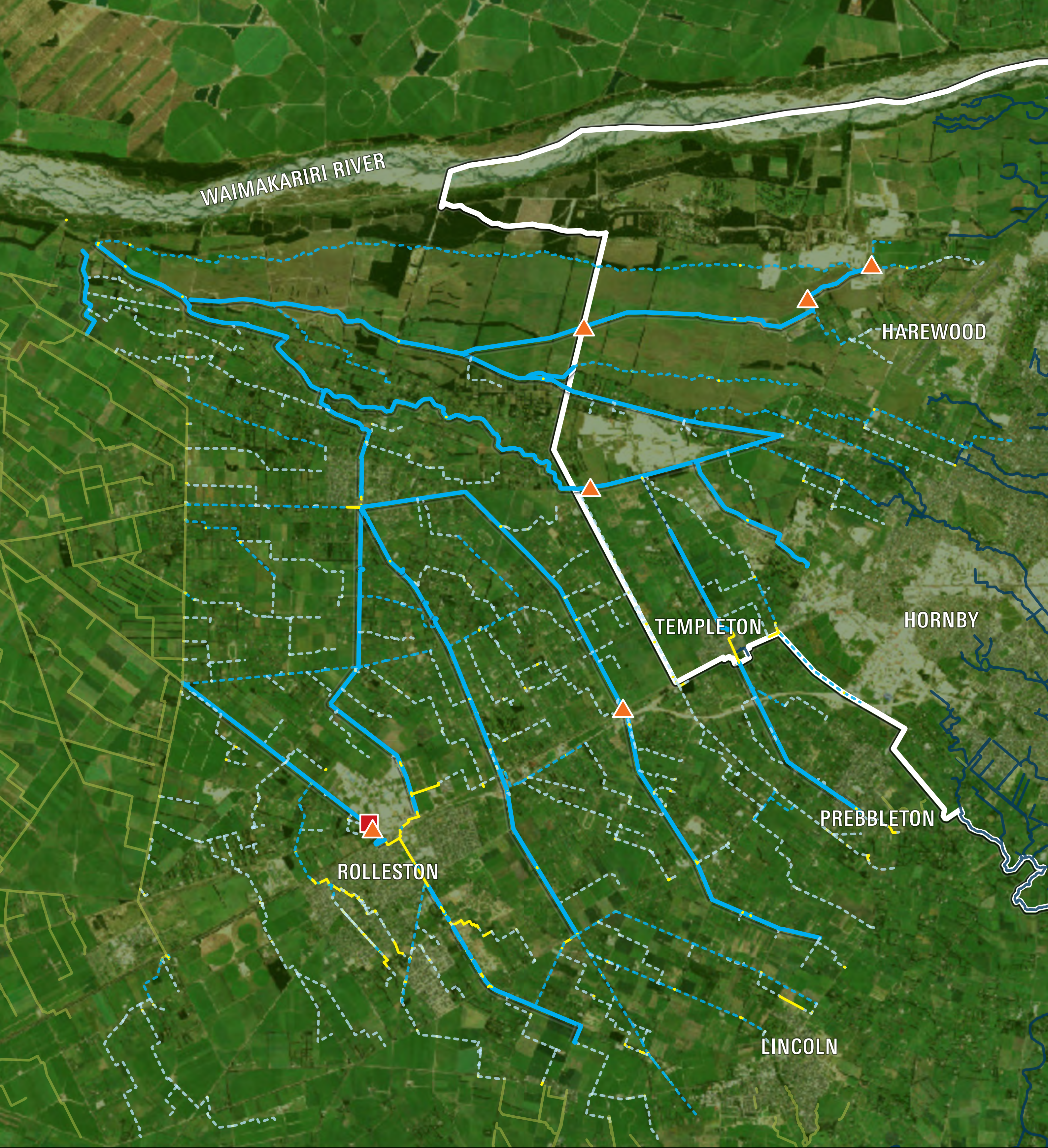
Table 5 Presence/absence data for fish captured from the 15 eDNA survey sites in February and March 2022.

		Species Presence ✓ / Absence ✗						
Site		Shortfin eel/ *Anguilla australis*	Longfin eel/ *Anguilla dieffenbachii*	Torrentfish/ *Cheimarrichthys fosteri*	Upland bully/ *Gobiomorphus breviceps*	Common bully/ *Gobiomorphus cotidianus*	Brown trout/ *Salmo trutta*	Rainbow trout/ *Oncorhynchus mykiss*
eDNA1	Tancreds Rd	✓	✗	✗	✓	✗	✗	✗
eDNA2	Boundary Rd	✓	✗	✗	✗	✗	✗	✗
eDNA3	Hoskyns Rd	✓	✓	✗	✓	✗	✓	✗
eDNA4	Curraghs Rd	✓	✗	✗	✓	✗	✓	✗
eDNA5	Hamptons Rd	✓	✗	✗	✓	✗	✓	✗
eDNA6	Dawsons Rd	✓	✓	✗	✓	✗	✓	✗
eDNA7	West Coast Rd	✓	✓	✗	✓	✗	✓	✗
eDNA8	Chattertons Rd	✗	✓	✗	✓	✗	✓	✗
eDNA9	Conservators Rd	✗	✓	✗	✓	✗	✗	✗
eDNA10	Chattertons Rd	✗	✓	✗	✓	✗	✗	✗
eDNA11	Chattertons Rd	✓	✗	✗	✓	✗	✗	✗
eDNA12	Weedons Ross Rd	✓	✓	✗	✓	✗	✓	✗
eDNA13	Halkett Rd	✓	✓	✓	✓	✓	✓	✓
eDNA14	Weedons Ross Rd	✓	✓	✗	✓	✗	✓	✗
eDNA15	Railway Rd	✗	✗	✗	✓	✗	✓	✗

3.4 Pest Species

A total of five pest species were detected during the ecological surveys and via eDNA sampling. These included one riparian plant (*Salix cinerea*/grey willow), one aquatic plant (*Lagarosiphon major*), and three aquatic macroinvertebrates (*Craspedacusta sowerbii*, *Physa acuta*, and *Radix auricularia*) (Figure 11 and Figure 12). Both plant species are listed in the National Pest Plant Accord, and all four aquatic species are listed in the Freshwater Invasive Species of New Zealand (NIWA, 2020). One species, the macrophyte *Lagarosiphon major,* is listed in the Canterbury Regional Pest Management Strategy as a pest to be managed under site-led programmes. Environment Canterbury should be consulted as to the appropriate way to manage this species at the single survey site at which it was found. Likewise, the recommendations for *Salix cinerea* in the National Pest Plant Accord are to consult the regional council for advice on management. None of the three pest macroinvertebrate species have a Biosecurity Status or a status under the Regional Pest Management Strategy. The introduced freshwater jellyfish *Craspedacusta sowerbii* was detected only via eDNA sampling. Observation records for this species are primarily from lakes (NIWA, 2020), but eDNA distribution records suggest they are far more widespread than previously recorded and are present in flowing water as well. It is unclear what if any biosecurity risk they pose. The introduced pond snail *Physa acuta* is widespread throughout the country and is thought to compete with and displace the native snails such as *Glyptophysa variabilis* and *Austropeplea tomentosa*. *Radix auricularia*, another species of pond snail, is not widely known in the South Island or in flowing water, although it has been recorded in the Avon River on at least one occasion (McMurtrie and Demchick, 2016). While no active management strategies exist for these macroinvertebrate species, their presence may be a factor in determining the desirability of retaining a given section of water race.

Figure 11 *…figure over page…*Map of aquatic and riparian plant pest species found at sites in the Paparua Water Race Scheme surveyed by EOS Ecology in February and March 2022.



Paparua Water Race (PWR)
Pest Species: PLANT

PEST SPECIES
- Lagarosiphon
- Salix cinerea

PWR WATERWAY TYPE
- Culvert/piped
- Lateral
- Local
- Main

- Christchurch City Council boundary
- Christchurch City waterways
- Other water race schemes

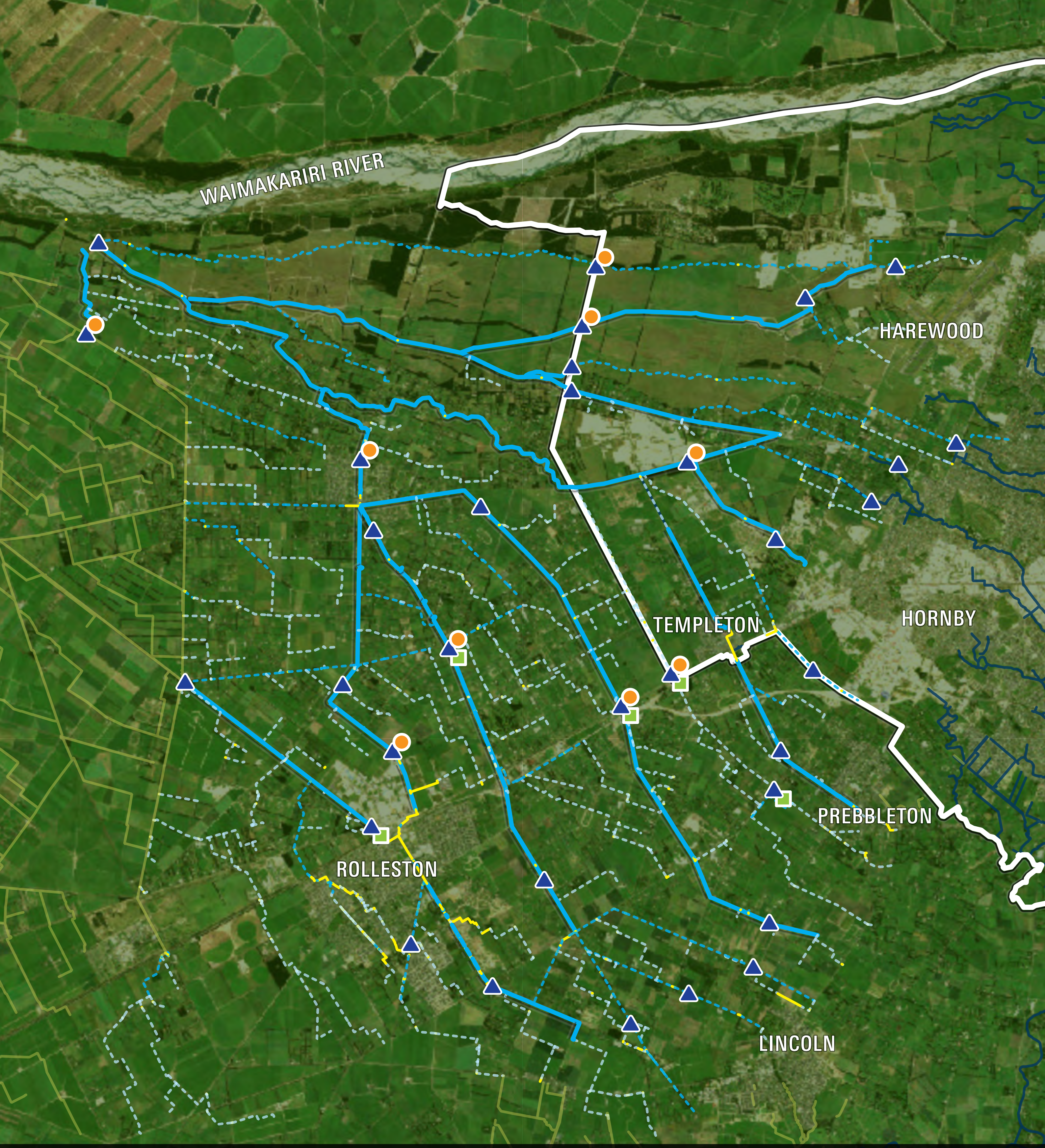
0 0.5 1 2 km

N

Map © EOS Ecology, 2022 / www.eosecology.co.nz

Layer source: Sites monitored by EOS Ecology, waterways: Christchurch City Council, Selwyn District Council.

Image source: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors



Paparua Water Race (PWR)
Pest Species: MACROINVERTEBRATE

PEST SPECIES
- Craspedacusta sowerbii
- Physa acuta
- Radix

PWR WATERWAY TYPE
- Culvert/piped
- Lateral
- Local
- Main

- Christchurch City Council boundary
- Christchurch City waterways
- Other water race schemes

0 0.5 1 2 km

N

Layer source: Sites monitored by EOS Ecology, waterways: Christchurch City Council, Selwyn District Council.

Image source: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors

Figure 12 …*figure on previous page*… Map of macroinvertebrate pest species found at sites in the Paparua Water Race Scheme surveyed by EOS Ecology in February and March 2022.

4 ECOLOGICAL VALUES ASSESSMENT

4.1.1 Criteria for Assessing Ecological Values

Identification of sites of high ecological value requires an unbiased method of determining such values. The designation of a particular location or site as being of high ecological value will preferably be based on a pre-existing standard of biodiversity importance. For the purposes of this report, we have based our assessment on the criteria developed in James (2011b), as these criteria were developed specifically for water race systems. Modifications were made in the assessment of some criteria based on the specific characteristics of the Paparua Water Race Scheme as well as the accessibility of new technologies, such as eDNA. Given that water race schemes are essentially artificial ecosystems, the focus of the criteria for assessing the ecological values of sites are the indigenous flora and fauna that have colonised the schemes since they were constructed. These include riparian and aquatic plants, aquatic invertebrates, and fish.

To objectively determine the ecological value of each site, an overall scoring system was developed which divided aspects of ecological value into three criteria, each of which was composed of sub-criteria used in making the assessment (Table 6). Descriptions of and rationale for each criterion are given in the points below:

» Criterion 1 was based on whether any taxa with a "Threatened" or "At Risk" threat classification were present. For the Paparua Water Race Scheme, potential species of note were kōwaro/Canterbury mudfish, waikōura/kēkēwai/freshwater crayfish, and kākahi/freshwater mussels. Of these three species, only kākahi were detected at any of the sites. eDNA and kicknet sampling identified a further 27 species of macroinvertebrate with a threat classification, but none of these had a threat classification of "Threatened" or "At Risk". eDNA sampling and electrofishing/trapping identified three fish species with an "At Risk" classification. However, these all require access to the ocean to complete their life cycle. Thus, they were excluded from this criterion on the basis that water races usually form a "dead end" since migrating downstream leads them to the terminal end of the water race, rather than to the ocean. In some rare cases, these fish may find access to the sea via connections of the Paparua Water Race Scheme to natural streams, but this is likely to be a small percentage of the fish within the Scheme. Therefore, while water races may provide habitat for these individuals to live, it does not usually provide the opportunity for them to reproduce, and thus does not contribute to sustaining abundance and genetic diversity of their wider metapopulation. If any of the sub-criteria for Criterion 1 were met (i.e., if any species with a threat classification of "Threatened" or "At Risk" were found), the site was deemed to have met Criterion 1.

» Criterion 2 incorporated a range of other ecological values. This criterion was divided into two parts: species abundance/diversity (part A) and uniqueness (part B). These two parts and their individual sub-criteria were considered to be of lower importance than the presence of a "Threatened" or "At Risk" species, and so a site was required to meet sub-criteria of both part 2A and 2B to qualify as ecologically significant. To meet Criterion 2, 50% or more of sub-criteria for both parts 2A and 2B needed to be met (i.e., two or more sub-criteria of 2A "species diversity" AND one or more of the sub-criteria of 2B "uniqueness").

   – Sub-criteria for part 2A (species abundance/diversity) included high species richness of native riparian plants (five or more species), native aquatic plants (four or more species), and native aquatic macroinvertebrates. High species richness for macroinvertebrates was considered to be at or above the 75^{th}

percentile for the 5-year median invertebrate species richness as measured at 17 Environment Canterbury ecological monitoring sites in the Waimakariri catchment (i.e., the catchment within which the water race network is fed from), which equates to 23 or more species. A sub-criterion was also included for high species richness of fish that do not require access to the ocean to complete their life cycle (four or more species). Both native and introduced species were included in the species richness for fish on the basis that the introduced trout species in these waterways may provide amenity and recreational values.

- Two sub-criteria were set for part 2B (uniqueness). The first relates to the riparian vegetation community and is based on the rapid habitat assessment categories (Figure 5). To meet this sub-criterion, the site must fall into one of the classes with high native vegetation diversity (Class D, E or F). Such sites are of note due to their relatively rarity in the water race scheme, and in fact no sites in classes E or F were found. The second "uniqueness" sub-criterion was the presence of species with a threat classification of "Data Deficient". The lack of population data on such taxa, while not necessarily an indication of rarity, does mean that their records may be of conservation interest. Two such species were found in the Paparua Water Race Scheme: the aquatic snails *Glyptophysa variabilis* and *Austropeplea tomentosa*.

» Criterion 3 accounts for the importance that some branches of the Paparua Water Race Scheme have in terms of contributing flow to the headwaters of natural surface water waterbodies in the Christchurch City Council area. These waterbodies are Paparua Stream, Ilam Stream and the Ōtakaro/Avon River (via several tributary drains). While not in itself a measure of ecological value, this criterion identifies sections of water race which may support the ecological values of other waterways, and thus, should be managed accordingly. To meet Criterion 3, a site needed to be near the headwaters of a natural surface water waterbody and constitute the headwaters of or contribute significant flow to this waterbody.

Eight sites were found to meet one of the three ecological significance criteria (Table 7). Four sites met Criterion 1, one site met Criterion 2, and three sites met Criterion 3, however no sites met more than one criterion.

Table 6 Criteria used for the assessment of ecological values by site (modified from James 2011b).

Criteria	Part	Sub-Criteria
1. "Threatened" or "At-Risk" species		
Were any species found that have a conservation status of "Threatened" or "At Risk"?		a. Were kōwaro/Canterbury mudfish, with a threat classification of "Threatened – Nationally Critical", detected?
		b. Were waikōura/kēkēwai/freshwater crayfish, with a threat classification of "At Risk – Declining", detected?
		c. Were kākahi/freshwater mussels, with a threat classification of "At Risk – Declining", detected?
2. Ecological community		
	A. Species abundance/diversity	
	Does the site preserve genetic diversity (i.e., is diverse or abundant in species which are able or potentially able to maintain self-sustaining populations?)	a. Does the site have high species richness of native riparian vegetation?
		b. Does the site have high species richness of native aquatic vegetation?
		c. Does the site have high species richness of fish that do not require access to the ocean to complete their life cycle?
		d. Does the site have high species richness of native aquatic macroinvertebrates?
	B. Uniqueness	
	Does the site contain unique species, populations, communities, or ecosystems?	a. Does the site fall into a higher quality riparian vegetation category when categorised according to the Rapid Habitat Assessment of James (2011a)?
		b. Does the site contain any taxa with a threat classification of "data deficient"?
3. Connection to other water bodies		
Does the waterway contribute or potentially contribute flow to a natural surface water waterbody?		a. Does the waterway constitute the headwaters of or likely contribute significant flow to a natural surface water waterbody?

Table 7 Summary of sites which met at least one ecological value criterion based on criteria modified from James (2011b). For those criteria which were met, a summary or description of sub-criteria met is provided in brackets.

		Criteria Met ✓/Not Met ✗			
Site		1. Threatened/ At Risk species	2. Ecological Values (species abundance/diversity & uniqueness)		3. Connection to other water bodies
			A. Species abundance/diversity	B. Uniqueness	
ES1	Ryans Rd	✗	✗	✗	✓ (connection to Ilam Stream, Ōtakaro/ Avon River)
ES2	Yaldhurst Rd	✗	✗	✗	✓ (connection to Paparua Stream)
ES3	Buchanans Rd	✗	✗	✗	✓ (connection to Paparua Stream)
ES6	Trents Rd	✓ (sub-criterion c – freshwater mussels)	✗	✗	✗
ES18	Curraghs Rd	✗	✓ (sub-criterion a – native riparian vegetation richness; sub-criterion d – native aquatic macroinvertebrates richness)	✓ (sub-criterion a – native riparian vegetation composition)	✗
eDNA1	Tancreds Rd	✓ (sub-criterion c – freshwater mussels)	✗	✗	✗
eDNA3	Hoskyns Rd	✓ (sub-criterion c – freshwater mussels)	✗	✗	✗
eDNA5	Hamptons Rd	✓ (sub-criterion c – freshwater mussels)	✗	✗	✗

5 RECOMMENDATIONS FOR MANAGEMENT

This study has identified eight sites with high ecological values, or which may support the ecological values of other waterways. The management approach to these sites should be tailored to the specific values identified at each site.

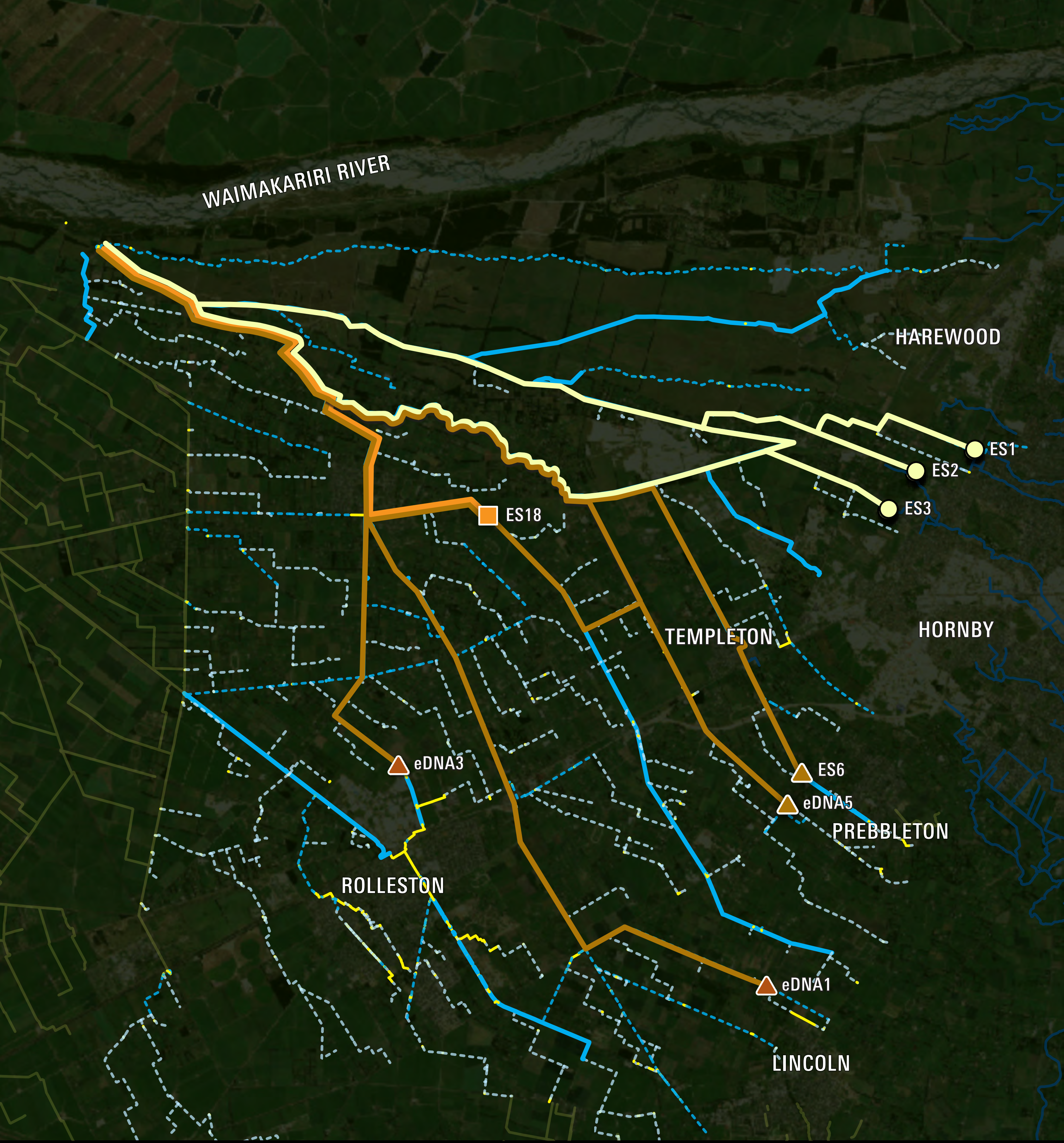
» Four sites were identified to have populations of kākahi/freshwater mussel nearby. Site eDNA5 and ES6 are known to have kākahi approximately 1.5 km and 1.8 km upstream respectively based on previous observations by EOS Ecology (Culhane, 2021) and Wildlands (as recorded in the NZFFD (Crow, 2017)). Detection of kākahi at the two remaining sites (eDNA1 and eDNA3) was via eDNA, and so the exact location of the kākahi populations in these areas is unknown. To ensure that these populations are protected, it is recommended that visual and hand surveys are conducted in the reaches upstream of these sites to determine where the kākahi are located. The success of kākahi relocations appears to be variable. Data from kākahi relocation in the non-wadeable sections of the Pūharakekenui/Styx and Ōpāwaho/Heathcote Rivers suggests that survival rates following relocations may be low (Instream Consulting, 2021), whilst anecdotal information from the Department of Conservation indicates some successful relocation of kākahi from sections of water race network that were being closed (Allanah Purdie, Department of Conservation, pers. com.).On this basis, we feel a precautionary approach is warranted, meaning that it would be preferable that these sites and the branches which supply them with water be preserved (Figure 13). If closure of these branches of water race is necessary, relocation of the kākahi populations to suitable habitat should follow the recommendations of Instream Consulting (2021).

Likewise, future management should take into consideration the impact that temporary shutdowns of these branches of water race may have on kākahi populations.

- A single site was identified to have high ecological values relating to species abundance/diversity and uniqueness. This site (ES18) had substantial plantings of native vegetation and supported diverse fish and macroinvertebrate populations. This site and the branch of water race that supplies it with water should be preserved (e.g., as shown in Figure 13). If this is not possible then significant mitigation measures such as the relocation of fauna or provision of new habitat will need to be considered, bearing in mind that some of the ecological values such as riparian vegetation will likely be lost in the process.
- Three sites were located on branches of water race which constitute the headwaters of or likely contribute significant flow to streams within the jurisdiction of Christchurch City Council – Paparua Stream, Ilam Stream, and the Ōtākaro/Avon River. While these sites themselves do not have high ecological values (and thus, would not need to be retained on that basis), consideration should be given to their retention on the basis that they may support high ecological values of other waterways. We recommend that further investigation be undertaken to understand these surface water connections and determine the level of contribution the Paparua Water Race Scheme has to the flow of these streams and thus what the impacts would be should these connections be terminated.
- It is possible that several branches of the Paparua Water Race Scheme may also contribute flow to tributaries of the Ararira/LII River. These connections would be via local branches of the water race that flow through private property and were therefore outside of the scope of this report. Current work being undertaken on the Ararira catchment management plan (EOS Ecology *et al.*, in preparation) indicates that two branches of the water race downstream of Site E10 may provide a surface water connection to roadside and farm drains, whilst branches of water race downstream of sites ES9 and ES11 most likely terminate at either a soak pit or along the roadside respectively. The Ararira Catchment Management Plan will provide guidance on the long-term management of the waterway network for Lincoln and the Ararira/LII. Following its completion, it may therefore be appropriate to undertake investigations to better understand the level of contribution from the Paparua Water Race Scheme to the flow of the Ararira/LII River waterway network for those water race branches that have a surface water connection, and thus what the impacts would be should these connections be terminated.
- Several pest species were found within or on the riparian margins of water races within the Scheme. We would recommend that the aquatic pest species be reported to NIWA to inform their records for future editions of their guide to freshwater invasive species (i.e., NIWA, 2020). We would also recommend consultation with Environment Canterbury with regards to management approaches for the pest plant species found. In some instances, it may be considered beneficial to close a branch of water race with otherwise low ecological values to prevent the spread of invasive species.
- If there is a proposal to close any significant branches of water race, we strongly recommend a more detailed branch-specific ecological survey. The current survey aimed to cover as great a geographical area of the Scheme as possible with limited resources and necessarily focussed on main branches. It is thus probable some sites (and branches) of high ecological value remain undocumented. Further, fish are found throughout the Scheme so any branches that are closed will require fish relocation actions.
- In addition to the ecological values discussed above, water races have other values which should be considered when determining appropriate management for a particular branch of water race. These values include habitat and provision of water for wildlife including birds, firefighting in areas where other water sources are limited, and contribution to shallow groundwater. The water races also provide some aesthetic value, particularly in areas with riparian plantings, and in residential areas such as the Faringdon development and Prebbleton where

the water races contribute to networks of landscaped ponds. The Paparua Water Race Scheme also has some historic value for its contribution to European agricultural development of the Canterbury Plains.

Figure 13 *…figure over page…* Map of sites determined to have high ecological significance, and the branches that supply them with water.



Paparua Water Race (PWR) Sites of Ecological Significance

SITE SIGNIFICANCE & FLOW PATH

- Contributes to natural surface water waterbody
- High ecological values
- Presence of threatened/ at risk species

WATERWAY TYPE

- Culvert/piped
- Lateral
- Local
- Main

Christchurch City waterways

Other water race schemes

Layer source: Sites monitored by EOS Ecology, waterways: Christchurch City Council, Selwyn District Council.

Image source: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors

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8 APPENDICES

8.1 Site Photos


Site ES1: Ryans Road. Looking downstream.


Site ES1: Ryans Road. Looking upstream.


Site ES2: Yaldhurst Road. Looking downstream.


Site ES2: Yaldhurst Road. Looking upstream.

Site ES3: Buchanans Road. Looking downstream.


Site ES3: Buchanans Road. Looking upstream.

Figure 14 Representative photos of all ecological survey sites visited by EOS Ecology in February and March 2022.


Site ES4: Hasketts Road. Looking downstream.


Site ES4: Hasketts Road. Looking upstream.


Site ES5: Marshs Road. Looking downstream.


Site ES5: Marshs Road. Looking upstream.


Site ES6: Trents Road. Looking downstream.


Site ES6: Trents Road. Looking upstream.


Site ES7: Robinsons Road. Looking downstream.


Site ES7: Robinsons Road. Looking upstream.

Figure 14 *…continued from previous page…*

Site ES8: Weedons Road. Looking downstream.

Site ES8: Weedons Road. Looking upstream.

Site ES9: Weedons Road. Looking downstream.

Site ES9: Weedons Road. Looking upstream.

Site ES10: Springston Rolleston Road. Looking downstream.

Site ES10: Springston Rolleston Road. Looking upstream.

Site ES11: Goulds Road. Looking downstream.

Site ES11: Goulds Road. Looking upstream.

Figure 14 *…continued from previous page…*


Site ES12: Intake below sediment ponds. Looking downstream.


Site ES12: Intake below sediment ponds. Looking upstream.


Site ES13: McLeans Island Road. Looking downstream.


Site ES13: McLeans Island Road. Looking upstream.


Site ES14: McLeans Island Road. Looking downstream.


Site ES14: McLeans Island Road. Looking upstream.


Site ES15: Old West Coast Road. Looking downstream.


Site ES15: Old West Coast Road. Looking upstream.

Figure 14 *…continued from previous page…*

Site ES16: Newtons Road. Looking downstream.

Site ES16: Newtons Road. Looking upstream.

Site ES17: West Coast Road. Looking downstream.

Site ES17: West Coast Road. Looking upstream.

Site ES18: Curraghs Road. Looking downstream.

Site ES18: Curraghs Road. Looking upstream.

Site ES19: West Melton Road. Looking downstream.

Site ES19: West Melton Road. Looking upstream.

Figure 14 *…continued from previous page…*


Site ES20: Weedons Ross Road. Looking downstream.


Site ES20: Weedons Ross Road. Looking upstream.


Site eDNA1: Tancreds Road. Looking downstream.


Site eDNA1: Tancreds Road. Looking upstream.


Site eDNA2: Boundary Road. Looking downstream.


Site eDNA2: Boundary Road. Looking upstream.


Site eDNA3: Hoskyns Road. Looking downstream.


Site eDNA3: Hoskyns Road. Looking upstream.

Figure 14 *…continued from previous page…*


Site eDNA4: Curraghs Road. Looking downstream.


Site eDNA4: Curraghs Road. Looking upstream.


Site eDNA5: Hamptons Road. Looking downstream.


Site eDNA5: Hamptons Road. Looking upstream.


Site eDNA6: Dawsons Road. Looking downstream.


Site eDNA6: Dawsons Road. Looking upstream.


Site eDNA7: West Coast Road. Looking downstream.


Site eDNA7: West Coast Road. Looking upstream.

Figure 14 *...continued from previous page...*

Site eDNA8: Chattertons Road. Looking downstream.

Site eDNA8: Chattertons Road. Looking upstream.

Site eDNA9: Conservators Road. Looking downstream.

Site eDNA9: Conservators Road. Looking upstream.

Site eDNA10: Chattertons Road. Looking downstream.

Site eDNA10: Chattertons Road. Looking upstream.

Site eDNA11: Chattertons Road. Looking downstream.

Site eDNA11: Chattertons Road. Looking upstream.

Figure 14 *…continued from previous page…*

Site eDNA12: Weedons Ross Road. Looking downstream.

Site eDNA12: Weedons Ross Road. Looking upstream.

Site eDNA13: Halkett Road. Looking downstream.

Site eDNA13: Halkett Road. Looking upstream.

Site eDNA14: Weedons Ross Road. Looking downstream.

Site eDNA14: Weedons Ross Road. Looking upstream.

Site eDNA15: Railway Road. Looking downstream.

Site eDNA15: Railway Road. Looking upstream.

Figure 14 *…continued from previous page.*

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