Long-term Monitoring of Aquatic Invertebrates:

OTUKAIKINO RIVER CATCHMENT 2012

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EXECUTIVE SUMMARY

The Christchurch City Council (CCC), in conjunction with Environment Canterbury (ECan) and the Avon-Heathcote Estuary Ihutai Trust, has instigated a long-term monitoring programme for aquatic invertebrates and habitat of the city's waterways. Invertebrates are useful animals to monitor as they are a good indication of stream health and respond to catchment land use changes. EOS Ecology was commissioned by the CCC to develop and undertake an aquatic invertebrate monitoring program that incorporated the Styx, Otukaikino, Avon, Heathcote, and Halswell River catchments. It was requested by the CCC that each catchment was surveyed once every five years, with two catchments to be surveyed in the first year of the programme.

This report summarises the results of the fifth year of monitoring, where nine sites in the Otukaikino River (official CCC name: Waimakariri River South Branch) catchment were surveyed during March 2012. The results were compared to those of 2008 to determine if there have been any substantial changes between surveys. A total of 58 invertebrate taxa were recorded from the Otukaikino River catchment in 2012. The most diverse groups were the true flies (Diptera: 18 taxa), followed by caddisflies (Trichoptera: 16 taxa), molluscs (Mollusca: 6 taxa), crustaceans (Crustacea: 5 taxa), and mayflies (Ephemeroptera: 2 taxa). The six most abundant taxa (*Potamopyrgus antipodarum*, *Pycnocentrodes*, *Pycnocentria*, *Deleatidium*, *Aoteapsyche*, and Orthocladiinae) accounted for 71% of all invertebrates captured.

The macroinvertebrate community health metric, QMCI-hb, indicated that most of the nine surveyed sites in the Otukaikino River catchment were rated as having "fair" or "good" water quality in both 2008 and 2012. Pollution-sensitive cleanwater taxa (made up of mayflies, stoneflies, and caddisflies) accounted for approximately 40% of all invertebrates captured overall in both years. The Otukaikino River continues to be the Christchurch waterway with the highest aquatic macroinvertebrate values and has a number of taxa that have disappeared from the more degraded catchments in the city. These high values are largely the result of the lack of urban development in the catchment. This catchment will likely remain the highest quality waterway in Christchurch for the forseeable future and could act as a source of colonist invertebrates should the more degraded waterways ever be in a fit state for the more pollution-sensitive taxa to return. The Otukaikino River catchment contains sensitive taxa that will be badly affected by ongoing stock access and any future agricultural intensification. As such, the highest ranked sites should be prioritised for protection (i.e., riparian fencing and planting), which would also require protecting their upstream sub-catchments. The current long-term survey programme could be improved by adding 1–2 sites in the lower non-wadeable part of the river and also including a fish survey at the same sites.

PHOTO
Clean gravels of the Otukaikino.

1. INTRODUCTION

In the Christchurch City Council's (CCC) Long-Term Council Community Plan (LTCCP; Christchurch City Council, 2006a) Christchurch residents identified the retention and restoration of biodiversity and protection of the environment as key factors important to their wellbeing. The LTCCP states that the CCC will know it is succeeding in meeting these community desires when 'our lifestyles reflect our commitment to guardianship of the natural environment in and around Christchurch', when 'biodiversity is restored, protected and enhanced', and when 'we manage our city to minimise damage to the environment' (Christchurch City Council, 2006a). Furthermore, in the recently adopted Surface Water Strategy 2009–2039 (Christchurch City Council, 2010) the CCC's vision is that "the surface water resources of Christchurch support the social, cultural, economic, and environmental well-being of residents, and are managed wisely for future generations."

To be successful in achieving the community's desire for biodiversity and healthy ecosystems we must first have a better understanding of the current state of our waterways. In an attempt to achieve this the CCC, in conjunction with Environment Canterbury (ECan) and the Avon-Heathcote Estuary Ihutai Trust (Batcheler *et al*., 2006) decided to instigate a freshwater monitoring programme that will help to determine the existing state of our waterways and monitor any change in health over time. Such monitoring is required for the CCC to successfully identify if they are making headway in achieving a number of the goals outlined in the Surface Water Strategy: 2009–2039 (Christchurch City Council, 2010), including, "improving the water quality of our surface water resources", "improving the ecosystem health of surface water resources", and "protecting and restoring Ngai Tahu values associated with surface water resources". Additionally, with the ongoing development of Stormwater Management Plans (SMPs) for catchments throughout Christchurch, one of the key measures of water quality is based on the invertebrate communities present. It is likely parts of this freshwater monitoring programme will assist in fulfilling the resource consent requirements of the various SMPs once they are operative.

Furthermore, the earthquakes of 4 September 2010, 22 February 2011, and 14 June 2011 caused damage to some of Christchurch's waterways through lateral spreading, inputs of liquefaction sediment, and discharges of wastewater from broken pipes. To assess the impacts of such unpredictable events on aquatic habitats and fauna it is imperative to have adequate pre-impact information against which to compare earthquake effects. Such data was used to assess the impacts of the 22 February 2011 earthquake in the Avon River catchment (see James & McMurtrie, 2011). It is thus important to have information for all of Christchurch's waterways as a reference point should they be subjected to some major disturbance; be it natural (e.g., earthquake) or human-induced (e.g., chemical spills, dredging).

EOS Ecology was commissioned by the CCC to develop and undertake a suitable freshwater invertebrate monitoring program for the City's main waterways. This incorporated the City's five main river catchments: the Styx, Otukaikino, Avon, Heathcote, and Halswell Rivers. The Styx and Otukaikino River catchments were surveyed in March 2008 (McMurtrie & Greenwood, 2008), the Avon River catchment in March 2009 (McMurtrie, 2009), the Heathcote River catchment in March 2010 (James, 2010), and the Halswell River in March 2011 (James, 2011). The current survey undertaken in the Otukaikino River in March 2012 marks the start of the second five-yearly sampling cycle that will allow for temporal comparisons within each catchment as well as between-catchment comparisons.

The majority of the waterways in the Christchurch area are impacted to some extent by urbanisation. Generally catchment urbanisation is detrimental to biodiversity values and the general health of waterways. As a catchment is developed it becomes more impervious to stormwater run-off, causing lower but flashier flows (Suren & Elliott, 2004). Pollutants and fine sediment from road run-off accumulate in the river sediment and the addition of buildings, bridges, culverts, and light pollution impede the dispersal and influence the behaviour of adult aquatic insects (Suren, 2000; Blakely *et al*., 2006). These factors detrimentally affect the health of our waterways by making them suitable for only a subset of the aquatic invertebrates and fish that may have existed there previously. With increasing residential development of the outlying areas of Christchurch City and infill housing occurring in the suburbs, much of the land surrounding our city's waterways has, or is, changing from rural to urban use. Of Christchurch's major waterways, the Otukaikino River is the least impacted by urban development and hence retains a number of more pollution-sensitive aquatic invertebrates (McMurtrie & Greenwood, 2008). The invertebrate fauna of this river gives an indication of the taxa that perhaps could be present in some of the other catchments (e.g., Heathcote River and Avon River) if the water and habitat quality issues bought about by urbanisation can ever be rectified.

1.1 AIM OF THIS REPORT

This report is designed to provide the first temporal comparison for the Otukaikino River catchment of the first survey (March 2008) and the second survey (March 2012). It is not designed to provide any comparisons between other previously surveyed catchments.

1.2 WHY IS MONITORING IMPORTANT?

Long-term monitoring of invertebrate communities will tell us how the health of a river is changing over time (i.e., is it getting better, worse, or remaining the same). In more sensitive systems such as the Otukaikino and Styx River catchments we would expect the fauna to change more rapidly in response to land use changes (e.g., rural to urban), which will give us an early warning that stream health is declining. In comparison, we would expect those rivers that are already heavily urbanised (e.g., the Avon and Heathcote) to change less over time as their invertebrate fauna may already be limited to pollution-tolerant taxa. Results from the monitoring will also be important in designing restoration and remediation efforts to minimise the impact of urban development on our rivers and potentially to determine the effects of unpredictable major disturbances (e.g., earthquakes and chemical spills). Refer to McMurtrie & Greenwood (2008) for further information on why invertebrates are important to monitor.

PHOTO ▶
The mayfly *Coloburiscus* is still found in the Otukaikino, but have become locally extinct from most of Christchurch's city rivers.

2. METHODS

The aim of the monitoring programme was to use the 'River Habitat and its Biota' section of Batcheler *et al*. (2006) as the basis for this monitoring programme. Batcheler *et al.* (2006) recommends sampling "within the shallower, gravel bottom reaches of the Avon/Otakaro and Heathcote/Opawaho rivers", which are the two main rivers that drain into the Avon-Heathcote Estuary/Ihutai. However, this programme has been broadened to include the Styx, Otukaikino, and Halswell River systems, which are partly or fully within the confines of the Christchurch City boundary.

Due to CCC budgetary limitations, it was not possible to sample all five catchments at one time, thus a yearly programme was developed to sample one catchment per year, with a five-year repeat cycle for each catchment. The catchments will be surveyed in the following order: Otukaikino, Styx, Avon, Heathcote, and Halswell. This report represents the fifth year of the monitoring programme, where the Otukaikino River catchment was sampled for the second time, while in previous years the Otukaikino and Styx Rivers (first year), Avon River (second year), Heathcote River (third year), and Halswell River (fourth year) catchments were surveyed (McMurtrie & Greenwood, 2008; McMurtrie, 2009; James, 2010; James 2011).

2.1 SITE SELECTION

In 2012 the sites orginally sampled in 2008 were revisted, with the exception of Site 1 which was relocated approximately 800 m upstream after consultaton with the CCC (Figure 1 and Table 1). The original Site 1 was in a section of the waterway that may be diverted to a new channel in the coming years to allow for the construction of the West Belfast Bypass motorway extension.

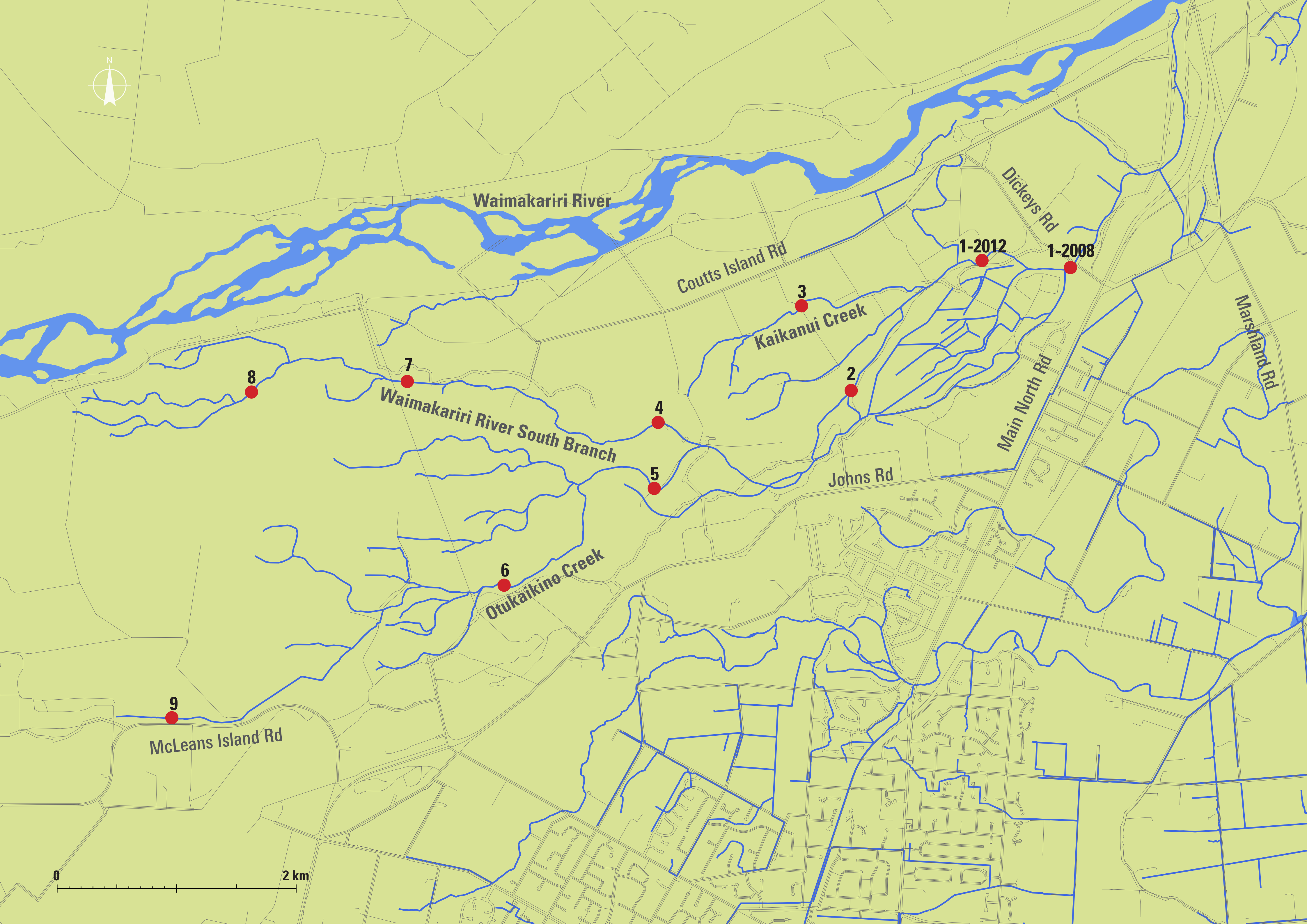
Sites throughout the wadeable part of the catchment were included, as the small size of headwater and tributaries streams makes them more susceptible to changes in environmental conditions, such as water quality or sediment inputs. Sampling sites were chosen in areas of riffle habitat, or if this did not exist, in runs with a coarse substratum; because these areas typically support the most diverse invertebrate communities that are also the most sensitive to change.

Throughout this report we have used the CCC's official waterway names (from CCC's WebMap) and as such what is commonly known as the Otukaikino River is referred to here as the "Waimakariri River South Branch". This is indicative of the the channel having once been a minor braid of the Waimakariri River which was cut-off by the installation of the Waimakariri stopbank and the land reclaimed for farming. "Otukaikino Creek" is a tributary of this channel and appears to be the source of the name "Otukaikino" which is now in common usage to refer to the whole catchment.

FIGURE 1 ▸
Location of the nine sites in the Otukaikino River (official CCC name: Waimakariri River South Branch) catchment surveyed for aquatic macroinvertebrates on the 27–29 March 2012. Note that Site 1 was moved 800 m upstream in 2012 compared to 2008. Site photographs are provided in Appendix I (Section 7.1).

TABLE 1 Locations of the Otukaikino River (official CCC name: Waimakariri River South Branch) monitoring sites. Refer to Figure 1 for further information on locations.

SITE NO.	STREAM NAME	APPROXIMATE SITE LOCATION
1	Waimakariri River South Branch	Upstream of Dickeys Road
2	Waimakariri River South Branch	Adjacent The Groynes dog park
3	Kaikanui Creek	Downstream of Clearwater Resort
4	Waimakariri River South Branch	At Clearwater Resort
5	Otukaikino Creek	At Clearwater Resort
6	Otukaikino Creek	At Omaka Scout Camp
7	Waimakariri River South Branch	Off Coutts Island Road
8	Waimakariri River South Branch	In headwaters
9	Otukaikino Creek	At McLeans Island Road



N
Waimakariri River
Coutts Island Rd
Dickeys Rd
1-2012
1-2008
3
Kaikanui Creek
2
Marshland Rd
Main North Rd
8
7
Waimakariri River South Branch
4
5
Johns Rd
6
Otukaikino Creek
9
McLeans Island Rd
0
2 km

2.2 SAMPLING

Following fine weather conditions, habitat and aquatic invertebrate communities were surveyed between the 27–29 March 2012. At each site three equally-spaced transects were placed across the stream at 10 m intervals (i.e., at 0, 10, and 20 m) and aspects of the instream habitat and aquatic invertebrate community quantified along them. A detailed and quantitative to semi-quantitative methodology was developed to act as a suitable monitoring protocol that would enable a comparable repeat survey of habitat and invertebrate communities.

Instream habitat variables were quantified at equidistant points across each of the three transects, with the first and last measurements across the transect at the water's edge. Habitat variables measured included substrate composition, presence and type of organic material, depths (water, macrophyte, and sediment), and water velocity (Figure 2). General bank attributes, including lower and upper bank height and angles, lower bank undercut, and lower bank vegetative overhang were measured for each bank at each transect. Bank material and stability were also assessed.

The riparian zone condition was assessed within a 5 m band along the 20 m site on either side of the bank. The cover of 15 different vegetation types were estimated on a ranking scale of present (<10%), common (10–50%), and abundant (>50%). The vegetation was assessed three-dimensionally so included ground, shrub, and canopy cover levels.

Aquatic benthic invertebrates were collected at each transect by disturbing the substrate across an approximate 1.5 m width and within a 0.3 m band immediately upstream of a conventional kicknet (500 µm mesh size; Figure 2). The full range of habitat types were surveyed across each transect, including mid-channel and margin areas, inorganic substrate (i.e., the streambed), and macrophytes (aquatic plants). Each invertebrate sample was kept in a separate container, preserved in 60% isopropyl alcohol, and taken to the laboratory for identification. The contents of each sample were passed through a series of nested sieves (2 mm, 1 mm, and 500 µm) and placed in a Bogorov sorting tray (Winterbourn et al., 2006). All invertebrates were counted and identified to the lowest practical level using a binocular microscope and several identification keys. Sub-sampling was utilised for particularly large samples and the unsorted fraction scanned for taxa not already identified.

For the first time in 2012, macrophyte and periphyton indicators from Table WQL5 of the Natural Resources Regional Plan (NRRP) (Environment Canterbury, 2011a) were estimated in the Otukaikino River catchment (percentage cover of riverbed by emergent macrophytes, total macrophytes, and filamentous algae >20 mm in length). While of not any immediate regulatory relevance given the Otukaikino River catchment is covered by the Waimakariri River Regional Plan (WRRP) (Environment Canterbury, 2011b), these are the indicators included in the recently approved Southwest Christchurch Stormwater Management Plan (SMP) (Christchurch City Council, 2012) and thus will more than likely be used in subsequent SMPs in the city as they are developed (eventually including one for the Otukaikino River catchment).

FIGURE 2
Measuring water velocity at (left) and collecting an invertebrate sample with a kicknet (right) in the Otukaikino River catchment.

2.3 DATA ANALYSIS

The data describing the substrate composition was simplified by creating a substrate index, such that:

Substrate index = [(0.7 x % boulders) + (0.6 x % large cobbles) + (0.5 x % small cobbles) + (0.4 x % pebbles) + (0.3 x % gravels) + (0.2 x % sand) + (0.1 x % silt) + (0.1 x % concrete/bedrock)] / 10

Where derived values for the substrate index range from 1 (i.e., a substrate of 100% silt) to 7 (i.e., a substrate of 100% boulder); the larger the index, the coarser the overall substrate. In general, coarser substrate (up to cobbles) represents better instream habitat than finer substrate. The same low coefficients for silt and concrete/bedrock reflect their uniform nature and lack of spatial heterogeneity, and in the case of silt, instability during high flow.

Invertebrate data were summarised by taxa richness, abundance of common taxa, and Non-metric Multidimesional Scaling (NMS) axis scores. Biotic indices calculated were the number of Ephemeroptera-Plecoptera-Trichoptera taxa (EPT richness), % EPT, the hard-bottomed Macroinvertebrate Community Index (MCI-hb), Urban Community Index (UCI), and their quantitative equivalents (QMCI-hb and QUCI, respectively). The paragraphs below provide brief clarification of these metrics. For a more detailed description see McMurtrie & Greenwood (2008).

» Taxa richness can be used as an indication of stream health or habitat type, where sites with greater taxa richness are usually healthier and/or have a more diverse habitat.
» NMS is an ordination of data that is often used to examine how communities composed of many different taxa differ between sites. It can graphically describe communities by representing each site as a point (an ordination score) on an x–y plot. The location of each point/site reflects its community composition, as well as its similarity to communities in other sites/points.
» 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. EPT richness and % EPT scores can provide a good indication as to the health of a particular site. The exceptions are the hydroptilid caddisflies (e.g., Trichoptera: Hydroptilidae: *Oxyethira* spp. and *Paroxyethira* spp.), which are algal piercers and often found in high numbers in nutrient enriched waters with high algal content (i.e., many degraded waterways). For this reason EPT metrics are presented without these taxa.
» The MCI/QMCI score can be used to determine the level of organic enrichment for stony-bottomed waterways in New Zealand (Stark, 1985). It calculates 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). The original MCI was intended for use in waterways with a stony substratum (and is now referred to as MCI-hb to distinguish it from the soft-bottomed variant, MCI-sb).
» The UCI/QUCI score can be used to determine the health of urban and peri-urban streams by combining tolerance values for invertebrates with presence/absence or abundance invertebrate data (Suren et al., 1998). This biotic index is indicative of habitat relationships, and to some degree incorporates urban impacts.

One-way analysis of variance (ANOVA) was used to compare habitat parameters and invertebrate community metrics between years to indicate if any overall catchment changes between 2008 and 2012 were evident. Where the assumptions of ANOVA (i.e., equal variance and normality) could not be met even after data transformation, the non-parametric Kruskal-Wallis procedure was used. The level of significance was set at 5%.

PHOTO
Taking measurements at Site 5.

3. RESULTS

3.1 HABITAT

The majority of the Otukaikino River catchment is of rural and park/reserve land use with no notable changes at any site between 2008 and 2012 except for at Site 1 which was moved 800 m upstream (Appendix II). The banks were comprised mostly of natural earth or rocks. Riparian vegetation composition changed little between 2008 and 2012 and was typically comprised of a grass/herb mix with a number of sites having a canopy of mostly exotic trees and/or shrubs (Sites 1, 4, 5, 6, & 8) (Figure 3). The greatest change to riparian vegetation was at Site 3 which has had exotic canopy trees (willows) removed between 2008 and 2012 (Figure 4). Canopy shade cover was greatest at those sites that had trees present (mostly exotic willows).

Substrate embeddedness was low to moderate at all sites, and most sites had a substratum dominated by gravel to pebble sized rocks. Over the whole catchment the substrate index was not significantly different between 2008 and 2012 with the only notable change being a decrease at Site 7 (Figure 5A; Kruskal-Wallis: H=0.72, p=0.4). Site 7 also displayed a sizeable increase in mean fine sediment depth between 2008 and 2012. While there was a signficant increase in fine sediment depth for all sites combined (Figure 5B; Kruskal-Wallis: H=7.3, p<0.01), it should be noted that mean fine sediment depths at most sites were still only a few centimetres (Figure 5B).

Overall, the mean channel width did not change between 2008 and 2012, although Site 5 had a notable increase in width (Figure 5C and 6; ANOVA: $F_{1,52}$=0.02, p=0.89). Similarly there were no significant differences in catchment-wide mean water depths or velocities (Figure 5D and E; ANOVA(depth): $F_{1,52}$=1.29, p=0.26; ANOVA(velocity): $F_{1,52}$=0.09, p=0.76). The greatest changes were observed at Site 5 where depth increased and velocity decreased between 2008 and 2012 (Figure 5D, E, and 6). The dramatic changes at Site 5 were due to

Site 1 was typical of the lower catchment with a willow canopy and an unmanaged grass-herb mix groundcover

Site 8 was typical of upper catchment sites with a mix of pasture and smaller shrubs and trees (e.g., gorse and young willows)

FIGURE 3
Representative riparian vegetation of the Waimakariri River South Branch catchment.

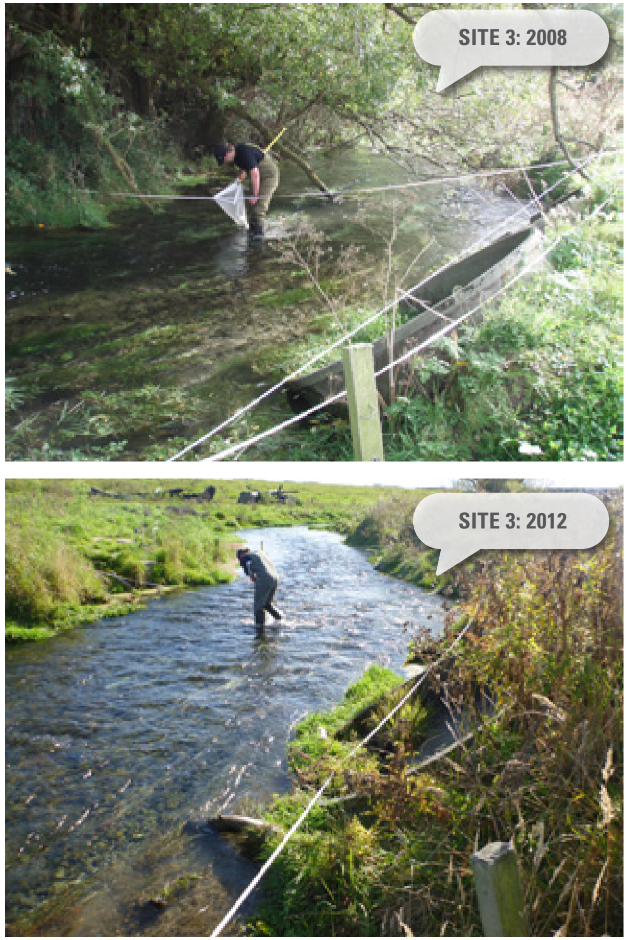


FIGURE 4
Site 3 had undergone the greatest change in riparian vegetation between 2008 (top) and 2012 (bottom) with the willow canopy being removed. Note the concrete troughs which have not been moved.

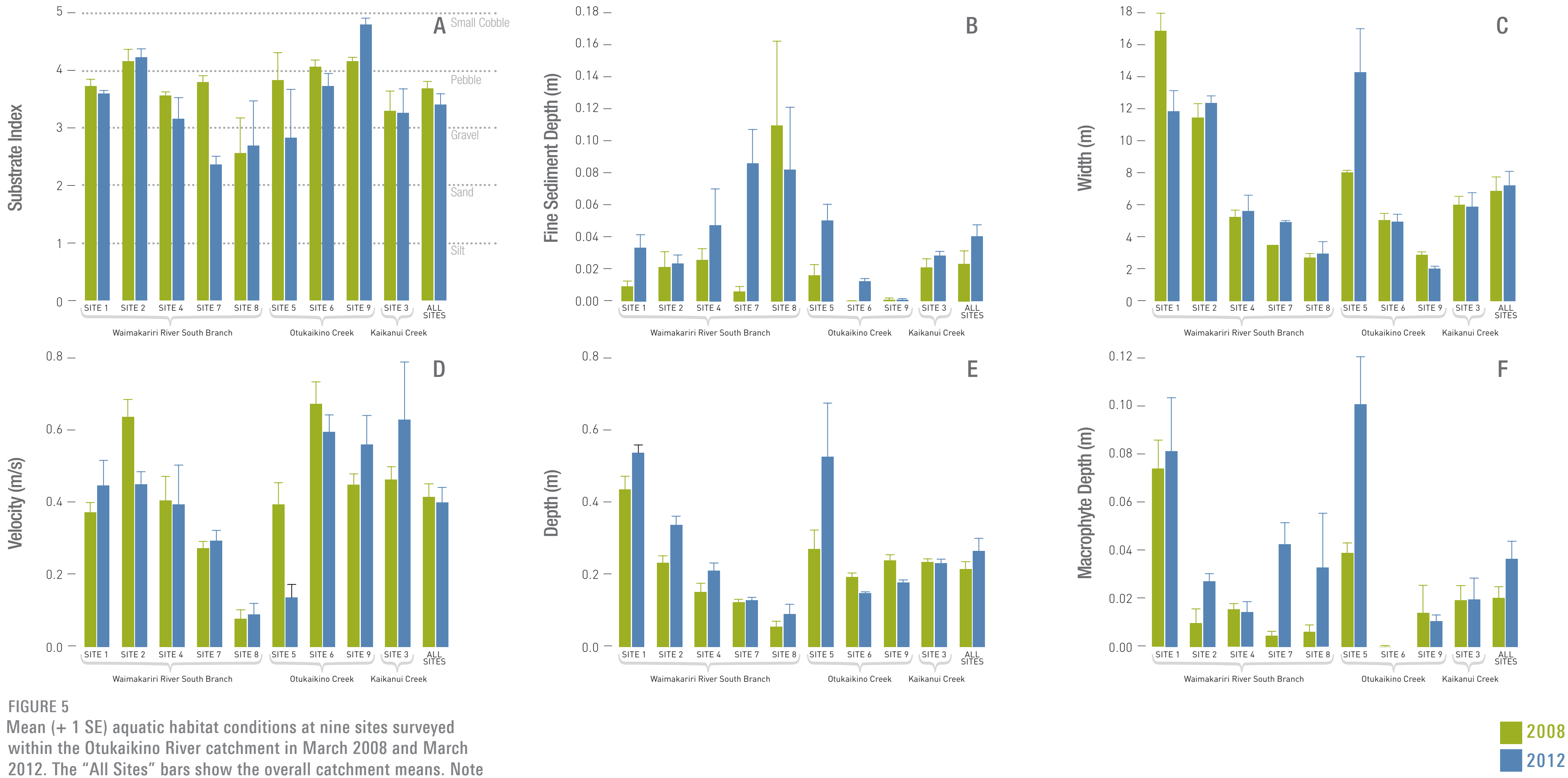


FIGURE 5
Mean (+ 1 SE) aquatic habitat conditions at nine sites surveyed within the Otukaikino River catchment in March 2008 and March 2012. The "All Sites" bars show the overall catchment means. Note that in 2012 the Site 1 survey point was moved 800 m upstream.

several of the 4 culvert pipes being blocked with rubbish (a large vinyl sheet). This has caused the water to backup substantially and drown out the riffle that was present in 2008 (Figure 6).

Aquatic macrophytes were prominent at most sites and this has not changed between 2008 and 2012, although the relative cover of the riverbed by various genera did vary (Appendix II). Notable native macrophytes found were *Potamogeton cheesmanii* at Site 7 and 8, and *P. ochreatus* at Site 9 (Figure 7). These were only observed in 2008 and not in 2012. The exotic cape pondweed (*Aponogeton distachyos*) was found for the first time in 2012 at Sites 5 and 8 (Figure 6; Appendix II). Macrophyte depths were not significantly different between 2008 and 2012, although they did more than double at Site 5 (Figure 5F; ANOVA: $F_{1,52}$=3.07, p=0.09). In 2012, the total cover of the riverbed by macrophytes ranged from 5% at Site 6 to 67% at Site 1 (Table 2). Woody debris and detritus were a small component of the organic material present in both 2008 and 2012 (Appendix II). Algal cover was dominated by green and brown mats, with filamentous algae greater than 20 mm long not being found at any site (Table 2).

Looking upstream

Looking downstream

FIGURE 6
Site 5 had undergone the greatest change in the width, water depth, and water velocity between 2008 (top) and 2012 (bottom). This was due to several of the 4 culvert pipes being blocked by rubbish, causing the water to backup and drown out the original riffle.

Photo: CCC, Kate McCombs
Potamogeton cheesmanii

Photo: Flickr, "eyeweed"
Potamogeton orchreatus

Photo: www.wildabouthteworld.com, "goosey"
Aponogeton distachyos (Cape pondweed)

FIGURE 7
Notable native (*Potamogeton* species) and exotic (*Aponogeton distachyos*) aquatic plants found in the Waimakariri River South Branch catchment. The year of the survey in which each species was found and whether it is native or exotic is shown.

TABLE 2 Comparison of percentage riverbed cover of emergent macrophytes, total macrophytes, and filamentous algae >20 mm with the limits of the Natural Resources Regional Plan (NRRP). Estimates were made March 27–29, 2012.

	SITE	EMERGENT MACROPHYTES (MAXIMUM COVER OF RIVERBED) %	TOTAL MACROPHYTES (MAXIMUM COVER OF RIVERBED) %	FILAMENTOUS ALGAE >20 mm (MAXIMUM COVER OF RIVERBED) %
NRRP "Spring-fed plains" limits		30%	50%	30%
Waimakariri River South Branch	1	9%	67%	0%
	2	14%	15%	0%
	4	5%	6%	0%
	7	17%	17%	0%
	8	23%	25%	0%
Otukaikino Creek	5	21%	35%	0%
	6	4%	5%	0%
	9	13%	20%	0%
Kaikanui Creek	3	10%	17%	0%

3.2 INVERTEBRATES

3.2.1 Overview

A total of 58 invertebrate taxa were recorded from the Otukaikino River catchment in 2012. The most diverse groups were the true flies (Diptera: 18 taxa), followed by caddisflies (Trichoptera: 16 taxa), molluscs (Mollusca: 6 taxa), crustaceans (Crustacea: 5 taxa), and mayflies (Ephemeroptera: 2 taxa). Damselflies (Odonata), flatworms (Platyhelminthes), mites (Arachnida: Acari), *Hydra* (Cnidaria: Hydrozoa: Hydridae), beetles (Coleoptera), springtails (Hexapoda: Collembola), leeches (Hirudinea), roundworms (Nematoda), worms (Oligochaeta), water bugs (Hemiptera,) and stoneflies (Plecoptera) were each represented by one taxon.

The snail *Potamopyrgus antipodarum* was the dominant species accounting for around a quarter of all invertebrates captured in 2012 (Figure 8). The cased caddisflies *Pycnocentrodes* and *Pycnocentria* combined made up another quarter of all invertebrates encountered while the mayfly *Deleatidium*, net-spinning caddisfly *Aoteapsyche*, and non-biting midge larvae Orthocladiinae round out those taxa that accounted for greater than 5% of relative abundance (Figure 8). The six above-mentioned taxa accounted for 71% or all invertebrates captured in 2012. These taxa were also widespread as they were found at all nine survey sites.

In terms of relative abundance, EPT taxa (mayflies, stoneflies, and caddisflies) or snails (molluscs) dominated at all sites, in both 2008 amd 2012 (Figure 9). The relative abundances of higher taxonomic groupings at Site 1 between 2008 and 2012 were very similar despite moving the survey location upstream 800 m in 2012. Over all the sites, there was no difference in the relative abundance of higher taxonomic groupings between 2008 and 2012 (Figure 9). However there were some site-specific shifts between years. Shifts in the relative abundance of invertebrate taxa groups between 2008 and 2012 were obvious at Site 5 (decrease in Mollusca, increase in Crustacea), Site 6 (decrease in Diptera, increase in Mollusca), and Site 7 (decrease in Mollusca, increase in EPT).

FIGURE 8
Photographs of the most abundant (% indicated) aquatic invertebrates in the Otukaikino River catchment from nine sites surveyed between 27–29 March 2012. Those taxa designated as "widespread" were found at all survey sites. Also shown are the EPT taxa that had relative abundances of 0.4% or greater.

COMMON POLLUTION-TOLERANT TAXA (>5% RELATIVE ABUNDANCE IN 2012)


Potamopyrgus antipodarum (27.7%, widespread)


Orthocladiinae midges (5.2%, widespread)

COMMON CLEANWATER (EPT) TAXA (>5% RELATIVE ABUNDANCE IN 2012)

Pycnocentrodes (13.6%, widespread)

Pycnocentria (11.8%, widespread)

Deleatidium (6.7%, widespread)

Aoteapsyche (6.3%, widespread)

OTHER CLEANWATER (EPT) TAXA (0.4–5% RELATIVE ABUNDANCE IN 2012)

Oxyethira albiceps (2.8%, widespread)

Hudsonema amabile (2.5%, widespread)

Helicopsyche (1.6%, six sites)

Hydrobiosis parumbripennis (0.7%, widespread)

Neurochorema (0.5%, widespread)

Psilochorema (0.4%, widespread)

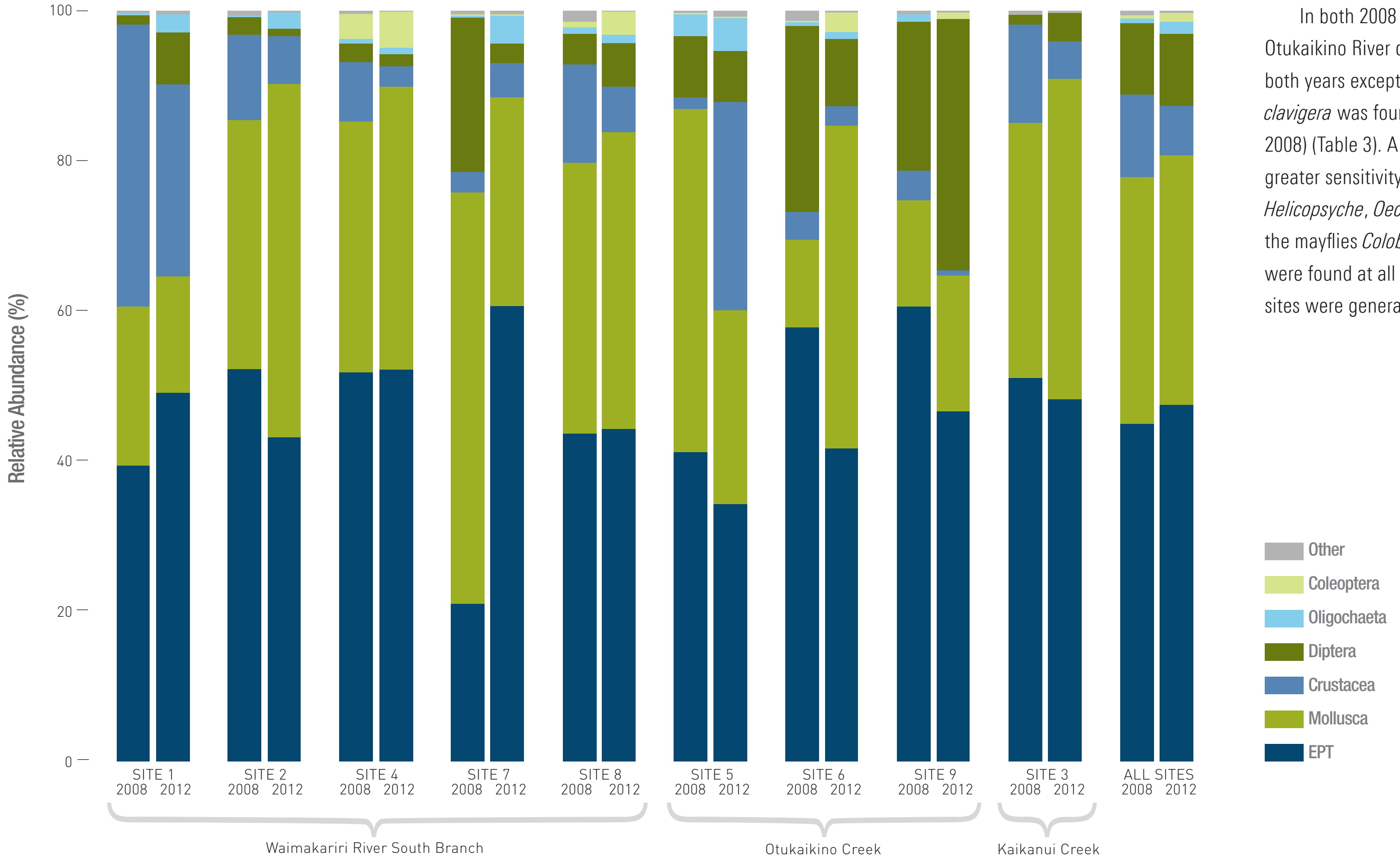
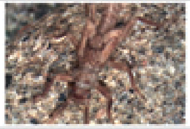
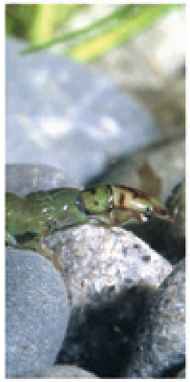
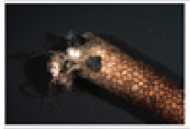
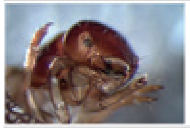


FIGURE 9
Relative abundances of higher taxonomic groupings in the Otukaikino River catchment from nine sites surveyed in March 2008 and March 2012. The “All Sites” bars show the overall catchment relative abundances.

In both 2008 and 2012 a total of 19 EPT taxa were found in the Otukaikino River catchment (Table 3). The same taxa were found in both years except for a swap in two *Hydrobiosis* caddisfly species (*H. clavigera* was found only in 2012 and *H. umbripennis* was found only in 2008) (Table 3). A number of taxa with high MCI scores (which indicate greater sensitivity to pollution) were found; including the caddisflies *Helicopsyche*, *Oeconesus*, *Olinga*, *Polyplectropus*, and *Psilochorema*, and the mayflies *Coloburiscus* and *Deleatidium* (Table 3). Eight of the 19 taxa were found at all sites in both years. Many of those taxa found at certain sites were generally found at the same sites in each year (Table 3).

TABLE 3 ▶
The presence of EPT taxa in the Otukaikino River catchment from surveys undertaken at nine sites in March 2008 and March 2012. Thumbs up indicated present, thumbs down not present. The sites at which they were found are shown in parentheses. The MCI values indicate the tolerance of the taxa to organic pollution (10 = highly pollution sensitive, 1 = pollution tolerant (Stark & Maxted, 2007).

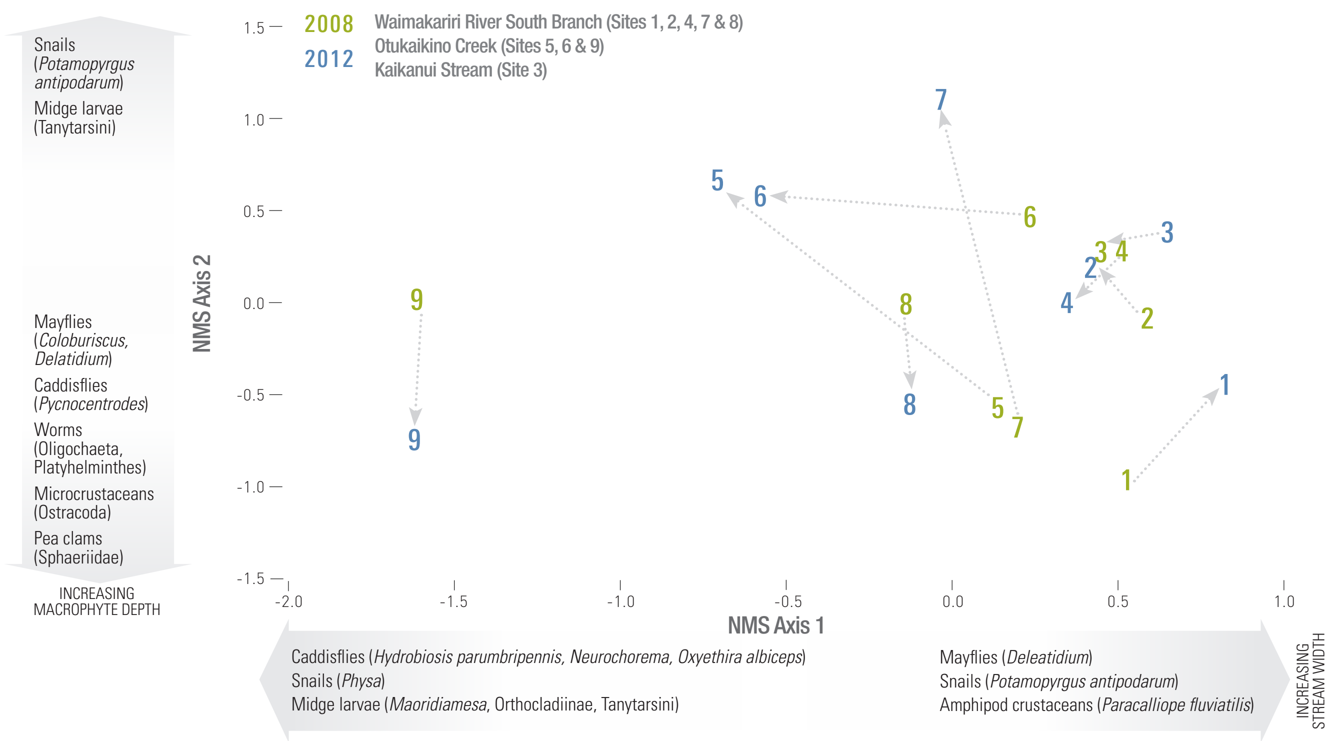
		EPT TAXA	MCI VALUE	2008	2012
Mayflies (Ephemeroptera)		*Coloburiscus humeralis*	9	👍 (Sites 1–6)	👍 (Sites 1–4 & 6)
		*Deleatidium*	8	👍 (All sites)	👍 (All sites)
Stoneflies (Plecoptera)		*Zelandobius*	5	👍 (Sites 5, 7, & 8)	👍 (Sites 8)
Caddisflies (Trichoptera)		*Aoteapsyche*	4	👍 (All sites)	👍 (All sites)
		*Helicopsyche*	10	👍 (Sites 1, 2, 4, 5, 7, & 8)	👍 (Sites 1, 2, 4, 5, 7, & 8)
		*Hudsonema amabile*	6	👍 (All sites)	👍 (All sites)
		Hudsonema alienum	6	👍 (Sites 5–8)	👍 (Sites 6 & 9)
		*Hydrobiosis clavigera*	5	👎	👍 (Site 3)
		Hydrobiosis parumbripennis	5	👍 (All sites)	👍 (All sites)
		Hydrobiosis umbripennis	5	👍 (Sites 3–6, 8, & 9)	👎

		EPT TAXA	MCI VALUE	2008	2012
Caddisflies (Trichoptera) ...continued		*Neurochorema*	6	(Sites 1–7, & 9)	(All sites)
		*Oecetis*	6	(Sites 1 & 5)	(Sites 1 & 5)
		*Oeconesus*	9	(Site 6)	(Sites 3 & 5)
		*Olinga*	9	(Sites 1 & 3–8)	(Sites 1 & 3–8)
		*Oxyethira albiceps*	2	(All sites)	(All sites)
		*Polyplectropus*	8	(Sites 1–5, 8, & 9)	(Sites 5, 8, & 9)
		*Psilochorema*	8	(All sites)	(All sites)
		*Pycnocentria*	7	(All sites)	(All sites)

		EPT TAXA	MCI VALUE	2008	2012
Caddisflies (Trichoptera) ...continued		*Pycnocentrodes*	5	(All sites)	(All sites)
		*Triplectides*	5	(Sites 1–6 & 8)	(Sites 1, 2, 4, 5, & 8)
		Total EPT taxa		19	19

3.2.2 Ordination

The most prominent feature of the NMS ordination is the separation of Site 9 from all other sites along Axis 1, irrespective of year (Figure 10). This site tended to have more caddisflies, midge larvae, and *Physa* snails than the other sites as well as the narrowest channel (Figure 10). Of the other sites, there is very little separation between Sites 2, 3, and 4 in 2008 and 2012 indicating there has been minimal change in their invertebrate communities over time. Similarily, Sites 1 and 8 displayed only minor seperation between years. Sites 5, 6, and 7 showed the most separation between years (Figure 10), which supports the changes observed in the relative abundance of higher taxonomic groupings at these sites (Figure 9). Site 5 was more associated with the snail *Potamopyrgus antipodarum* in 2008 and crustaceans (ostracods and pea clams) in 2012 along Axis 2. Site 6 was associated with midge larvae and caddisflies in 2008 and the snail *P. antipodarum* and mayfly *Deleatidium* in 2012 along Axis 1. Site 7 had the greatest separation between years of all sites being associated with the snail *P. antipodarum* in 2008 and EPT taxa (mayflies and caddisflies) in 2012 along Axis 2 (Figure 10).



3.2.3 Biotic Indices

Taxa richness averaged between 20 and 27 per site and overall was slightly higher in 2008 (Figure 11A: ANOVA: $F_{1,52}=4.24$, $p=0.04$). MCI-hb scores indicated most sites in 2008 and 2012 were of fair water quality while QMCI-hb scores showed a few sites to be of good water quality (e.g., Sites 1 and 3) and Site 9 to have poor water quality in both years (Figure 11B and C). Combining all sites, there was no significant difference between years for either index (ANOVA(MCI-hb): $F_{1,52}=3.61$, $p=0.06$; and Kruskal-Wallis(QMCI-hb): H=0.17, $p=0.68$). Average EPT taxa richness ranged between eight and 13 per site, with Site 9 consistently having fewer EPT taxa than the other sites (Figure 11D). Fewer EPT taxa were present at most sites in 2012 than in 2008, leading to a significant decrease between years (Figure 11D; ANOVA: $F_{1,52}=13.35$, $p<0.01$). The %EPT individuals was quite variable, especially at Sites 6 and 7 (higher in 2012) and Site 9 (higher in 2008) (Figure 11E). However, combining all sites, the was no significant difference between years (Kruskal-Wallis: H=0.01, $p=0.91$). Combining all sites there were no significant differences in QUCI between years (Kruskal-Wallis: H=3.24, $p=0.07$), but was quite variable between sites (Figure 11F).

FIGURE 10
Non-metric multidimensional scaling (NMS) ordination of the aquatic invertebrate community from nine sites surveyed in the Otukaikino River catchment in March 2008 and March 2012. Each point represents the mean relative abundance of three replicate samples. Invertebrate taxa and habitat variables correlated with the axes are shown. Waterway names are those used officially by Christchurch City Council. Note that in 2012 the Site 1 survey location was moved 800 m upstream. For site locations see Figure 1.

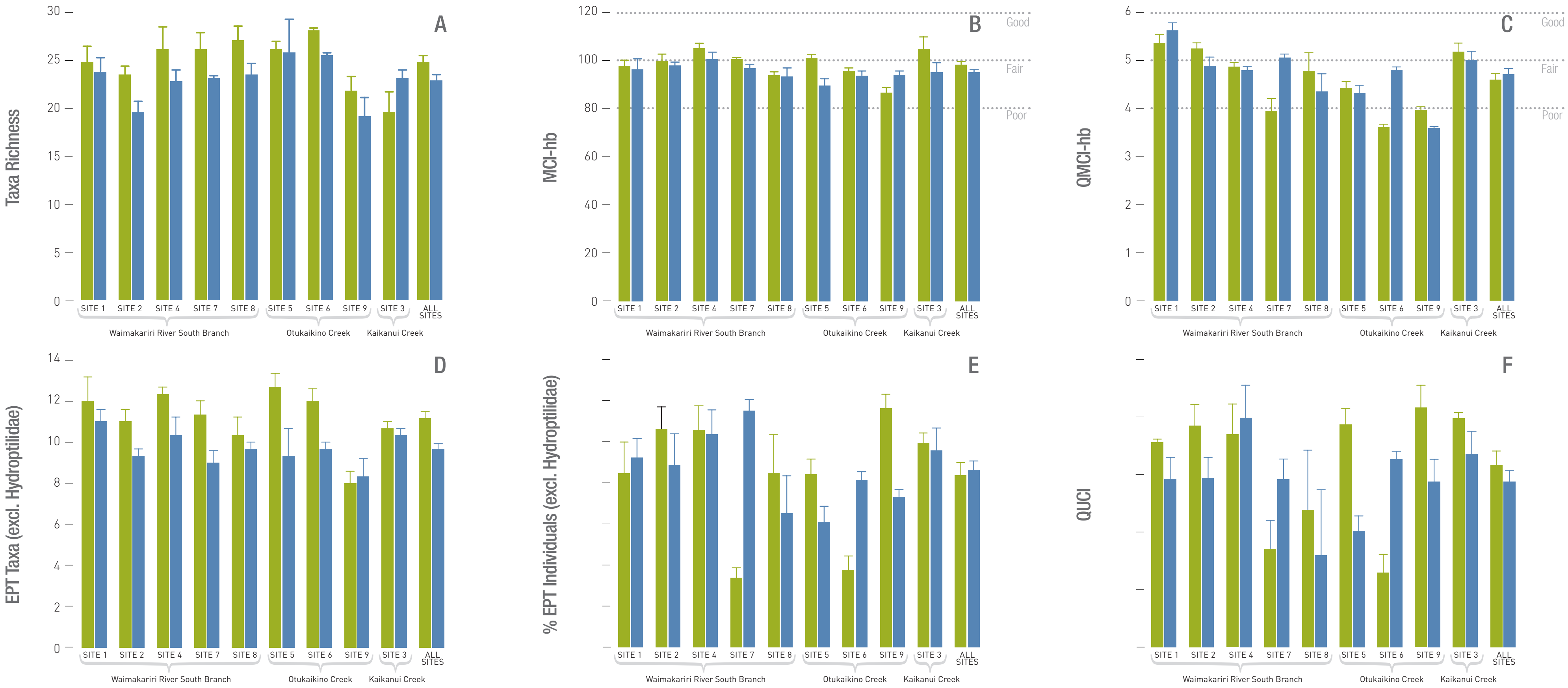


FIGURE 11
Mean (+ 1 SE) biotic indices of invertebrate community health at the nine sites surveyed within the Otukaikino River catchment during March 2008 and March 2012. The "All sites" bars show the overall catchment means. The dotted lines on the MCI-sb and QMCI-sb graphs indicate the probable level of water quality (Stark & Maxted, 2007). Note that in 2012 the Site 1 survey point was moved 800 m upstream.

The overall best site in terms of ranking of the seven biotic indices in 2012 was Site 3 (Kaikanui Creek) (Table 4 and Figure 12). This site ranked first, second, or third for five of the seven metrics calculated (Table 4). This site was also highly ranked (third of nine sites) in 2008. The next two highest ranked sites were in the Waimakariri River South Branch (Table 4 and Figure 12). Ranked second was Site 4 which is upstream of the confluence with Otukaikino Creek, while the third ranked site (Site 1) is the most downstream site sampled. These sites were ranked first and fifth in 2008 respectively, however note that Site 1 was moved 800 m upstream in 2012.

The worst equal sites in 2012 were both in Otukaikino Creek (Sites 5 and 9; Table 4 and Figure 12). Site 9 was also the lowest ranked site in 2008, however, Site 5 had the second best ranking in 2008 (Table 4). Site 5 had also showed the greatest changes in physical habitat (Figure 4) which likely contributed to this drop in ranking (Table 4 and Figure 13). Another notable change in ranking was an improvement by two places by Site 7 (ranked 7th in 2008 and 5th in 2012); a rural site which had been partially fenced off from stock sometime between 2008 and 2012 (Figure 13). Also, Site 6 showed a marked improvement in ranking from 8th in 2008 to 4th in 2012 (Table 4 and Figure 13). The instream and riparian habitat characteristics of this site changed little between the surveys, however QMCI-hb, %EPT individuals, and QUCI scores were markedly higher in 2012 (Figure 11).

TABLE 4 An overall site ranking (1 (best) – 9 (worst)) of each of the nine sites surveyed in the Otukaikino River catchment in March 2012; with site rank based on the summation of ranks for each biotic index. The possible final ranking score is from 7 (ranking 1 on all variables) to 63 (ranking 9 on all variables). The sites have also been divided into comparative groupings (best, medium, and worst) according to their final score. WRSB = Waimakariri River South Branch. Note that in 2012 the Site 1 survey point was moved 800 m upstream. Also shown are the rankings from 2008. For site locations see Figure 1.

WATERWAY	SITE	BIOTIC INDICES							SUM	FINAL RANK	GROUPING	2008 FINAL RANK
		TAXA	EPT	% EPT	MCI-hb	QMCI-hb	UCI	QUCI				
Kaikanui Creek	3	5	2	3	5	3	1	2	21	1	Best	3
WRSB	4	7	3	2	1	6	3	1	23	2	Best	1
WRSB	1	3	1	4	4	1	6	5	24	3	Best	5
Otukaikino Creek	6	2	4	6	7	5	2	3	29	4	Medium	8
WRSB	7	6	8	1	3	2	8	6	34	5	Medium	7
WRSB	2	8	6	5	2	4	7	4	36	6	Medium	4
WRSB	8	4	5	8	8	7	5	9	46	7	Worst	6
Otukaikino Creek	5	1	7	9	9	8	9	8	51	8=	Worst	2
Otukaikino Creek	9	9	9	7	6	9	4	7	51	8=	Worst	9

SITE 3:
Kaikanui Stream (looking downstream from top of site).
Ranked 1st in 2012 and 3rd in 2008.

SITE 4:
Waimakariri River South Branch (looking upstream from bottom of site).
Ranked 2nd in 2012 and 1st in 2008.

SITE 1:
Waimakariri River South Branch upstream of Dickeys Road (looking downstream from top of site). Ranked 3rd in 2012 and 5th in 2008.

SITE 5:
Otukaikino Creek (looking upstream from bottom of site).
Ranked 8th= in 2012 and 2nd in 2008.

SITE 9:
Otukaikino Creek (looking downstream from top of site).
Ranked 8th= in 2012 and 9th in 2008.

FIGURE 12
The three highest ranking (Sites 3, 4, and 1) and two lowest ranking (Sites 5 and 9) sites in 2012, based on the combined ranks of seven invertebrate community metrics.

FIGURE 13
Sites that had the most notable changes in ranking between the May 2008 and May 2012 surveys.

PHOTO
Collecting a kicknet sample.

4. DISCUSSION

The QMCI-hb macroinvertebrate community health metric indicated the health of the Otukaikino River catchment in 2012 was relatively high with most of the surveyed sites rated as "fair" or "good", just as they were in 2008. It remains the healthiest river catchment in Christchurch with the Halswell and Heathcote River catchments having all sites rated as 'poor', and the Avon River and Styx Rivers having a mixture of 'poor' and 'fair' sites (McMurtrie & Greenwood, 2008; McMurtrie, 2009; James, 2010; James, 2011). Combining all the Otukaikino River catchment sites, pollution-sensitive EPT taxa make up around 40% of all invertebrates present in both 2008 and 2012. There is a lack of historic invertebrate data from the Otukaikino River catchment, although the thesis of Fowles (1972) investigated the invertebrate fauna of a section of what is officially named Otukaikino Creek that encompasses our Site 6. In his study section, he found ten EPT taxa, seven of which we also found at Site 6 when we converted our data to the same level of identification. This indicates that the pollution sensitive EPT taxa, at least at this site, have probably changed little over the last 40 years. Fowles (1972) did find two EPT taxa that we have not found in the Otukaikino River catchment during either the 2008 or 2012 surveys, the mayfly *Neozephlebia scita* and the stonefly *Acroperla trivacuata*. We have, however, found a small number of *Neozephlebia scita* in samples taken as part of another investigation within 500 metres of the downstream-most 2012 survey site (Site 1) (EOS Ecology, unpublished data). Both these taxa were rarely encountered by Fowles (1972) and are hence are probably still uncommon today.

Between 2008 and 2012 there have been some notable changes at a few sites. Water had backed up substantially at Site 5 between 2008 and 2012, caused by the partial blockage of the culvert pipes immediately downstream of the site. The result was a much wider and deeper site, with slower water velocity, more macrophyte cover and more fine sediment in 2012 compared to 2008 (see Figures 5 and 6). The physical changes have resulted in a reduction in the dominance of many pollution-sensitive EPT taxa that prefer the shallower, swifter riffle habitat that was present in 2008. The loss of these taxa was responsible for this site showing the greatest drop in overall site ranking between the two survey years (ranked second in 2008 and eighth equal in 2012). In contrast, Site 6 increased from a ranking of eighth in 2008 to fourth in 2012. At this site the measured physical parameters remained unchanged (see Figure 5 and 13), however invertebrate metrics such as QMCI-hb, %EPT individuals, and QUCI all increased between 2008 and 2012. The Kaikanui Stream site (Site 3) underwent the greatest obvious change in riparian condition, as sometime between 2008 and 2012 a canopy of willows were removed (see Figure 4). This canopy removal did not result in any great changes to the invertebrate metrics calculated, however the relative ranking of this site increased from third in 2008 to first in 2012. Another notable change in riparian conditions was at Site 7 which was partially fenced off from stock some time between 2008 and 2012 (see Figure 13). This site showed sizeable increases in the QMCI-hb score and %EPT, which resulted in an improvement in ranking from 7th in 2008 to 5th in 2012. The removal of stock disturbance from this site and subsequent recovery of marginal vegetation may well have allowed an increase in EPT densities.

There were some spatial patterns of the rankings of sites. The three highest ranking sites in 2012 (Sites 1, 3, and 4) were spread through the mid to lower catchment. They were in Kaikanui Creek (Site 3) and Waimakariri River South Branch (Site 1 and 4) (Figure 12). In 2008 Site 3 and 4 also rated highly (third and first respectively). Given the Otukaikino River catchment has the highest ecological quality of all Christchurch's waterways, these sites are therefore the best of all sites surveyed in Christchurch in terms of the aquatic macroinvertebrate community. Sites 5 and 9, both on the Otukaikino Creek tributary, were ranked the worst sites in the catchment in 2012 (Figure 12). Despite

◀ PHOTO
Taking velocity measurements.

this, these sites had fifteen and nine EPT taxa respectively in 2012, which is still more than the vast majority of long-term monitoring sites in other surveyed catchments (McMurtrie & Greenwood, 2008; McMurtrie, 2009; James, 2010; James, 2011). Thus even these lowest ranked sites in the Otukaikino River catchment would be considered among the higher quality sites of greater Christchurch.

The high ecological quality of the Otukaikino River relative to Christchurch's other rivers is directly related to the lack of urban development in its catchment. This has meant stormwater-derived contaminants such as fine sediment and heavy metals are not as prevalent as they are in the heavily urbanised Christchurch rivers. The substratum in the Otukaikino River catchment therefore remains largely clear of the sand/silt particles that have smothered much of the coarse substratum in Christchurch's rivers (Figure 14). There are also fewer barriers to invertebrate migration (e.g., culverts, bridges, and light pollution). It must be noted however, that the Otukaikino River we see today is vastly different to what existed at the time of European settlement. At that time it was a braid permanently connected to the Waimakariri River with numerous other flow channels around it, many of which probably only flowed during floods. The CCC's 'Black Maps' which depict waterways from 1856 show a wide channel, then known as the River Courtney, which was a braid of the Waimakariri River, flowing through where the lower reaches of the Otukaikino River now are (Christchurch City Council, 2006b). Its current official name, the Waimakariri River South Branch, reflects that history. Over time as the area was developed for farming and flood control measures were built, the channel was cut off from the main Waimakariri River flow by stop banks and became a spring-fed river. Being spring-fed and no longer subjected to regular flood disturbance led to the development of a more stable instream environment with abundant growths of macrophytes, especially in the mid to lower reaches. Thus, in some respects these anthropogenic changes have inadvertently assisted in the creation of the high quality river environment we see now.

Many of the cleanwater EPT taxa found in the Otukaikino River catchment were historically present in other Christchurch river catchments. For example, the Halswell River catchment surveys undertaken in the early 1980's by Dr. J. Robb of the Christchurch Drainage Board found four EPT taxa (*Deleatidium*, *Zelandobius*, *Pycnocentrodes*, and *Olinga)* that have now apparently disappeared (Robb, 1981; James, 2011). Similarily, two mayfly taxa (*Deleatidium* and *Coloburiscus*) are known to have dissappeared from the Avon River catchment, although at least 13 caddisfly taxa still persist there (Robb, 1992; McMurtrie, 2009). Should Christchurch's more degraded urban waterways ever be improved such that they can again support the more pollution-sensitive EPT taxa, then the Otukaikino River catchment will be a key source of colonists. Such colonisation may occur naturally via flying adults, however because of the migration barriers (e.g., buildings, light pollution, culverts, and distance) between this catchment and the more urbanised ones, human intervention (i.e., translocations) may be required.

FIGURE 14
The gravels of the Otukaikino River catchment (left) are clean compared to the silted gravels of Christchurch's other rivers such as the Avon (right). This is related to the lack of urban development and stormwater discharges. Subsequently, the Otukaikino River catchment supports the city's healthiest and most diverse invertebrate communities.


Otukaikino Creek


Avon River

5. RECOMMENDATIONS

Having completed two rounds of long-term monitoring we are now able to provide recommendations to improve the coverage of the long-term ecological survey programme and protect those parts of the catchment with the highest aquatic macroinvertebrate community values.

» The rubbish blocking the culvert pipes immediately downstream of Site 5 should be removed as soon as possible to allow the stream to return to its natural state, restore fish passage and reduce the chance of flooding. (The large vinyl sheet was too heavy for two people to remove.)

» Given the high ecological values of the Otukaikino, any future crossings of this river should involve the installation of either a bridge (preferred option) or a single oversized boxed culvert.

» The current survey is limited to the wadeable parts of the catchment. Below Dickeys Road there is approximately 2.5 km of river that is not covered by the existing survey design. We recommend one or two sites be added in the lower, non-wadeable portion of the river to get more complete coverage of the catchment.

» The current long-term survey design does not include fish. We recommend fish be surveyed at the same sites to attain a more complete picture of aquatic ecological values. It will also provide baseline data against which to better measure the impacts of any future disturbance (e.g., earthquakes and land-use changes).

» The best macroinvertebrate sites in Christchurch have been identified in the Otukaikino River catchment. These sites, and more importantly their upstream sub-catchments, should be prioritised for protective measures (e.g., fencing from stock and planting of native riparian vegetation). Wider catchment plans for large reserves in McLeans Island should be supported and realised, and should include the headwaters of Otukaikino Creek and the Waimakariri River South Branch. These headwaters are small and at most risk from flow reductions and stock damage. It is vital they are fenced and planted as soon as possible.

PHOTO
Collecting fyke nets in the lower non-wadeable section of the Otukaikino. We suggest fish also be surveyed at the same sites in future years, and that the non-wadeable section of the river also be included in the survey.

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PHOTO
The diverse macrophyte beds found in the Otukaikino River.

7 APPENDICES

7.1 APPENDIX I: SITE PHOTOGRAPHS

WAIMAKARIRI RIVER SOUTH BRANCH

2008

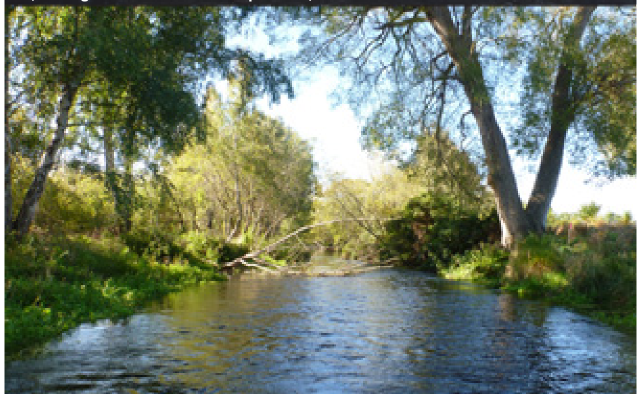
SITE 1:
Waimakariri River South Branch upstream of Dickeys Road
(looking upstream from middle of site)

SITE 2:
Waimakariri River South Branch at The Groynes dog park
(looking downstream from top of site)

SITE 4:
Waimakariri River South Branch at Clearwater Resort
(looking upstream from bottom of site)

2012

SITE 1:
Waimakariri River South Branch upstream of Dickeys Road
(looking downstream from top of site)

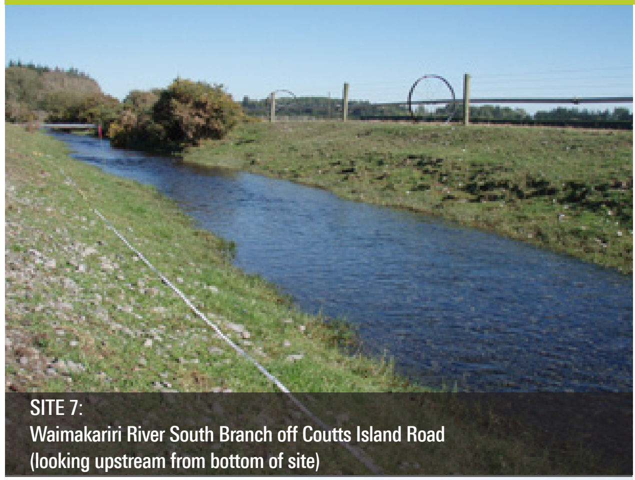


SITE 2:
Waimakariri River South Branch at The Groynes dog park
(looking downstream from top of site)

SITE 4:
Waimakariri River South Branch at Clearwater Resort
(looking upstream from bottom of site)

WAIMAKARIRI RIVER SOUTH BRANCH... CONTINUED

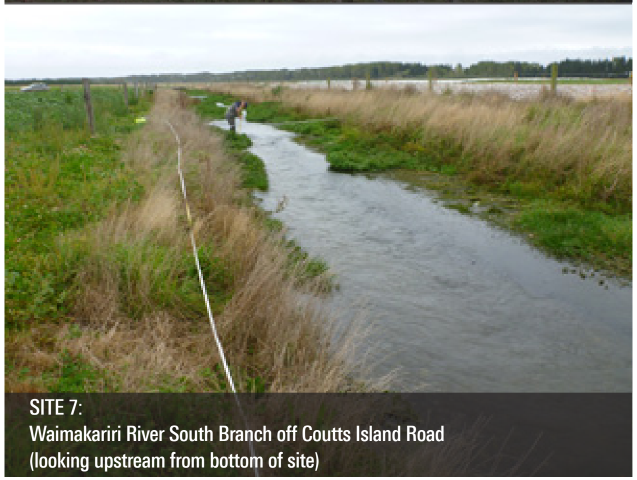
2008



SITE 7:
Waimakariri River South Branch off Coutts Island Road
(looking upstream from bottom of site)

SITE 8:
Waimakariri River South Branch headwaters
(looking upstream from bottom of site)

2012



SITE 7:
Waimakariri River South Branch off Coutts Island Road
(looking upstream from bottom of site)

SITE 8:
Waimakariri River South Branch headwaters
(looking upstream from bottom of site)

KAIKANUI CREEK

2008

SITE 3:
Kaikanui Creek downstream of Clearwater Resort
(looking downstream from middle of site)

2012

SITE 3:
Kaikanui Creek downstream of Clearwater Resort
(looking downstream from middle of site)

OTUKAIKINO CREEK

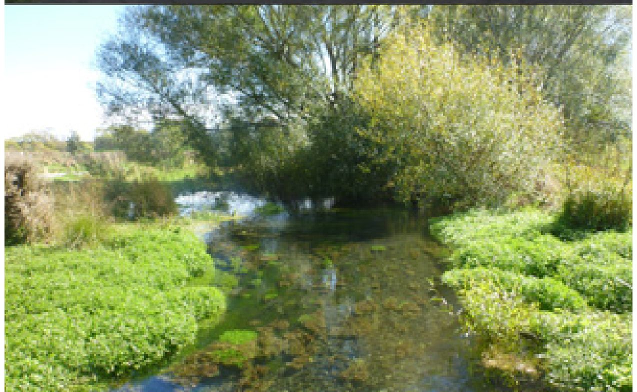
2008

SITE 5:
Otukaikino Creek at Clearwater Resort
(looking upstream from bottom of site)

SITE 6:
Otukaikino Creek at Omaka Scout Camp
(looking upstream from bottom of site)

SITE 9:
Otukaikino Creek at McLeans Island Road
(looking downstream from top of site)

2012



SITE 5:
Otukaikino Creek at Clearwater Resort
(looking upstream from bottom of site)

SITE 6:
Otukaikino Creek at Omaka Scout Camp
(looking upstream from bottom of site)

SITE 9:
Otukaikino Creek at McLeans Island Road
(looking downstream from top of site)

7.2 APPENDIX II: HABITAT ATTRIBUTES

Habitat attributes of nine sites in the Otukaikino River catchment surveyed in March 2008 and March 2012. Note that in 2012 the Site 1 survey site was moved 800 m upstream. For site locations refer to Figure 1 and Table 1.

	WAIMAKARIRI RIVER SOUTH BRANCH									
	SITE 1		SITE 2		SITE 4		SITE 7		SITE 8	
	2008	2012	2008	2012	2008	2012	2008	2012	2008	2012
Surrounding land use	50% fenced rural (stock); 50% industrial	50% fenced rural (stock); 50% park/reserve	100% park/reserve	No change	50% park/reserve (golf course); 50% fenced rural (stock)	No change	100% unfenced rural (stock)	100% fenced rural (stock)	100% unfenced rural (stock)	No change
Bank material composition	Earth	No change	Earth	No change	Earth	No change	Earth	Earth (some rock)	Earth	Earth and rock
Riparian vegetation	Mostly a mix of low ground cover and grass/herb mix. Canopy of exotic trees.	Grass/herb mix with canopy of exotic trees.	Mostly a mix of low ground cover and grass/herb mix. Some ferns present.	Mostly grass/herb mix. Some low ground cover and ferns.	Sedges, ferns, low ground cover and grass/herb mix. Canopy of exotic and native trees.	Mostly grass/herb mix with ferns and some coarse exotic vegetation. Canopy of exotic and native trees.	Mostly lawn. Some grass/herb mix and unvegetated areas.	Mostly grass/herb mix. Some sedges and unvegetated areas.	Mostly grass/herb mix. Some exotic shrubs and trees.	Mostly grass/herb mix. Some unvegetated areas. Canopy of exotic trees and shrubs.
Canopy cover	50–75%	5–25%	25–75%	5–25%	25-50%	>75%	<5%	No change	>75%	<5%
Substrate embeddedness	<5%	25–50%	5–25%	<5%	5–25%	25-50%	<5%	5–25%	5–25%	25-50%
Habitat type (riffle:pool:run)	0:0:100	No change	30:0:70	0:0:100	100:0:0	No change	20:0:80	0:0:100	50:0:50	20:0:80
Aquatic vegetation and organic material cover	*Ranunculus*: 40% *Elodea*: 10% *Rorippa*: 7% *Mimulus*: 5% Algal mats: 1% Detritus (leaf litter): 1% Terrestrial roots/vegetation: 1% Woody debris: 1%	*Ranunculus*: 40% *Nitella*: 15% Algal mats: 5% Terrestrial roots/vegetation: 5% *Azolla:* 1% Detritus (leaf litter): 1% *Elodea*: 3% *Lemna*: 1% *Mimulus*: 1% *Rorippa*: 1% Woody debris: 1%	Algal mats: 5% *Rorippa*: 5% Detritus (leaf litter): 2% *Elodea*: 2% *Nitella*: 2% *Ranunculus*: 2% Terrestrial roots/vegetation: 2% *Myriophyllum*: 1%	Algal mats: 75% *Mimulus*: 7% *Rorippa*: 5% Terrestrial roots/vegetation: 2% *Azolla:* 1% Detritus (leaf litter): 1% *Lemna*: 1% *Myriophyllum*: 1% Woody debris: 1%	*Rorippa*: 5% Terrestrial roots/vegetation: 5% Detritus (leaf litter): 2% Woody debris: 2% Algal mats: 1% *Elodea*: 1% Filamentous algae: 1% *Lemna*: 1% Moss/liverworts: 1% *Nitella*: 1%	Algal mats: 60% *Rorippa*: 3% Terrestrial roots/vegetation: 2% Detritus (leaf litter): 1% *Elodea*: 1% *Lemna*: 1% *Ludwigia*: 1% *Mimulus*: 1% Woody debris: 1%	Filamentous algae: 10% *Potamogeton cheesmanii*: 10% Algal mats: 5% *Elodea*: 5% *Rorippa*: 3% *Mimulus*: 2% Callitrichaceae: 1% Detritus (leaf litter): 1% *Lemna*: 1%	Algal mats: 20% *Elodea*: 15% *Rorippa*: 15% *Lemna*: 1% *Mimulus*: 1% Terrestrial roots/vegetation: 1%	*Myriophyllum*: 10% *Rorippa*: 10% *Elodea*: 5% *Mimulus*: 5% *Potamogeton cheesmanii*: 5% Terrestrial roots/vegetation: 5% *Nitella*: 2% *Azolla:* 1% Detritus (leaf litter): 1% *Lemna*: 1%	Algal mats: 50% *Elodea*: 9% *Rorippa*: 7% *Mimulus*: 2% Terrestrial roots/vegetation: 2% *Aponogeton*: 1% *Juncus*: 2% *Myosotis*: 1% *Myriophyllum*: 1%

	OTUKAIKINO CREEK						KAIKANUI CREEK	
	SITE 5		SITE 6		SITE 9		SITE 3	
	2008	2012	2008	2012	2008	2012	2008	2012
Surrounding land use	100% park/reserve	No change	100% park/reserve	No change	100% unfenced rural (stock)	No change	100% fenced rural (stock)	50% fenced rural (stock): 50% unfenced rural (stock)
Bank material composition	Earth	Earth (minor brick/ concrete)	Earth (minor brick/ concrete)	Earth (minor brick/ concrete and rock)	Rock	Rock (minor earth)	Earth	Earth (minor brick/ concrete)
Riparian vegetation	Mostly grass/herb mix. Some sedges and exotic canopy trees.	Mostly grass/herb mix. Some sedges and exotic canopy trees.	Mostly lawn and grass/ herb mix. Some exotic canopy trees.	Mostly grass/herb mix. Some sedges and exotic canopy trees.	Grass/herb mix and unvegetated areas.	Mostly grass/herb mix and unvegetated areas. Canopy of exotic shrubs.	Mostly grass/herb mix. Some moss/liverworts. Canopy of exotic trees.	Mostly grass/herb mix. Some moss/liverworts and unvegetated areas.
Canopy cover	5–25%	<5%	5–25%	No change	<5%	No change	25–75%	<5%
Substrate embeddedness	25–50%	5–25%	25–50%	No change	Not recorded	<5%	5–25%	<5%
Habitat type (riffle:pool:run)	50:0:50	0:0:100	100:0:0	No change	100:0:0	No change	90:0:10	95:5:0
Material cover	Algal mats: 25% *Ranunculus*: 20% *Rorippa*: 10% *Elodea*: 5% *Mimulus*: 3% Detritus (leaf litter): 2% Terrestrial roots/ vegetation: 1% Woody debris: 1%	Algal mats: 20% *Rorippa*: 15% *Elodea*: 5% *Ludwigia*: 5% *Mimulus*: 5% *Myriophyllum*: 5% *Aponogeton*: 1% Detritus (leaf litter): 1% Terrestrial roots/ vegetation: 1% Woody debris: 1%	Algal mats: 20% Filamentous algae: 10% *Rorippa*: 5% Detritus (leaf litter): 3% *Lemna*: 2% *Azolla*: 1% *Mimulus*: 1%	Algal mats: 50% *Myriophyllum*: 1% *Mimulus*: 1% *Rorippa*: 1% *Lemna*: 1% *Azolla*: 1% Terrestrial roots/ vegetation: 1% Detritus (leaf litter): 1%	Algal mats: 25% *Lilaeopsis*: 15% *Ranunculus*: 10% *Elodea*: 5% *Nitella*: 5% *Potamogeton crispus*: 5% *Rorippa*: 5% Filamentous algae: 2% *Lemna*: 2% *Azolla*: 1% Detritus (leaf litter): 1% *Potamogeton ochreatus*: 1%	Algal mats: 65% *Rorippa*: 10% *Ludwigia*: 5% *Azolla*: 1% Filamentous algae: 1% *Lemna*: 1% Moss/liverworts: 1% *Myosotis*: 1% Terrestrial roots/ vegetation: 1%	Moss/liverworts: 25% Woody debris: 10% *Glyceria*: 7% Detritus (leaf litter): 5% Terrestrial roots/ vegetation: 5% *Rorippa*: 3% *Mimulus*: 2% Algal mats: 1%	Algal mats: 20% *Rorippa*: 7% Moss/liverworts: 5% Terrestrial roots/ vegetation: 5% *Elodea*: 2% *Azolla*: 1% *Lemna*: 1% *Mimulus*: 1% Woody debris: 1%

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