Long-term Monitoring of Aquatic Invertebrates and Fish:

STYX RIVER CATCHMENT 2013

EOS Ecology Report No: 12074-CCC02-01 | July 2013
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Approved for release by:
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22-07-13

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. In 2013, the programme was extended to include monitoring of fish and non-wadeable habitats. This report summarises the results of the sixth year of monitoring, where twelve sites in the Styx River catchment were surveyed during February to April 2013. The original nine sites sampled in 2008 were revisited while three non-wadeable sites in the lower river were added.

A total of 60 invertebrate taxa were recorded from the Styx River catchment in 2013. The most diverse groups were the two-winged flies (Diptera: 16 taxa) and caddisflies (Trichoptera: 16 taxa), followed by molluscs (Mollusca: 6 taxa), crustaceans (Crustacea: 6 taxa), damselflies and dragonflies (Odonata: 3 taxa), and flatworms (Platyhelminthes: 2 taxa). The four most abundant taxa (the snail *Potamopyrgus antipodarum*, the amphipod crustacean *Paracalliope fluviatilis*, oligochaete worms, and ostracod micro-crustaceans) accounted for 78% of all invertebrates captured, with *P. antipodarum* alone accounting for nearly 60%. The QMCI-hb macroinvertebrate community health metric indicated the health of the wadeable Styx River catchment in 2013 was moderate in the mainstem with four of the five mainstem sites rated as "fair". In contrast the four tributary sites were all rated as "poor" in 2013. A similar distinction between mainstem and tributary sites was seen in 2008. In 2013 only three mainstem sites were within the minimum QMCI range of the Proposed Canterbury Land and Water Regional Plan (PLWRP) for 'spring-fed – plains' designated waterways. The wadeable mainstem sites have retained a core sensitive EPT assemblage although the filter-feeding mayfly *Coloburiscus humeralis* has disappeared while the cased-caddisfly, *Olinga feredayi*, is now restricted to one site. The Styx River catchment exemplifies a system where the most sensitive aquatic invertebrate taxa appear to be in the process of becoming locally extinct due to the degradation of instream habitat.

A total of nine fish species and one freshwater crayfish/kōura species were found across the twelve survey sites. Shortfin eel, longfin eel, and upland bully were the most common species at the wadeable sites while giant bully and shortfin eel were the most common at the non-wadeable sites. Three fish species (longfin eel, inanga, and lamprey) along with freshwater crayfish/kōura were of conservation concern with a 'declining' threat classification. Two exotic fish species (brown trout and rainbow trout) were found. The fish assemblage of the Styx River was typical of lowland, spring-fed waterways.

Of Christchurch's main river catchments, the Styx River is second in terms of ecological quality after the Otukaikino River. Its high quality is directly related to the limited urban development in the catchment which means stormwater-derived contaminants such as fine sediment and heavy metals are not as prevalent as they are in the more heavily urbanised Christchurch rivers. Should Christchurch's more degraded urban waterways ever be improved such that they can again support the more pollution-sensitive EPT taxa, then the Styx River along with the Otukaikino River catchment will be a key source of colonists. As such it is even more important to protect the existing EPT community of these two catchments. There is indication that some of the more sensitive taxa (mayflies) are being lost from the Styx River catchment, and this will be exacerbated by ongoing development. The incorporation of low impact urban design (LIUD) in development and a catchment-wide strategy for stormwater treatment that improves stormwater quality and minimises the number of stormwater discharges to the river will be important components of future developments if we are to maintain populations of at least some of the more sensitive invertebrate taxa.

PHOTO
Retrieving a fyke net from the Styx River.

1. INTRODUCTION

The Christchurch City Council's (CCC) Surface Water Strategy 2009–2039 includes the vision 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." (CCC, 2010). In the recent CCC Three Year Plan (TYP), community outcomes include the protection of existing ecosystems and indigenous biodiversity, the enhancement of a range of indigenous habitats and species, and improvement of water quality in rivers, streams, lakes, and wetlands (CCC, 2013). The TYP states that these outcomes must be measurable and the CCC have a range of indicators against which to measure progress. As part of the CCC's stormwater service, one of their roles is to continue monitoring water quality and the health of habitats (CCC, 2013).

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 (CCC, 2010) and TYP (CCC, 2013) including, "improving the water quality of our surface water resources", "improving the ecosystem health of surface water resources", "protecting and restoring Ngai Tahu values associated with surface water resources", "existing ecosystems and indigenous biodiversity are protected", and "a range of indigenous habitats and species is enhanced". 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., earthquakes) or human-induced (e.g., chemical spills, dredging, land development).

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), the Halswell River in March 2011 (James, 2011a), and the Otukaikino River catchment again in March 2012 (James, 2012) as the start of the second five-yearly sampling cycle. The current survey undertaken in the Styx River catchment in February and April 2013 was the first year of an expanded survey that includes additional non-wadeable sites in the lower river, as well as fish sampling.

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 Styx River ranks second to the Otukaikino River as the least impacted by urban development and hence retains a number of more pollution-sensitive aquatic invertebrates in its upper reaches (McMurtrie & Greenwood, 2008). The invertebrate fauna of this river gives an indication of the taxa that could perhaps 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, while the fish fauna present will allow comparisons with more urbanised catchments.

1.1 AIM OF THIS REPORT

This report is designed to provide the first temporal comparison of habitat variables and the aquatic invertebrate community for the Styx River catchment between the first survey (March 2008) and the second survey (February 2013). It is not designed to provide any comparisons between other previously surveyed catchments. Further it presents the first catchment-wide survey of the fish community and includes three additional sites to the 2008 survey in the lower, non-wadeable mainstem of the Styx River.

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 (e.g., 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 in river systems.

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. For the 2013 sampling of the Styx River catchment sites in the lower, non-wadeable river were also added, which are typically deep, slow-flowing, soft-bottomed habitats.

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 sixth year of the monitoring programme, where the Styx 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), Halswell River (fourth year), and Otukaikino River (fifth year) catchments were surveyed (McMurtrie & Greenwood, 2008; McMurtrie, 2009; James, 2010; James 2011; James, 2012).

2.1 SITE SELECTION

In 2013 the nine wadeable sites originally sampled in 2008 were resurveyed. A further three non-wadeable sites in the lower river were selected by the CCC, however, one of these was moved after consultation with the CCC for access reasons (Table 1; Figure 1). Site numbering is continuous through all the catchments of the long-term monitoring programme hence the three new non-wadeable sites were numbered accordingly (i.e., 48–50).

TABLE 1 Locations of the Styx River monitoring sites. Refer to Figure 1 for further information on locations.

WATER-WAY		SITE NO.	LOCATION
Smacks Creek		17	Hussey Rd
Kaputone Creek		11	Between Blakes and Belfast Rds
		10	Ouruhia Reserve
Horners Drain		12	Hawkins Rd
Styx River	Upstream	18	Claridges Rd
		16	Upstream of Styx Mill Reserve
		15	Adjacent to Styx Mill Dog Area car park[1]
		14	Styx Mill Conservation Reserve
		13	Main North Rd
		50	Marshlands Rd[2]
		49	Richards Bridge
	Downstream	48	Kainga Rd

1 This site was not listed in CCC's Request for Proposal (RFP) but was sampled due to being a monitoring site in previous long-term aquatic invertebrate survey (McMurtrie & Greenwood, 2008).

2 Original RFP site was "Styx River at Dunlops Rd" but site was moved upstream to be just downstream of Marshlands Rd for access reasons and to match a CCC water quality monitoring site.

FIGURE 1
Location of the 12 sites in the Styx River catchment surveyed in 2013 for aquatic macroinvertebrates (Sites 10–18: 25–27 February; Sites 48–50: 12 April) and fish (Sites 10–18: 19–21 March; Sites 48–50: 11 April). Site photographs are provided in Appendix I (Section 8.1).

2.2 SAMPLING

2.2.1 Aquatic Invertebrates and Habitat

Following fine weather conditions, habitat and aquatic invertebrate communities were surveyed at the nine wadeable (Sites 10–18) between the 25–27 February and the three non-wadeable (Sites 48–50) on 12 April 2013. Sampling at the non-wadeable sites was delayed as a weed-harvester boat was operating and we did not want to risk one or more of the sites being surveyed too soon after the disturbance of such an activity. 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 each one. 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. At the three non-wadeable sites measures were taken from a kayak, although water velocity was not measured because the deep macrophyte beds and tidal influence at these sites meant reliable recordings could not be obtained. 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 for the site as a whole.

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 (ca. 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 (e.g., the streambed), and macrophytes (aquatic plants). At the three non-wadeable sites the invertebrate samples were taken from a kayak by pushing the kicknet through the thick macrophyte beds (Figure 2). 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.

Macrophyte and periphyton indicators from Table 1a of the Proposed Canterbury Land and Water Regional Plan (PLWRP) (Environment Canterbury, 2012) were estimated. This included the percentage of riverbed covered by emergent macrophytes, total macrophytes, and filamentous algae >20 mm in length). These indicators are likely to be used in the Styx River SMP.

FIGURE 2
Collecting aquatic invertebrate samples in non-wadeable and wadeable sections of the Styx River catchment.

2.2.2 Fish

Following fine weather conditions, fish communities were surveyed at the nine wadeable (Sites 10–18) between 19–21 March and the three non-wadeable (Sites 48–50) on 11 April 2013. Sampling at the non-wadeable sites was delayed as a weed-harvester boat was operating and we did not want to risk one or more of the sites being surveyed too soon after the disturbance of such an activity. At the nine wadeable sites two-pass electrofishing was undertaken over a 20 m long reach (Figure 3). As recommended by the New Zealand Freshwater Fish Sampling Protocols, stopnets to block the upstream and downstream ends of the reach were not used (Joy *et al*., 2013). At each of the three non-wadeable sites six fyke nets (15 mm stretched mesh size) and six Gee minnow traps (5 mm mesh size) were deployed for one night along a 40 m long reach (Figure 3). Traps were unbaited to ensure they did not attract fish from too far outside the site and inflate the abundance of fish captured. All fish captured were identified to species and their length recorded.

FIGURE 3
Surveying the fish community in the Styx River catchment – wadeable and non-wadeable methods.

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 Multidimensional 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 (very 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 2013 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%.

Fish communities from the nine wadeable sites were summarised by taxa richness, number caught per m^2 (standardised to 100 m^2 of wetted streambed area), and catch per unit effort (CPUE). CPUE refers to the number of fish captured per unit of effort expended. In the case of the current survey, effort is the time (minutes) spent electrofishing. The size distributions of shortfin and longfin eels were calculated to investigate any potential recruitment issues for this diadromous species (lifecycle involves a migration to and from the ocean). The three non-wadeable sites were analysed separately as the differing sampling methodologies (i.e., electrofishing vs netting/trapping) make direct comparison with the wadeable sites invalid. The non-wadeable fish community was summarised by taxa richness, and CPUE. In the case of the non-wadeable sites, the effort is the number of fyke nets and Gee minnow traps set. The size distrbution of the two most common non-wadeable species (shortfin eel and giant bully) were also calculated.

It was requested by the CCC that we make some comparison with previous fish community data collected as part of the development of the Styx River catchment SMP (Golder Associates Ltd, 2009). Of the nine wadeable sites surveyed, two had been sampled by Golder in 2009 (Sites 15 and 18). Their report did not include any detail on sampling effort (number of repeat runs, total fishing time) or area fished so the only wadeable site comparison that could be made was species richness. Even this comparison must made with caution as there may have been large differences in sampling effort. All three of the non-wadeable sites had been sampled by Golder in 2009 (Sites 48–50). As their report did detail the fishing effort in this instance (the number of nets/traps set) we were able to compare CPUE and species richness for these sites. Golder used fine mesh Gee minnow traps however did not state the mesh size of their fyke nets so there could be some sampling-based variation if their mesh size was different to the current survey.

3. RESULTS

3.1 HABITAT

The majority of the Styx River catchment is rural and park/reserve land use with minor residential and there were no notable changes at any site between 2008 and 2013 (Appendix II). The non-wadeable sites were mostly bounded by rural land. Banks were comprised mostly of natural earth apart from the boxed Horners Drain (Appendix I and II). Riparian vegetation composition changed little between 2008 and 2013 and was typically comprised of a grass/herb mix, various shrubs, rushes/tussocks, and mostly exotic trees (Figure 4). Site 17 (Smacks Creek) and Site 18 (Styx River mainstem) were the only sites to have a significant cover of native vegetation (Figure 5; Appendix I and II).

Substrate embeddedness was moderate to high at all sites, and most sites had a substratum dominated by gravel to pebble sized rocks. Over the whole wadeable catchment the substrate index was not significantly different between 2008 and 2013 with the only notable change being a decrease in substrate size at Site 18 (Figure 6A; ANOVA: $F_{1,52}$=0.27, p=0.6). The riverbed of the non-wadeable sites was much finer than the wadeable sites, being mostly silt (Figure 6A). Fine sediment depth for the combined wadeable sites was not significantly different between 2008 and 2013 (ANOVA: $F_{1,52}$=3.8, p=0.06), however, on a site basis there were some increases at Sites 10 and 18 (Figure 6B). Only Site 12 in Horners Drain had minimal fine sediment depth while the non-wadeable sites tended to have greater fine sediment depths than the wadeable sites (Figure 6B).

Overall, the mean channel width was unchanged between 2008 and 2013 at the wadeable sites (Figure 6C; Kruskal-Wallis: H=0.89, p=0.35). The non-wadeable sites were two to three times wider than the wadeable sites (Figure 6C). There was no significant difference between 2008 and 2013 in mean velocities for the combined wadeable sites, however at Sites 13, 15, and 16 mean velocities decreased by around half in 2013

Site 15 was typical of the wadeable mainstem with long grass, various herbaceous plants and sporadic trees (often willows).

Site 49 was typical of the non-wadeable sites with long grass and sporadic exotic trees.

FIGURE 4
Representative riparian vegetation of the Styx River catchment. Site 15 (top) was typical of the wadeable mainstem with long grass, various herbaceous plants and sporadic trees (often willows). Site 49 (bottom) was typical of the non-wadeable sites with long grass and sporadic exotic trees.

FIGURE 5
Site 17 (Smacks Creek) and Site 18 (Styx River) were the only sites to have significant cover of native vegetation.

(Figure 6D; ANOVA: $F_{1,52}$=3.59, *p*=0.06). Site 13 (2008: 100% run; 2013: 100% riffle) and Site 15 (2008: 80% riffle, 20% run; 2013: 20% riffle, 80% run) have also undergone shifts in the dominant habitat type (Appendix II). The mean depth of the wadeable sites was significantly greater overall in 2013 than in 2008 (Figure 6E; ANOVA: $F_{1,52}$=4.86, *p*=0.03). This was most evident in the Styx River mainstem sites (Sites 13–16, and 18; Figure 6E). Not surprisingly the non-wadeable sites were deeper than the wadeable sites (Figure 6E).

Macrophytes were prominent at the non-wadeable sites and macrophyte depths were greater than the wadeable sites (Figure 6F). In 2013, total macrophyte cover ranged from 5 to 95% with five of the 12 sites being greater than the 50% maximum cover indicator of the PLWRP, however three of those were the non-wadeable sites, where macrophyte cover would be expected to be higher (Table 2). Only Site 10 was above the PLWRPs 30% maximum emergent macrophyte cover indicator and only Site 11 was above the 30% maximum filamentous algae cover indicator (Table 2). The relative cover of the riverbed by various macrophyte genera did vary between 2008 and 2013 (Appendix II). Macrophyte depths at wadeable sites were also greater in 2013 than in 2008, especially at Sites 10, 13, 14, 16, and 18) (Figure 6F; Kruskal-Wallis: H=11.8, p<0.01). Notable native macrophytes found in 2013 were *Potamogeton cheesemanii* at Site 17 and *P. ochreatus* at Sites 12 and 48 (Figure 7). *P. ochreatus* was particularly prominent at Site 48 (the downstream-most non-wadeable site) where it accounted for 70% of the instream vegetative cover (Appendix II).

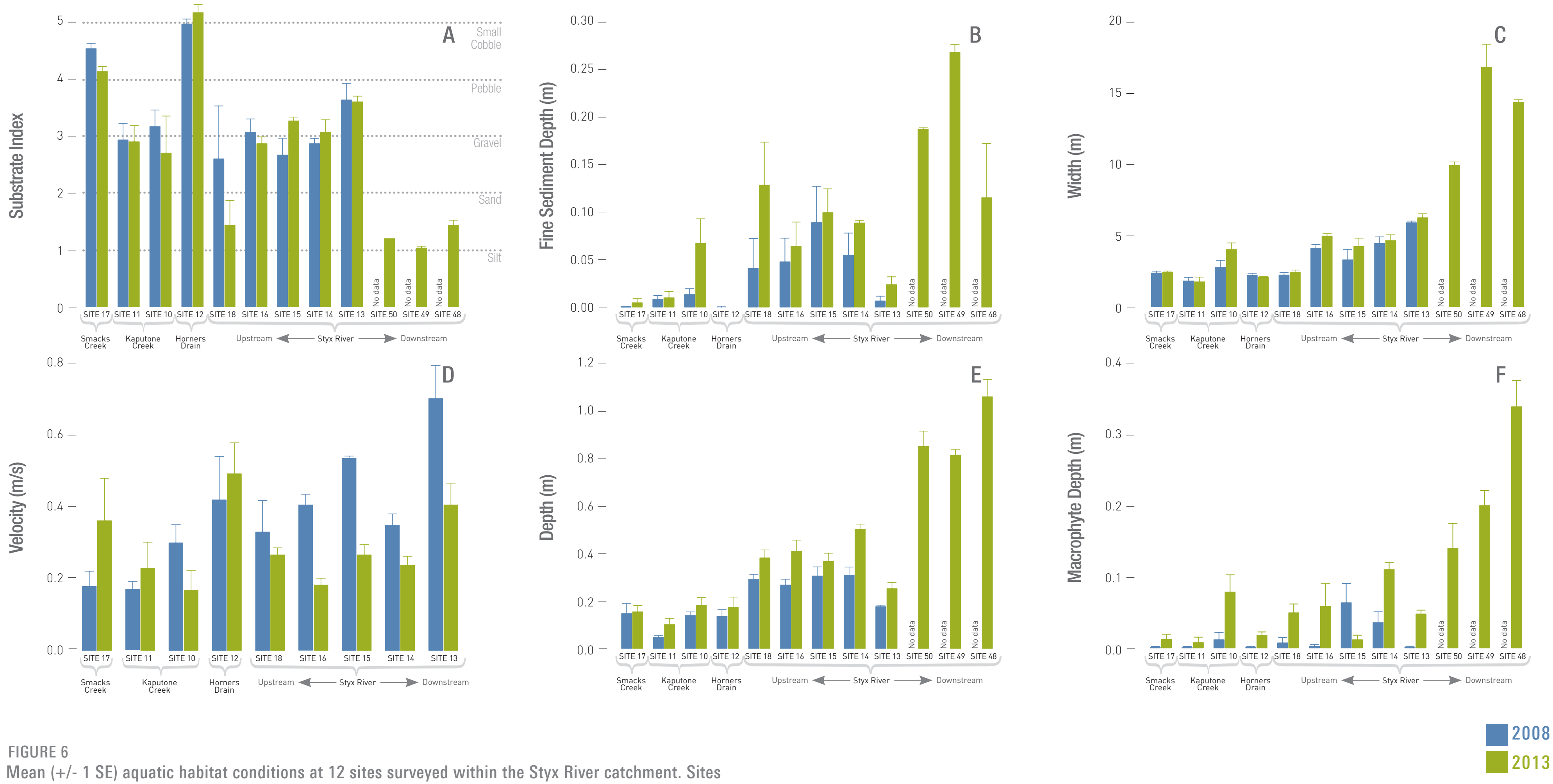


FIGURE 6
Mean (+/- 1 SE) aquatic habitat conditions at 12 sites surveyed within the Styx River catchment. Sites 10–18 were surveyed in March 2008 and February 2013. Sites 48–50 were in the lower non-wadeable part of the Styx River and were only surveyed in April 2013. Water velocity was not measured at Sites 48–50 in 2013 thus they are not shown on the velocity graph.

Potamogeton cheesemanii

Potamogeton orchreatus

FIGURE 7
Notable native (*Potamogeton* species) aquatic plants found in the Styx River catchment during the 2013 survey.

TABLE 2
Comparison of riverbed percentage cover of emergent macrophytes, total macrophytes, and filamentous algae >20 mm with the limits of the Proposed Land and Water Regional Plan (PLWRP). Estimates from sites 10–18 were made 25–27 February 2013 and from sites 48–50 on 12 April 2013. Exceedance of these limits are orange.

WATERWAY	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%
Smacks Creek	17	1%	9%	0%
Kaputone Creek	11	2%	7%	70%
	10	64%	88%	5%
Horners Drain	12	1%	66%	0%
Styx River WADEABLE	18	1%	27%	0%
	16	4%	5%	0%
	15	17%	19%	0%
	14	8%	39%	0%
	13	11%	25%	0%
Styx River NON-WADEABLE	50	3%	63%	0%
	49	5%	95%	5%
	48	4%	85%	0%

3.2 INVERTEBRATES

3.2.1 Overview

A total of 60 invertebrate taxa were recorded from the Styx River catchment in 2013 (52 taxa were recorded in 2008). The most diverse groups were the two-winged flies (Diptera: 16 taxa) and caddisflies (Trichoptera: 16 taxa), followed by molluscs (Mollusca: 6 taxa), crustaceans (Crustacea: 6 taxa), damselflies and dragonflies (Odonata: 3 taxa), and flatworms (Platyhelminthes: 2 taxa). Mites (Arachnida: Acari), hydra (Cnidaria: Hydrozoa: Hydridae), beetles (Coleoptera), springtails (Hexapoda: Collembola), leeches (Hirudinea), moths (Lepidoptera), mayflies (Ephemeroptera), nematodes (Nematoda), worms (Oligochaeta), water bugs (Hemiptera), and horsehair worms (Nematomorpha) were each represented by one taxon.

The snail *Potamopyrgus antipodarum* was the dominant species, accounting for nearly 60% of invertebrates captured in 2013 (Figure 8). The amphipod crustacean *Paracalliope fluviatilis*, oligochaete worms, and ostracod micro-crustaceans round out those taxa that accounted for greater than 5% of relative abundance (Figure 8). The four above-mentioned taxa accounted for 78% of all invertebrates captured in 2013. These taxa were also widespread as they were found at all 12 survey sites with the exception of oligochaete worms which were found at 11 sites. Of the EPT taxa that are considered cleanwater taxa, three caddisfly taxa (*Pycnocentrodes*, *Pycnocentria*, and *Hudsonema amabile*) were common enough to account for greater than 1% of relative abundance. Of these, *H. amabile* was relatively widespread being present at ten sites (Figure 8). A notable find was a juvenile (8 mm long) freshwater mussel (*Echyridella menziesii*) at the non-wadeable Site 49 (Figure 9). This species with a threat classification of "gradual decline" (Hitchmough *et al.*, 2007) is occasionally found during weed clearance in the lower Styx River but to date there has been no detailed survey of their distribution and abundance. Another notable find was a horsehair worm (Nematomorpha) at the non-wadeable Site 50. Horsehair worms are uncommonly found and have larvae that are parasitic on a number of insect and crustacean species.

In terms of relative abundance, various combinations of molluscs, crustaceans, and EPT taxa (mayflies and caddisflies) dominated at all sites in 2008 and 2013 (Figure 10). Diptera were particularly common at Sites 10 and 12 while Oligochaeta were in high relative abundance at Site 16 in 2013 (Figure 10). At Sites 14, 17, and 18 the relative abundance of higher taxonomic groupings were similar between years while at other sites there were some shifts in relative dominance. For example, Diptera decreased while crustaceans increased between 2008 and 2013 at Site 10 and Crustacea decreased and EPT increased between years at Site 13 (Figure 10). Site 16 saw a sizeable decline in the relative abundance of EPT taxa from 2008 to 2013. The non-wadeable sites had broadly similar assemblages dominated by molluscs and crustaceans (Figure 10).

In both 2008 and 2013 a total of 17 EPT taxa were found in the Styx River catchment (Table 3). The same EPT assemblage was present in both years with the only minor difference being the cased caddisflies *Triplectides cephalotes* and *Hudsonema alienum* not being found in 2008 and 2013 respectively (Table 3). A number of taxa with high MCI scores (which indicate greater sensitivity to pollution) were found; the caddisflies *Oeconesus*, *Olinga*, *Polyplectropus*, and *Psilochorema*, and the mayfly *Deleatidium* (Table 3). Taxa were generally found at similar sites between years. The most pollution sensitive taxa present, *Deleatidium*, was only found at four sites in 2013 compared to six sites in 2008, however it was very uncommon in 2008 at the two sites from which it had disappeared in 2013 (Site 11: one individual; Site 18: nine individuals). Sixteen EPT taxa were found in the wadeable section of the catchment. In contrast, only seven EPT taxa were found in the non-wadeable section of the river; the caddisflies *Hudsonema amabile*, *Hydrobiosis parumbripennis*, *Oecetis*, *Oxyethira albiceps*, *Paroxyethira hendersoni*, *Triplectides cephalotes*, and *Triplectides obsoletus* (Table 3).

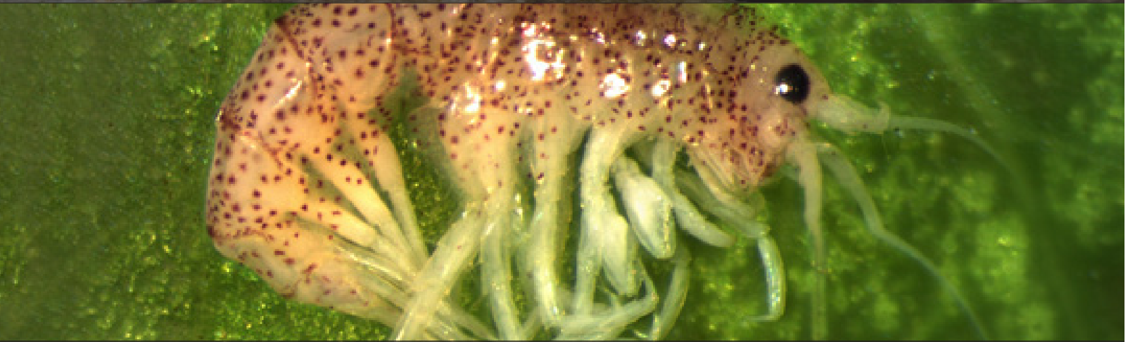
FIGURE 8

Photographs of the most abundant (% indicated) aquatic invertebrates in the Styx River catchment from 12 sites surveyed in 2013. Also shown are the EPT taxa that had relative abundances of 1% or greater.

Unless indicated, photos are © of EOS Ecology.

COMMON POLLUTION-TOLERANT TAXA (>5% RELATIVE ABUNDANCE IN 2013)

Potamopyrgus antipodarum (58.3%, all sites)



Paracalliope fluviatilis (8%, all sites)

Oligochaeta (6.2%, 11 sites)

Ostracoda (5.3%, all sites)

CLEANWATER (EPT) TAXA (>1% RELATIVE ABUNDANCE IN 2013)

Pycnocentrodes (3.5%, four sites)

Pycnocentria (2.3%, five sites)

Hudsonema amabile (1.3%, 10 sites)

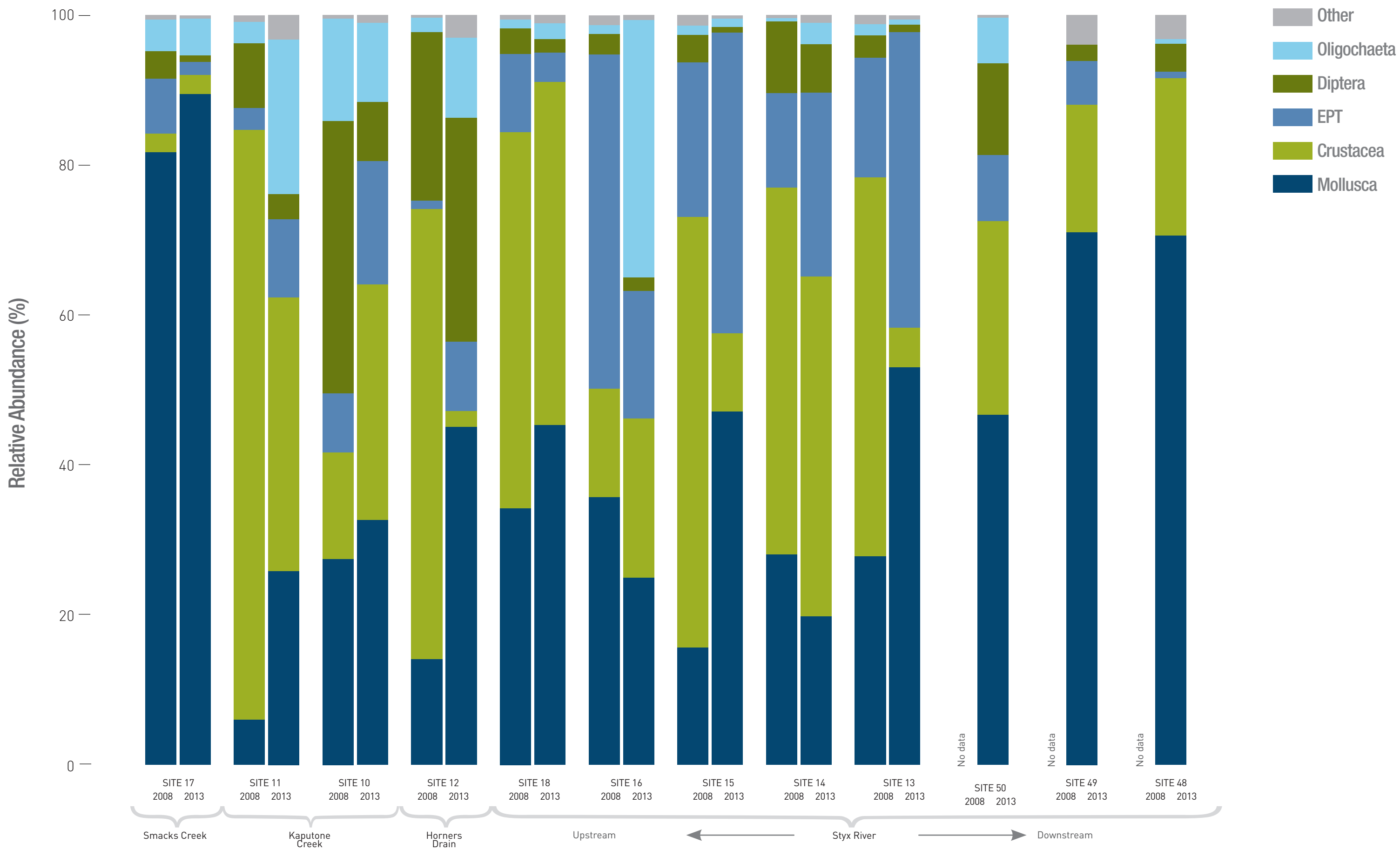
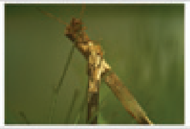
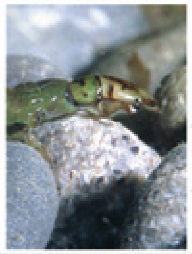
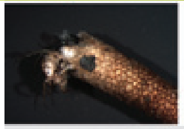
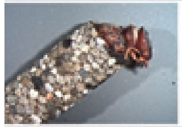
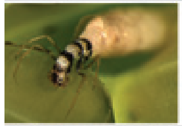
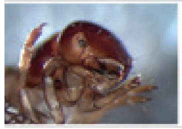


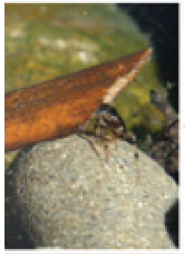
FIGURE 9
Freshwater mussel/ kakāhi (*Echyridella menziesii*) is found in the Styx River catchment.

FIGURE 10
Relative abundances of higher taxonomic groupings in the Styx River catchment. Sites 10–18 were surveyed in March 2008 and February 2013. Sites 48–50 were in the lower non-wadeable part of the Styx River and surveyed in April 2013.

TABLE 3
The presence of EPT taxa in the Styx River catchment from surveys undertaken at twelve sites. Sites 10–18 were surveyed in March 2008 and February 2013. Sites 48–50 were in the lower non-wadeable part of the Styx River and were only surveyed in April 2013. 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). Unless indicated, photos are © of EOS Ecology.

		EPT TAXA	MCI VALUE	2008	2013
Mayflies (Ephemeroptera)		*Deleatidium*	8	(Sites 11, 13–16, & 18)	(Sites 13–16)
Caddisflies (Trichoptera)		*Aoteapsyche*	4	(Sites 13–16)	(Sites 13–16)
		*Hudsonema amabile*	6	(Sites 10–18)	(Sites 10–18, & 50)
		*Hudsonema alienum*	6	(Sites 13–16, & 18)	
		*Hydrobiosis* (probably *H. umbripennis & parumbripennis*)	5	(Sites 13, & 16–17)	All identified to species in 2013
		Hydrobiosis parumbripennis	5	(Sites 12–17)	(Sites 10–18, & 50)
		Hydrobiosis umbripennis	5	(Site 15)	(Sites 10,13, & 14)
		*Neurochorema*	6	(Sites 13, 14, & 16)	(Sites 10, & 13–16)

		EPT TAXA	MCI VALUE	2008	2013
Caddisflies (Trichoptera) ...continued		*Oecetis*	6	(Sites 10–12, 16 & 17)	(Sites 10–12, & 48–50)
		*Oeconesus*	9	(Sites 15, 16, & 18)	(Sites 13–15, & 17)
		*Olinga*	9	(Site 18)	(Site 18)
		*Oxyethira albiceps*	2	(Sites 10, 12–18)	(Sites 10–15, 17, 18, 48–50)
		*Paroxyethira hendersoni*	2	(Site 12)	(Site 48)
		*Polyplectropus*	8	(Sites 10, 14–16, & 18)	(Sites 10, 14–16, & 18)
		*Psilochorema*	8	(Sites 11, & 13–18)	(Sites 10, 11, 13–16, & 18)
		*Pycnocentria*	7	(Sites 10, 11, & 13–16, & 18)	(Sites 13–16, & 18)

		EPT TAXA	MCI VALUE	2008	2013
Caddisflies (Trichoptera) ...continued		*Pycnocentrodes*	5	(Sites 13–16, & 18)	(Sites 13–16)
		*Triplectides cephalotes*	5		(Sites 10, 48, & 49)
		Triplectides obsoletus	5	(Sites 10–18)	(Sites 10–12, 14–17, 48, & 50)
		Total EPT taxa		**17**	**17**

When compared to historic information collected by the Christchurch Drainage Board (CDB), it is evident that some sites have seen some sensitive species disappear over the last 25 years. For example, Site 17 on Smacks Creek has seen several pollution-sensitive mayfly and caddisfly taxa disappear such that only one such species, the caddisfly *Psilochorema*, still persists there (Table 4). In contrast, the two Kaputone Creek sites (Sites 10 and 11) appear to have gained sensitive taxa but it must be noted these were only present in very low numbers (i.e., < five individuals) and may well have been present earlier but missed by the potentially less robust sampling or laboratory processing techniques of the CDB surveys. Horners Drain has never had any of the more sensitive EPT taxa reported over the four surveys (Table 4). The wadeable mainstem Styx River sites (Site 13–16 and 18) have a sensitive EPT core assemblage that has persisted to the current survey (Table 4). However, it is notable that the particularly pollution-sensitive mayfly *Coloburiscus humeralis* (MCI=9) has not been found since 1987–88, and the cased caddisfly Olinga feredayi is now restricted to a single site (Site 18) after formerly being present at four wadeable mainstem sites (Table 4). The mayfly *Deleatidium* has also disappeared from Sites 11 and 18 between the 2008 and 2013 surveys, however it was already rare at those sites in 2008. At the non-wadeable sites, apart from a few sensitive EPT taxa being found in the CDB surveys at the upstream most site (Site 50), such taxa are absent as they generally prefer shallower sections with hard stony bottoms.

TABLE 4

Pollution sensitive EPT taxa with MCI scores ≥7 found at each site during sampling in 1978–79, 1987–89, 2008, and 2013. MCI score is shown in brackets at first listing of each taxon.

blue = free-living caddis *green = cased caddis* *red = mayfly*

WATER-WAY	SITE	1978–79 (CDB, 1980)	1987–88 (CDB, 1989)	2008 (McMurtrie & Greenwood, 2008)	2013 (current EOS Ecology survey)
Smacks Creek	17	*Coloburiscus humeralis (9)* *Deleatidium (8)* *Olinga feredayi (9)* *Polyplectropus (8)* *Psilochorema (8)* *Pycnocentria (7)* *Zephlebia (7)*	*Deleatidium* *Psilochorema* *Pycnocentria* *Pycnocentrodes* *Zephlebia*	*Psilochorema*	*Psilochorema*
Kaputone Creek	11	No EPT taxa with MCI ≥ 7	*Oeconesus (9)* *Pycnocentria*	*Deleatidium* *Psilochorema* *Pycnocentria*	*Psilochorema*
	10	No EPT taxa with MCI ≥ 7	No EPT taxa with MCI ≥ 7	*Polyplectropus* *Pycnocentria*	*Polyplectropus* *Psilochorema*
Horners Drain	12	No EPT taxa with MCI ≥ 7	No data	No EPT taxa with MCI ≥ 7	No EPT taxa with MCI ≥ 7
Styx River Upstream → Downstream	18	*Deleatidium* *O. feredayi* *Polyplectropus* *Zephlebia*	*O. feredayi* *Polyplectropus* *Pycnocentria*	*Deleatidium* *Oeconesus* *O. feredayi* *Polyplectropus* *Psilochorema* *Pycnocentria*	*O. feredayi* *Polyplectropus* *Psilochorema* *Pycnocentria*
	16	*C. humeralis* *Deleatidium* *Oeconesus* *O. feredayi* *Polyplectropus* *Pycnocentria*	*C. humeralis* *Deleatidium* *Oeconesus* *O. feredayi* *Pycnocentria*	*Deleatidium* *Oeconesus* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Deleatidium* *Polyplectropus* *Psilochorema* *Pycnocentria*
	15	*Deleatidium* *O. feredayi* *Pycnocentria*	*C. humeralis* *Deleatidium* *Oeconesus* *O. feredayi* *Pycnocentria*	*Deleatidium* *Oeconesus* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Deleatidium* *Oeconesus* *Polyplectropus* *Psilochorema* *Pycnocentria*
	14	*Deleatidium*	*Deleatidium* *Oeconesus* *O. feredayi* *Pycnocentria*	*Deleatidium* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Deleatidium* *Oeconesus* *Polyplectropus* *Psilochorema* *Pycnocentria*
	13	*Deleatidium* *Polyplectropus* *Psilochorema* *Pycnocentria*	*Deleatidium*	*Deleatidium* *Psilochorema* *Pycnocentria*	*Deleatidium* *Oeconesus* *Psilochorema* *Pycnocentria*
	50	*Deleatidium* *Polyplectropus*	*C. humeralis*	*Deleatidium* *Psilochorema* *Pycnocentria*	No EPT taxa with MCI ≥ 7
	49	No EPT taxa with MCI ≥ 7	No EPT taxa with MCI ≥ 7	No data	No EPT taxa with MCI ≥ 7
	48	No EPT taxa with MCI ≥ 7	No EPT taxa with MCI ≥ 7	No data	No EPT taxa with MCI ≥ 7

3.2.2 Ordination

The NMS ordination showed that Sites 10, 11, 16, 18 and 48–50 were similar and clustered around the centre of the plot while Site 12–15, and 17 were spread wider apart and thus more dissimilar (Figure 11). The non-wadeable sites clustered in the middle of the graph while wadeable sites showed a wider variation in composition indicated by a greater spread across the plot (Figure 11). The invertebrate assemblage of the non-wadeable sites are largely composed of a subset of species found throughout the catchment. The most prominent temporal feature of the NMS ordination is the shift in community composition at Sites 11, 12, 13, and 15 from right to left along Axis 1 (Figure 11). The snail *Potamopyrgus antipodarum* became a more prominent component of the invertebrate community at these sites in 2013 while the amphipod crustacean *Paracalliope fluviatilis* became less so (Figure 11). Along Axis 2 there was some separation in sites based on the abundance of several of EPT taxa. Sites 13 and 15 in 2013 and Site 16 in 2008 were associated with greater abundance of the caddisflies *Aoteapsyche*, *Oeconesus*, *Pycnocentria*, and *Pycnocentrodes*, and the mayfly *Deleatidium* (Figure 11). Sites 14, 18, and especially 17 showed the least change between 2008 and 2013.

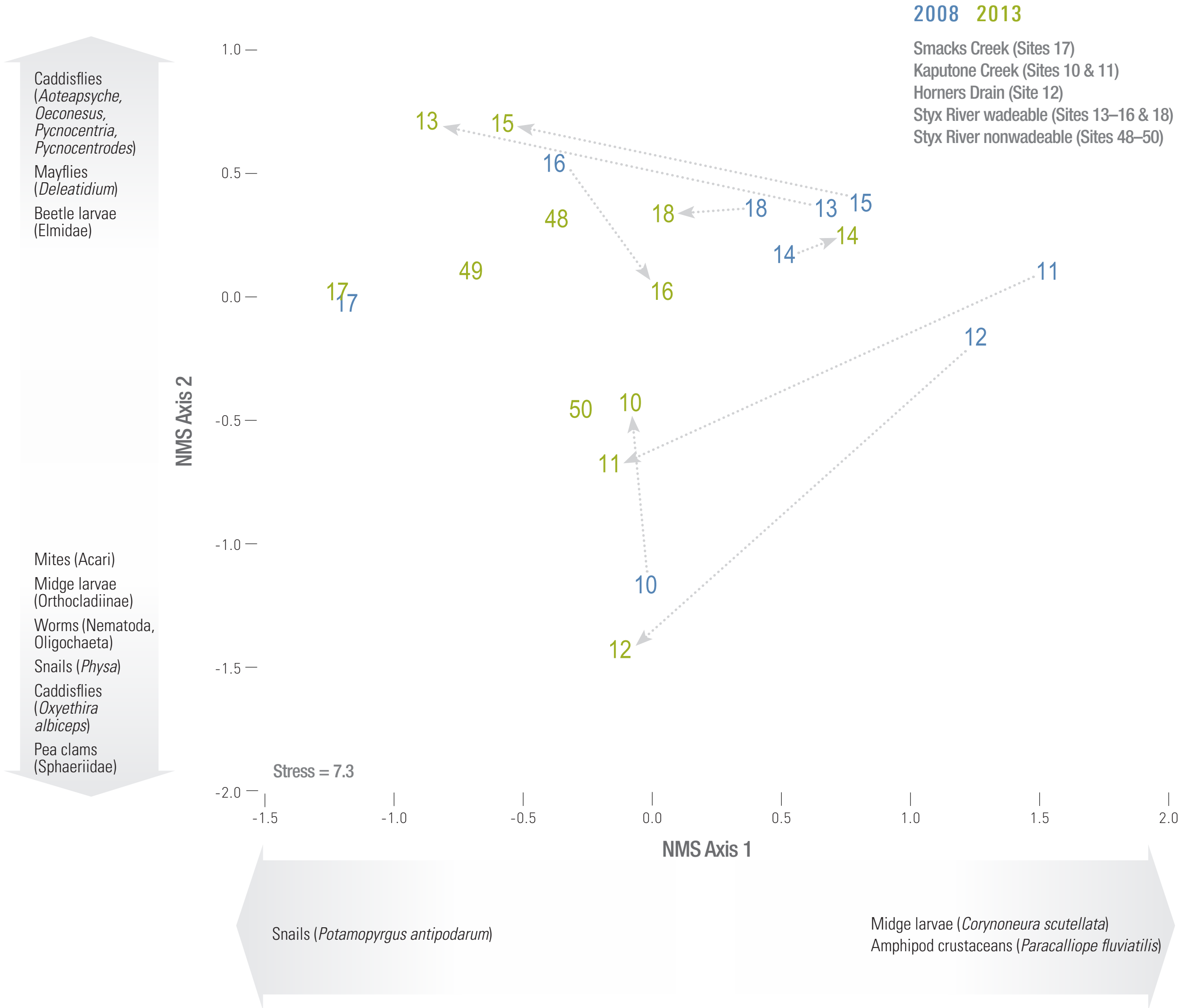


FIGURE 11

Non-metric multidimensional scaling (NMS) ordination of the aquatic invertebrate community from twelve sites surveyed in the Styx River catchment. Sites 10–18 were surveyed in March 2008 and February 2013. Sites 48–50 were in the lower non-wadeable part of the Styx River and were only surveyed in April 2013. Each point represents the mean relative abundance of three replicate samples. Invertebrate taxa correlated with the axes are shown. A relatively low NMS stress value of 7.3 means the ordination provides a good representation of the data.

3.2.3 Biotic Indices

Taxa richness averaged between 14 and 25 per site and the three non-wadeable sites (Sites 48–50) had taxa richness averages within the range of the wadeable sites (Figure 12A). MCI-hb scores indicated Sites 10–12 (Kaputone Creek and Horners Drain) were of poor water quality and Sites 13–18 were of fair water quality in 2013. QMCI-hb showed a similar result with Sites 13–15 and 18 being of fair water quality, in 2013, and Sites 10–12, 16 and 17 being of poor water quality (Site 16 was just below the fair threshold) (Figure 12B). QMCI-sb is also shown as one wadeable site (Site 18) and the three non-wadeable sites (Site 48–50) were soft bottomed and therefore QMCI-hb is not suitable for assessing water quality ratings (Figure 12C). All four of these sites would be interpreted as having poor water quality, however, it must be noted that such interpretation for non-wadeable sites must be treated with caution as MCI score based metrics were designed for use in wadeable habitats, and are largely untested in non-wadeable environments.

Average EPT taxa richness ranged between two and 10 per site, with the non-wadeable Sites 48–50 and wadeable Sites 12 and 18 having fewer EPT taxa than the other sites (Figure 12D). Sites 13–16 consistently had %EPT than the other sites (Figure 12E). Among the non-wadeable sites %EPT declined in a downstream direction (Figure 12E). In 2013 QUCI was notably higher at Sites 13–15 (Figure 12F).

There was no overall difference between years for the combined nine wadeable sites for taxa richness (Figure 12A: ANOVA: $F_{1,52}$=1.14, p=0.29), MCI-hb (ANOVA: $F_{1,52}$=0.21, p=0.65), QMCI-hb (Kruskal-Wallis: H=2.56, p=0.11), EPT taxa richness (Kruskal-Wallis: H=0.23, p=0.63), or %EPT (Kruskal-Wallis: H=0.17, p=0.68). For MCI-hb only Site 17 (Smacks Creek) changed interpretation categories, being rated poor in 2008 and just above the fair water quality threshold in 2013. Two sites (Sites 11 and 16) dropped from fair to poor water quality based on QMCI-hb (Figure 12B). For EPT taxa richness, Sites 13–16 consistently had higher values in both years, while Site 18 showed the greatest change between years with a notable decline in 2013 (Figure 12D). As with EPT taxa richness, Sites 13–16 consistently had higher %EPT (Figure 12E). Sizeable changes in %EPT were seen at Site 16 (large decline between 2008 and 2013) and Site 13 (large increase between years)(Figure 12E). Combining all wadeable sites QUCI was significantly higher in 2008 compared to 2013 (ANOVA: $F_{1,52}$=6.85, p=0.01). In 2013 QUCI was notably higher at Sites 13–15 and similar to the scores from 2008, while there were declines at the other wadeable sites (Figure 12F).

The overall best wadeable site in terms of ranking of the seven biotic indices in 2013 was Site 15 (Styx River) (Table 5; Figure 13). This site ranked first or second for six of the seven metrics calculated (Table 5). This site was also highly ranked (second of nine sites) in 2008. The next three highest ranked sites were also on the Styx River mainstem (Table 5; Figure 13). These top four sites were all relatively close to one another and were the same as the top four sites in 2008, albeit in a different order (Table 5; Figure 13). Note however, that Site 16 has dropped three places from first in 2008 to fourth in 2013 (Table 5).

The worst sites in 2013 were both tributaries (Kaputone Creek: Site 11 and Horners Drain: Site 12). Site 11 was the lowest ranked site in 2008, while Site 12 was 7th, therefore the relative condition of these sites have not changed much over time (Table 5). The only sites to have changed their ranking postions by more than two places was Site 10 (Kaputone Creek) which had risen from 8th in 2008 to 5th in 2013 and Site 16 (Styx River) which had dropped from 1st in 2008 to 4th in 2013 (Table 5; Figure 14). Site 10 had not undergone any obvious changes over time although the marginal vegetation was more intact and lush and taxa richness, QMCI-hb, and EPT taxa richness were higher in 2013 compared to 2008. Notable habitat changes at Site 16 that may have resulted in taxa richness, QMCI-hb, EPT taxa richness, and % EPT individuals being lower in 2008 relative to 2013 were decreased velocity, and increased water and macrophyte depths (Appendix II; Figure 12; Figure 14). However, other mainstem Styx River sites (Sites 13–15) also showed similar habitat changes yet did not display such consistent decreases in invertebrate metrics between years.

It is notable that of the wadeable Styx River mainstem sites, the two upstream-most sites (Sites 16 and 18) have shown declines across most of the indices used to calculate rankings including some big drops in EPT taxa richness and %EPT (Figure 12). In contrast the other wadeable mainstem sites further downstream (Sites 13–15) have shown either an increase, decrease, or no change in the various metrics between 2008 and 2013. This indicates that some activity in the upper catchment may be affecting habitat/water quality at these sites.

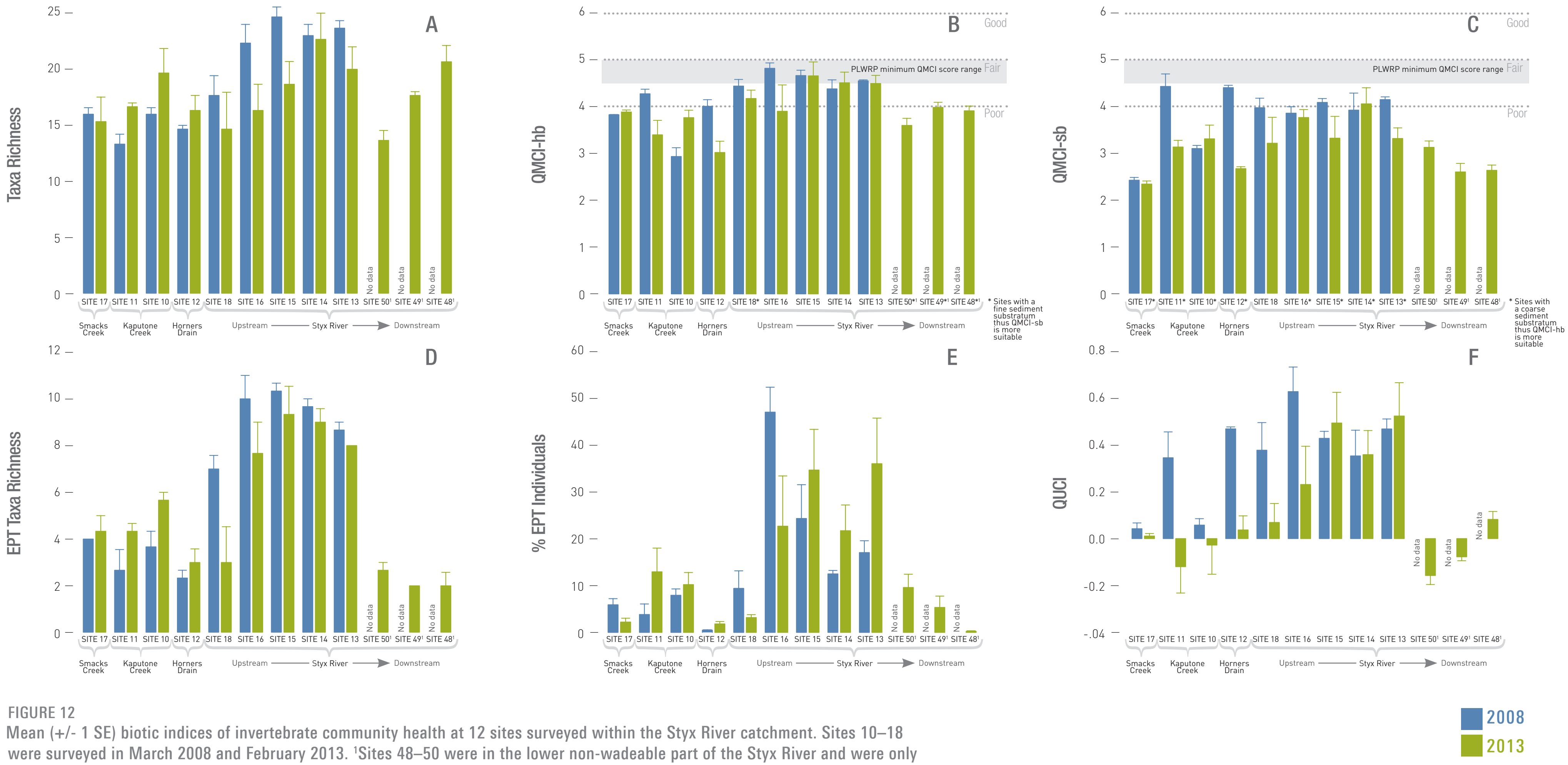


FIGURE 12
Mean (+/- 1 SE) biotic indices of invertebrate community health at 12 sites surveyed within the Styx River catchment. Sites 10–18 were surveyed in March 2008 and February 2013. [1]Sites 48–50 were in the lower non-wadeable part of the Styx River and were only surveyed in April 2013. The dotted lines on the QMCI graphs indicate the probable level of organic pollution (Stark & Maxted, 2007) and the shaded box the minimum QMCI score range of the PLWRP for "spring-fed – plains" designated waterways. Note that QMCI and QUCI were designed for use in wadeable streams thus interpretation for non-wadeable sites must be done with caution.

SITE 15: 2013=1st from 2008 = 2nd

SITE 13: 2013=2nd from 2008 = 3rd

SITE 14: 2013=3rd from 2008 = 4th

TABLE 5

An overall site ranking (1 (best)–9 (worst)) of each of the nine wadeable sites (Sites 10–18) surveyed in the Styx River catchment in February 2013; 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. The three non-wadeable sites (Sites 48–50) have been omitted from the ranking exercise as four of the metrics were designed for use in wadeable habitats only (i.e., MCI-hb, QMCI-hb, UCI, and QUCI). For site locations see Figure 13.

WATERWAY	SITE	BIOTIC INDICES							SUM	FINAL RANK	GROUPING	2008 FINAL RANK
		TAXA	EPT	% EPT	MCI-hb	QMCI-hb	UCI	QUCI				
Styx River	15	4	1	2	1	1	1	2	12	1	Best	2
Styx River	13	2	3	1	3	3	3	1	16	2	Best	3
Styx River	14	1	2	4	4	2	4	3	20	3	Best	4
Styx River	16	6	4	3	2	5	2	4	26	4	Best	1
Kaputone Creek	10	3	5	6	7	7	5	8	41	5	Medium	8
Smacks Creek	17	8	6	8	5	6	6	7	46	6	Medium	6
Styx River	18	9	8	7	6	4	8	5	47	7	Medium	5
Kaputone Creek	11	5	6	5	8	8	9	9	50	8	Worst	9
Horners Drain	12	6	8	9	9	9	7	6	54	9	Worst	7

SITE 16: 2013=4th from 2008 = 1st

SITE 11: 2013=8th from 2008 = 9th

SITE 12: 2013=9th from 2008 = 7th

FIGURE 13
Rankings and location of the nine wadeable sites based on based on the combined ranks of seven invertebrate community metrics.

FIGURE 14
Site 10 (Kaputone Creek at Ouruhia Reserve, looking downstream from top site) and Site 16 (Styx River upstream of Styx Mill Reserve, looking downstream from top site) were the only sites to have a change of rankings by greater than two places between 2008 and 2013.

3.3 FISH (INCLUDING FRESHWATER CRAYFISH/KŌURA)

3.3.1 Wadeable

A total of eight fish species and one freshwater crayfish/kōura species were found across the nine wadeable sites in the Styx River catchment (Table 6; Figure 15). Shortfin eel and upland bully were the most widespread being found at all nine sites followed by longfin eel at eight sites (Table 6). Four of the species found are in decline (longfin eel, inanga, lamprey, and freshwater crayfish/kōura) and two introduced trout species were present (Table 6). Some species that were only caught at one or a few sites are likely more widespread. Brown trout and inanga are highly mobile and probably present throughout most of the catchment while lamprey can be cryptic and often missed by conventional electrofishing sampling as their distribution is patchy and they prefer habitats not always targeted by electrofishing.

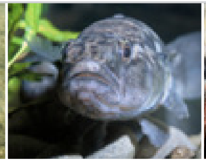
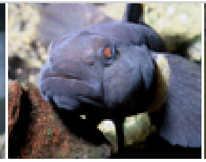
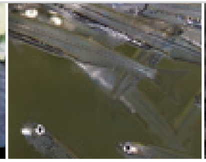
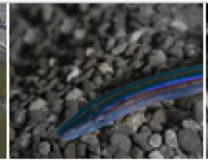
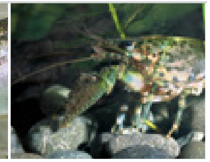
Fish species richness (including freshwater crayfish/kōura) ranged between four and six species with Site 14 having the greatest diversity (Figure 15). Tributary sites tended to have fewer species than mainstem Styx River sites (Figure 15). Comparison of species richness at Sites 15 and 18 with 2009 data collected by Golder Associates Ltd (2009) indicated that the current EOS Ecology survey found two and three additional species at these sites, respectively (Figure 15).

Shortfin eel were the most abundant species overall and when corrected for the area fished, were particularly abundant at Sites 10–13 and 15 (Figure 16). Similarly, shortfin eel had the greatest CPUE at most sites with this being particularly high at Sites 10 and 13 (Figure 16). Site 13 had the greatest numbers (per 100 m^2) of shortfin eel closely followed by Site 12 (Horners Drain), which also had the greatest numbers of longfin eel and upland bully of all surveyed wadeable sites (Figure 16). The Kaputone Creek and Horners Drain tributaries tended to have more fish overall compared to mainstem sites, with the exception of Site 13 (Styx River), when data was standardised to 100 m^2 of fished area (Figure 16). Sites 16 and 18 had particularly low fish abundance and CPUEs. Freshwater crayfish/kōura were only found at three mainstem sites (Sites 14, 15, and 18) (Figure 16).

Few large eels were captured in the wadeable part of the catchment with the majority of shortfin eel being 150–250 mm and longfin eel being 300–400 mm in length (Figure 17). Likewise, few young of the year eels (<100 mm long) of either species were caught (Figure 17).

TABLE 6

The total number caught and size range (length in mm) of each fish species (including freshwater crayfish/kōura) from electrofishing undertaken at nine wadeable sites in the Styx River catchment 19–21 March 2013. The latest conservation status of fish (Allibone *et al.*, 2010) and freshwater crayfish/kōura (Hitchmough *et al.*, 2007) are shown.

		SHORTFIN EEL	LONGFIN EEL	COMMON BULLY	UPLAND BULLY	INANGA	LAMPREY (AMMOCETE)	BROWN TROUT	RAINBOW TROUT	FRESHWATER CRAYFISH/KŌURA*
Conservation Status		Not threatened	Declining	Not threatened	Not threatened	Declining	Declining	Introduced & naturalised	Introduced & naturalised	Gradual decline
WATER-WAY	SITE									
Smacks Creek	17	7 (167–324)	9 (273–640)		1 (57)			2 (63–220)		
Kaputone Creek	11	16 (196–610)	4 (101–544)	9 (21–40)	4 (33–61)					
	10	30 (121–445)	2 (92–413)	19 (36–109)	3 (41–64)	2 (85–91)				
Horners Drain	12	24 (122–261)	20 (139–472)	1 (38)	13 (38–72)					
Styx River (Upstream)	18	5 (171–356)	1 (302)		1 (36)					2 (18–19)
	16	7 (160–271)	6 (238–597)		1 (56)			1 (110)	1 (259)	
	15	25 (111–383)			1 (63)		4 (75–83)	5 (75–295)		5 (8–27)
	14	17 (134–374)	4 (545–730)	1 (66)	7 (37–70)			1 (215)		10 (19–33)
(Downstream)	13	75 (88–392)	7 (137–500)	1 (60)	8 (38–71)			3 (83–314)		
	Total	**206**	**53**	**31**	**39**	**2**	**4**	**12**	**1**	**17**

* Freshwater crayfish/kōura size was determined by measuring the occipital carapace length (OCL), which is the distance between the eyes and the rear of the carapace.

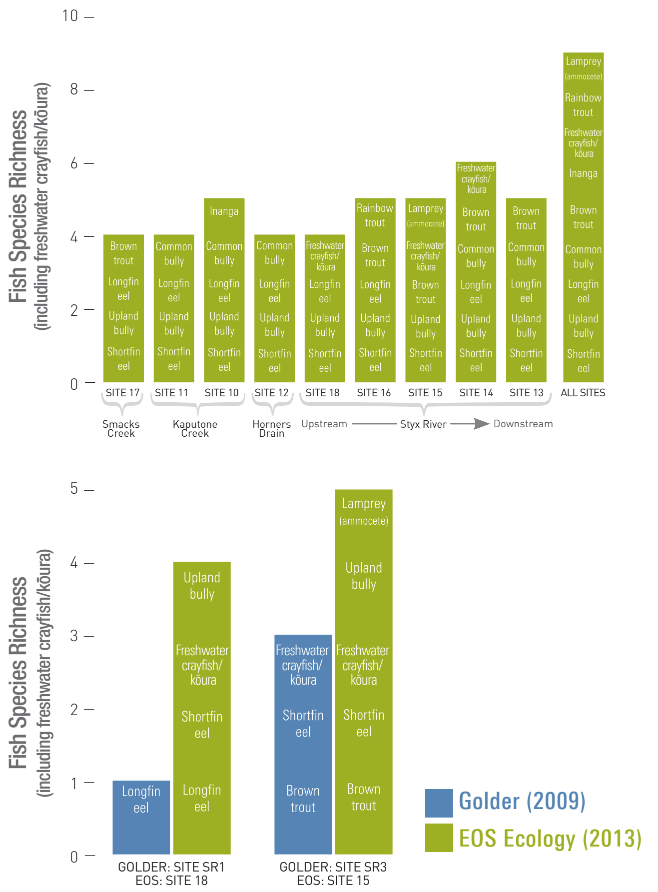


FIGURE 15
Fish species richness (including freshwater crayfish/kōura) at nine wadeable sites in the Styx River catchment undertaken 19–21 March 2013 and comparison of two sites from the current survey with data from Golder Associates Ltd (2009).

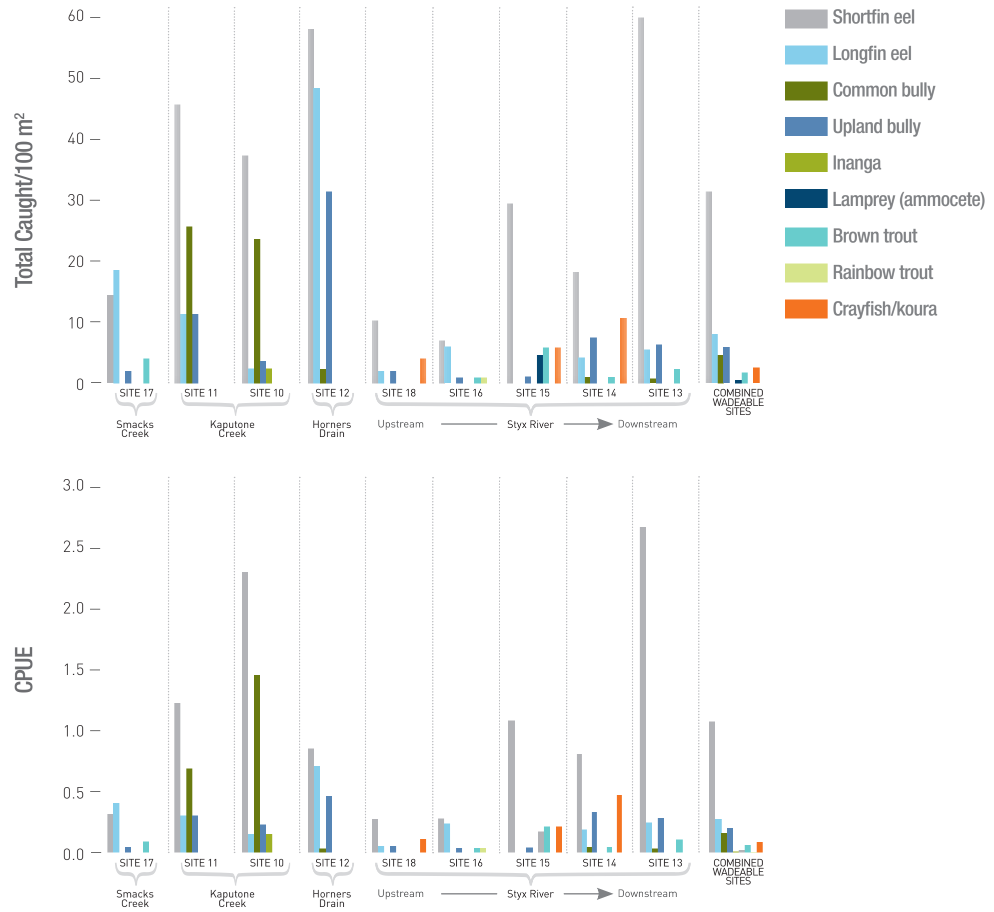


FIGURE 16
The total number of fish caught (per 100 m^2) and CPUE of fish from sampling at nine wadeable sites in the Styx River catchment undertaken 19–21 March 2013. Data includes freshwater crayfish/kōura as these are more reliably sampled via fish sampling methods rather than invertebrate sampling methods.

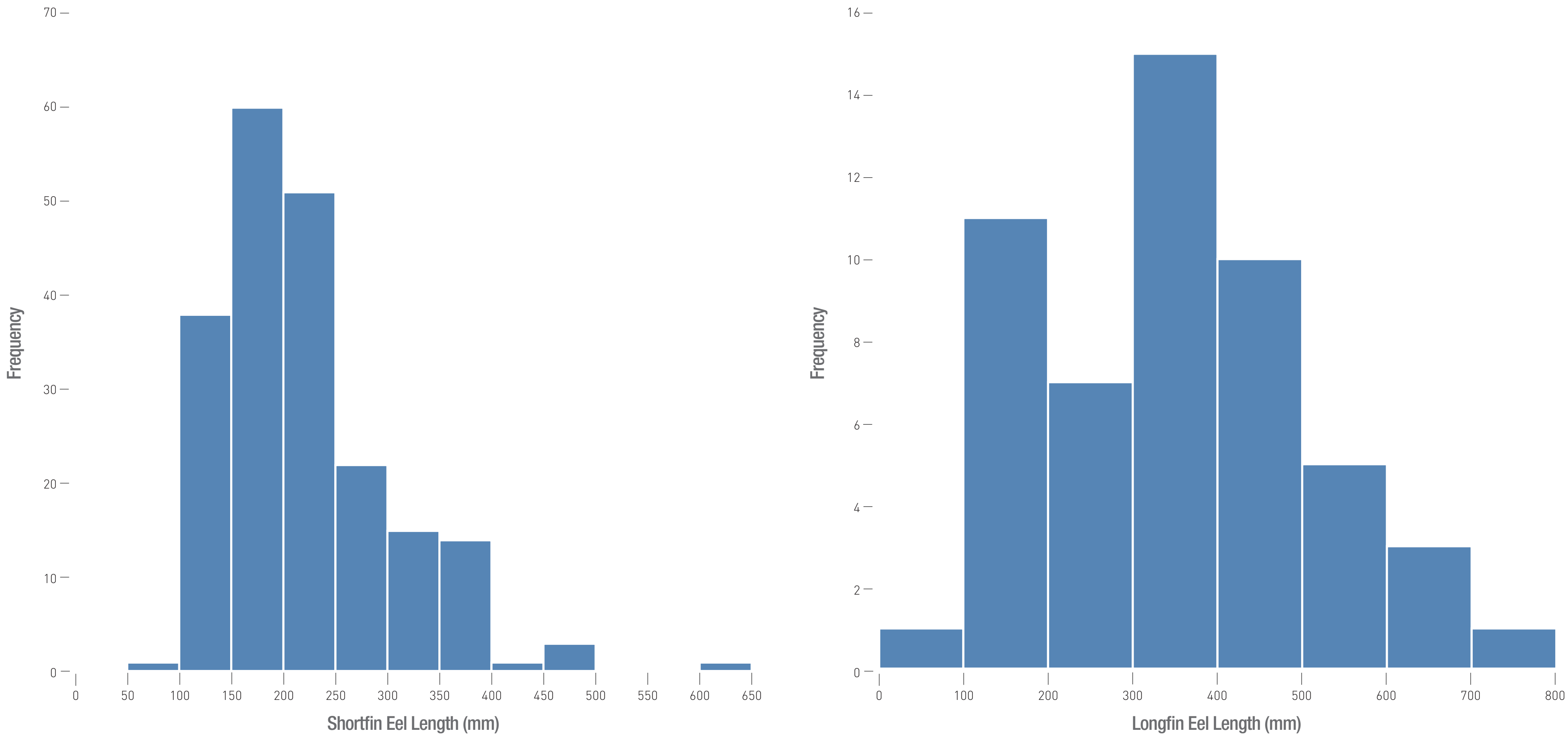


FIGURE 17
Length distribution of the two eel species captured at nine wadeable sites in the Styx River catchment from sampling undertaken 19–21 March 2013.

3.3.2 Non-wadeable

A total of five fish species were found across the three non-wadeable sites in the lower Styx River. All are native and two are in decline (Table 7). Only one species, giant bully, is additional to the eight species found during sampling of the nine wadeable sites. Giant bully and shortfin eel were the most commonly caught species and had the highest CPUEs for fyke nets. Gee minnow traps caught fewer eels and more common bully and giant bully compared to fyke nets; with this being reflected in their respective CPUEs (Figure 18).

Sampling by Golder Associates Ltd (2009) at the same sites showed a similar fish assemblage with the addition of upland bully which we did not find in the non-wadeable section of river, although it was present at all nine of our wadeable sites. The combined fyke net and Gee minnow trap CPUE was overall lowest at Site 50 for both surveys, while at both the other sites Golder Associates Ltd (2009) had notably higher CPUEs for common bully (Figure 19). Golder baited their fyke nets and Gee minnow traps with Marmite (our traps were unbaited) which may account for such high CPUEs for common bully. It would be expected using such a bait may have attracted eels which does not appear to be the case as they only managed to catch eels at one site (Figure 19). The current study had higher CPUE for giant bully at all sites compared to the Golder study. Fish species richness was the same at Sites 49 and 50 while the current EOS Ecology study captured two additional species at Site 48 (Figure 19).

The size distribution of giant bully was skewed towards larger fish with no small fish or juveniles captured (Figure 20). This matches the findings of others who also report small giant bully are rarely captured (McDowall, 1990; Julian Sykes, NIWA, pers. com.). Similarity most shortfin eels captured were of a large size being >500 mm in length (Figure 20). This may be an attribute of the sampling method.

TABLE 7
The total number caught and size range (length in mm) of each fish species from fyke netting and Gee minnow trapping undertaken at three non-wadeable sites in the Styx River catchment 11 April 2013. The latest conservation status is shown (Allibone *et al.*, 2010).

	SHORTFIN EEL	LONGFIN EEL	COMMON BULLY	GIANT BULLY	INANGA
Conservation Status	Not threatened	Declining	Not threatened	Not threatened	Declining
SITE					
50	3 (110-525)		8 (55-121)	3 (119-158)	
49	9 (475-595)	1 (688)	6 (50-106)	24 (93-169)	2 (81-103)
48	11 (345-672)	3 (393-506)	3 (55-93)	7 (70-160)	
Total	**23**	**4**	**17**	**34**	**2**

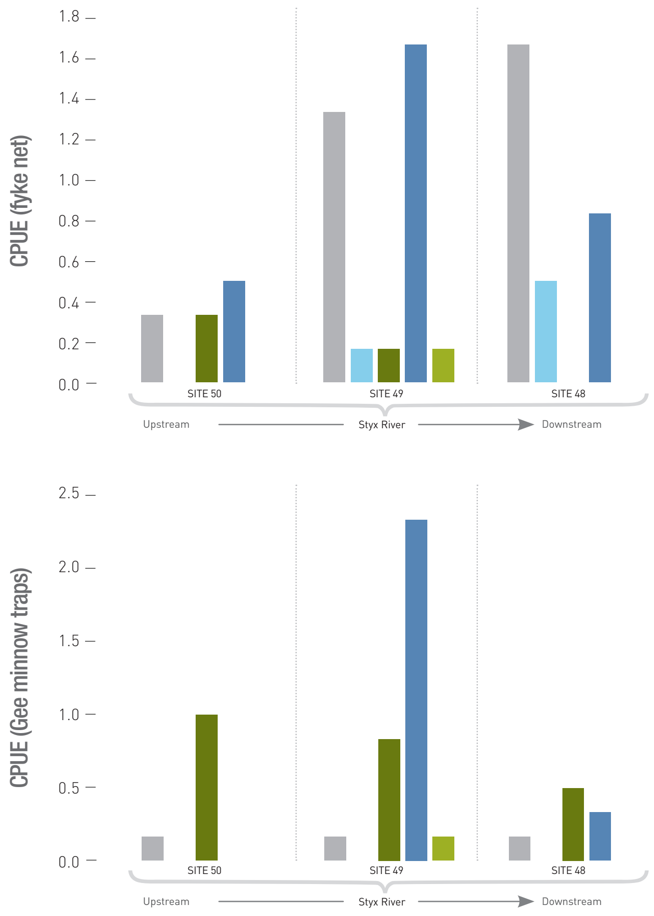


FIGURE 18
CPUE for fyke nets and Gee minnow traps from three sites in the non-wadeable section of the Styx River sampled 11 April 2013.

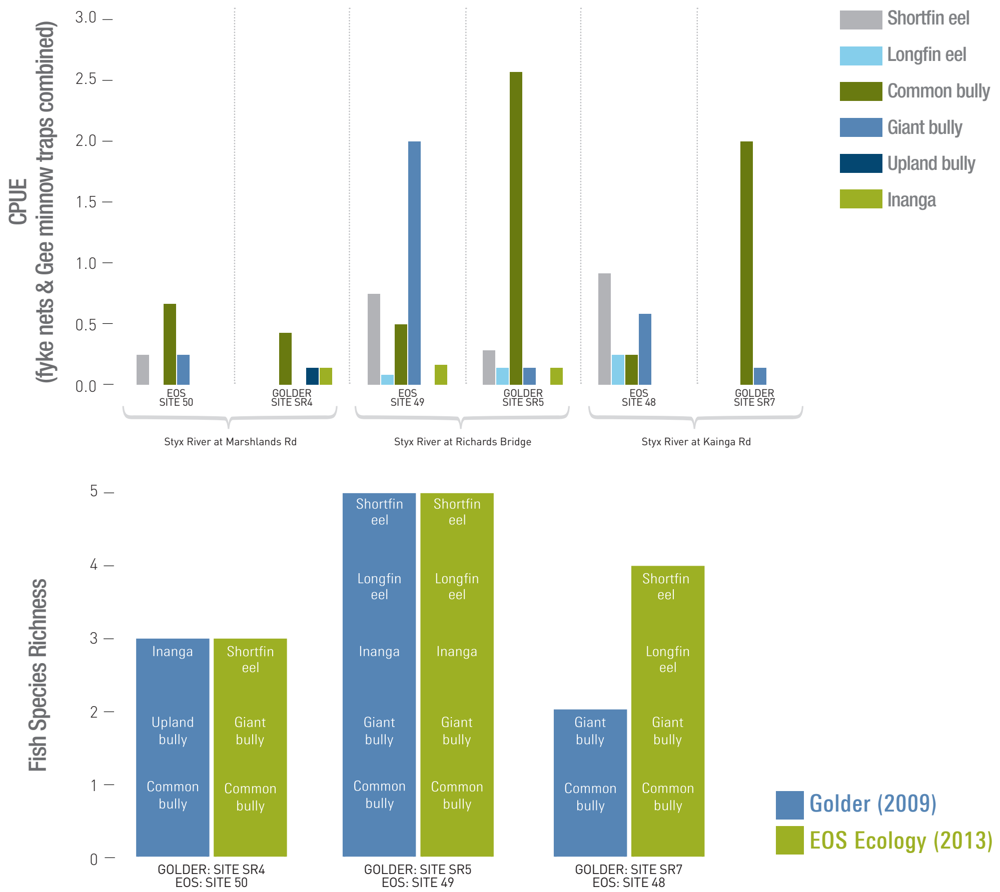


FIGURE 19
Comparison of CPUE (fyke nets and Gee minnow traps combined) and fish species richness from the three non-wadeable sites of the current survey sampled 11 April 2013 with data from Golder Associates Ltd (2009).

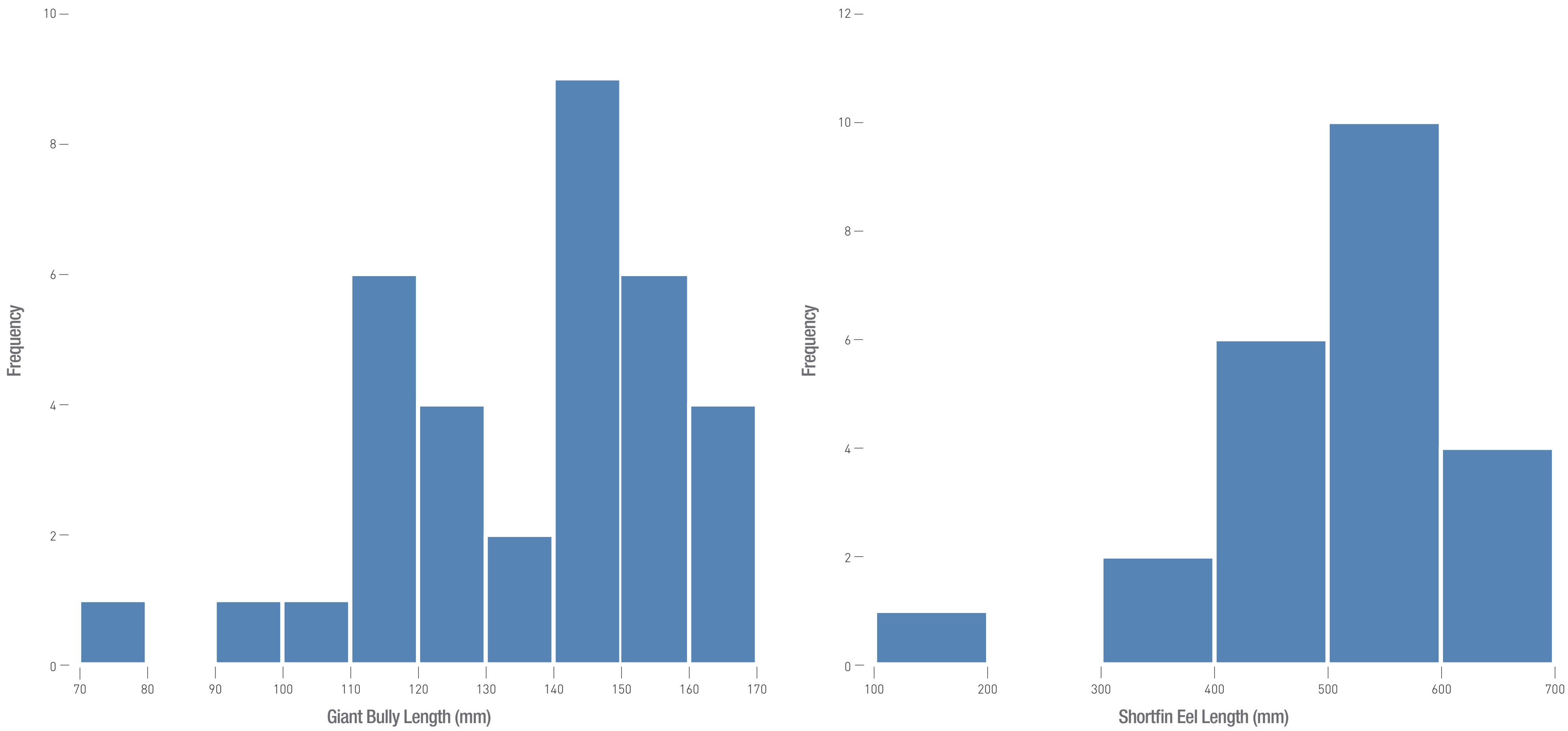


FIGURE 20
Length distributions of the two most common species (giant bully and shortfin eel) captured at three non-wadeable sites in the Styx River catchment from sampling undertaken 11 April 2013.

4. DISCUSSION

The QMCI-hb macroinvertebrate community health metric indicated the health of the wadeable Styx River catchment in 2013 was moderate in the mainstem with four of the five mainstem sites rated as "fair". In contrast the four tributary sites were all rated as "poor" in 2013. A similar distinction between mainstem and tributary sites was seen in 2008. In 2013 only three mainstem sites were within the minimum QMCI range of the PLWRP for 'spring-fed – plains' designated waterways (QMCI of 4.5–5) and of those, two only barely reach the low end of this range. QMCI is the only invertebrate community-based ecological health indicator of the PLWRP. However, overall the Styx River catchment would be the second healthiest river catchment in Christchurch behind the Otukaikino River where all sites were rated "fair" or "good" (James, 2012). Closely following in third place is the Avon River which also had a mixture of 'poor' and 'fair' sites (McMurtrie, 2009). The Halswell and Heathcote River catchments are clearly in the poorest condition based on QMCI, with all sites rated as 'poor' (James, 2010; James, 2011a). The three non-wadeable sites in the lower Styx River had similar invertebrate assemblage to the wadeable sites and were dominated by taxa typical of lowland, macrophyte filled waterways such as snails (Mollusca) and amphipod crustaceans. Several caddisflies (Trichoptera) that prefer or are tolerant of non-wadeable conditions (slow flow, macrophytes) were present at the non-wadeable sites, albeit in low numbers. EPT taxa richness was greatest in the wadeable mainstem sites, intermediate in the tributary sites, and least in the non-wadeable mainstem sites. Such taxa are generally more commonly found in wadeable, hard-bottomed waterways so it is not surprising fewer EPT taxa were found at the non-wadeable sites, however fewer EPT taxa at the tributary sites coupled with lower QMCI scores indicate the tributaries are more degraded than the Styx River mainstem. The first detailed aquatic invertebrate survey of the Styx River catchment was undertaken by Dr. J. Robb of the Christchurch Drainage Board in 1978-79 and repeated in 1987-89 (CDB, 1980; CDB, 1989). Comparison of presence/absence over time of the more sensitive EPT taxa (MCI scores ≥7) indicated that Site 17 (Smacks Creek) had undergone the greatest change over the last 25 years and had lost several mayfly and caddisfly species by 2008. The wadeable mainstem sites have retained a core sensitive EPT assemblage although the filter-feeding mayfly *Coloburiscus humeralis* has disappeared while the cased-caddisfly, *Olinga feredayi*, is now restricted to one site. The Styx River catchment exemplifies a system where the most sensitive aquatic invertebrate taxa appear to be in the process of becoming locally extinct due to the degradation of instream habitat.

There is little evidence of any habitat changes that could be attributed to the earthquake sequence that occurred between our original 2008 and current surveys. With the exception of Site 18 where there had been an increase in fine sediment, substrate size is largely unchanged at all sites indicating liquefaction did not occur or was minor and has dispersed. Liquefaction maps indicate that liquefaction occurred in a few small localised patches in the upper wadeable catchment while it was extensive along the lower, non-wadeable portion of the river (Brackley, 2012). The increase in fine sediment at Site 18 was the result of vegetation clearance by the landowner directly upstream resulting in a significant area of bare earth from which silt is transported to the channel during rain events. Channel widths were very similar between years at the wadeable sites indicating channel narrowing resulting from lateral spread was not an issue at any site. At the wadeable mainstem sites there were, however, increased water velocities and depths which are indicative of greater discharge during the 2013 survey. In general the observed habitat changes were relatively minor at most sites and resulted in no great variation in the ranking of the nine wadeable sites based on seven invertebrate community metrics between 2008 and 2013. The four highest ranking sites were the same in 2008 and 2013 (Sites 13–16) and encompassed a continuous section of the Styx River mainstem that flows through the Styx Mill Reserve. Likewise, the two lowest ranked sites in 2013, (Site 11 – Kaputone Creek and Site 12 – Horners Drain) were also among the lowest ranked sites in 2008. Incidently, our four highest ranked sites are encompassed by the section identified as of high ecological value by Golder Associates Ltd (2009) as part of the investigations undertaken for the development of the Styx River SMP. However, it is notable that Site 16 dropped from a first place ranking in 2008 to fourth in 2013 and saw a decline in most of the metrics used to calculate the ranking. This site along with Site 18 were the lowest ranked wadeable mainstem sites and also the two upstream most sites, which indicates something may be occurring in the upper Styx River catchment that is negatively affecting habitat and/or water quality. Based on aerial photography, there have been no obvious dramatic large-scale changes in land use that would result in such effects. However, the clearance of vegetation and subsequent siltation of the stream bed at Site 18 illustrates how even small-scale activities can have serious localised impacts. Ongoing poor treatment of the riparian zone by landowners will result in further deterioration of instream conditions.

Two aquatic macroinvertebrate species of conservation concern (both considered to be in decline), the freshwater mussel/kākahi (*Echyridella menziesii*) and freshwater crayfish/kōura (*Paranephrops zealandicus*) were found during the current survey. A single juvenile kākahi (8 mm long) was found at Site 49 in the non-wadeable, lower river. This is significant as it indicates the mussel population has been successfully reproducing in recent years. There has never been a detailed survey of kākahi distribution and abundance in the Styx River catchment however information from macrophyte harvester operators indicate that kākahi are present through most of the lower Styx River, especially the section that runs adjacent to Lower Styx Rd. Koura have only been found at a few wadeable locations (Sites 14, 15, and 18; and in Horners Drain at the Prestons Rd-Hills Rd intersection (Belinda Whyte, CCC pers. com.)) in the current survey and as with kākahi no detailed survey of distribution and abundance has been undertaken in the Styx River catchment. These two species are absent or very rare in the majority of urban waterways in Christchurch. It is highly likely they would have been found extensively through Christchurch's waterways prior to urbanisation, therefore their presence in the Styx River is notable and needs to be maintained. Both species appear to be very sensitive to urbanisation, so protection of their populations would require a change to standard urban development practices and use of more low impact urban design (LIUD) approaches.

The fish fauna of Styx River is typical of many New Zealand lowland, spring-fed catchments that are dominated by rural and rural/urban land use. There is a tide control gate near the mouth of the Styx River which may have some impact on migratory fish species although with six of the nine fish species present requiring access to the ocean to complete their lifecycles, it is unlikely to be having a significant impact on fish migration. Seven of the nine fish species found were native, with brown trout and rainbow trout being the only exotics. Shortfin eel, longfin eel, and upland bully where the most abundant and widespread species at wadeable sites, while giant bully and short fin eel were most prominent at the non-wadeable sites. Shortfin eel CPUE in the non-wadeable river was low with fewer than two eels caught per net or trap. There is a potential that commercial fishing in the lower Styx River may impact the abundance of eels (Julian Sykes, NIWA, pers. com.) and this needs to be taken into account when comparing the current survey's data with future surveys. Notable finds were lamprey ammocoetes (juveniles) (Site 16) and a single rainbow trout (Site 15). Adult lamprey that had returned from the ocean to breed have been observed (author, pers. obs.) and finding juveniles confirms they spawn in the Styx River catchment. It is probable they are more widespread than the current survey would indicate as juvenile lamprey are often missed using standard fish sampling methods due in part to their patchy distribution and preference for soft-bottomed habitats that are often not targeted. Rainbow trout are not commonly found in lowland Canterbury streams and the individual found may have found its way from Isaacs ponds in the Otukaikino River catchment where Fish & Game operate a hatchery or be a stray from the upper Waimakariri River catchment (Julian Sykes, NIWA, pers. com.; Tony Hawker, Fish & Game, pers. com.). In contrast, the other exotic fish found, brown trout, spawn in multiple locations through the wadeable upper Styx River catchment thus likely have a self-sustaining population (Taylor, 2005).

The Styx River, in particular the non-wadeable, lower river from Main North Rd all the way to the mouth at Brooklands is subjected to regular weed harvesting using a weed cutter boat (Figure 21). Harvesting is done at least three to four times a year (Owen Southen, CCC, pers. com.). Weed cutting had occurred in the weeks prior to our non-wadeable sampling which may have impacted results to some extent, although macrophytes were still abundant at all non-wadeable sites and providing ample habitat for invertebrates and fish. Additionally, it must be noted that this harvesting is so regular that the fish and invertebrate communities of the lower Styx River are likely resilient to its impacts, although the effects of macrophyte management on New Zealand fauna have rarely been studied (James, 2011b). The summer of 2013 also saw dredging undertaken along an approximately 600 m section between Heyders Rd and Spencerville Rd which is adjacent to Spencerville. Dredging of the lower Styx River is not a regular activity and has not been done for 20–25 years (Owen Southen, CCC, pers. com.). This would have had some significant short-term impacts on the fauna of that section but was downstream of all of the current study's survey sites except for Site 48 which was a further 3.5 km downstream and therefore unlikely to have been heavily impacted by any sediment released by the dredging given the slow flowing and deep nature of the river over that reach.

The high ecological quality of the Styx River relative to Christchurch's other rivers with the exception of the Otukaikino River, is directly related to the limited 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 wadeable Styx River catchment therefore remains largely clear of the sand/silt particles that have smothered much of the coarse substratum in Christchurch's rivers. There are also fewer barriers to invertebrate migration (e.g., culverts, bridges, and light pollution). The Styx River catchment is however undergoing significant changes in land use, predominantly rural land becoming urban, as well as the impending construction of the Northern Arterial motorway extension that will result in a new bridge over the Styx River mainstem and up to three crossings of Kaputone Creek. Best practice contaminant, especially sediment, controls will be required during all construction activities while effective stormwater treatment systems and low impact urban design will be required to reduce the effects of long-term, ongoing urban runoff if we are to have any chance of retaining many of the sensitive invertebrate taxa that remain.

Many of the cleanwater EPT taxa found in the Styx 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, 2011a). Similarly, two mayfly taxa (*Deleatidium* and *Coloburiscus*) are known to have disappeared from the Avon River catchment, although at least 13 caddisfly taxa still persist there (Robb, 1992; McMurtrie, 2009). Even the less-developed Styx River catchment appears to have lost *Coloburiscus* although it still supports more EPT taxa than these other Christchurch waterways. Should Christchurch's more degraded urban waterways ever be improved such that they can again support the more pollution-sensitive EPT taxa, then the Styx River along with 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 21
The weed cutter boat that harvests weed from the lower Styx River up to four times a year.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5. RECOMMENDATIONS

Having completed two rounds of long-term monitoring we are in a position to provide recommendations on protecting the ecological values of the Styx River catchment.

» The current survey is limited to the wadeable parts of the catchment and three non-wadeable sites downstream of Marshlands Rd. This omits an approximate 4.2 km section of mostly non-wadeable mainstem between Main North Rd and Marshlands Rd. We recommend at least one site be added to this section to give more complete coverage of the catchment.

» The Styx River catchment retains several invertebrate taxa that are sensitive to pollution and now absent from the more degraded and urbanised catchments in Christchurch (e.g., Avon, Heathcote, and Halswell). There is evidence that the most sensitive taxa have disappeared in the last 25 years. There is every chance that other taxa will follow given the development pressures of the catchment. It would be strategic and far less costly to prevent further degradation now rather than attempt restoration in the future. Some degradation was evident in the better-quality parts of the catchment indicating that some current land use practices are failing to even retain the status quo, let alone improving the current situation. So it maybe time to consider more strategic catchment management planning. Protecting the headwaters is the most critical factor for waterway protection, and in the Styx River the highest quality sites are in the upper catchment. To protect the quality of the upper Styx River we recommend:

1. Ensuring the inputs of diffuse and point source contaminants upstream of Styx Mill Reserve are minimised by constructing comprehensive stormwater treatment systems comprised of multi-element treatment trains, minimising the number of stormwater discharge points, and utilising low impact urban design (LIUD) features in all new developments.
2. Secondary to improving the quality of stormwater inputs in the upper catchment, investigate the quality of stormwater entering through the Styx Mill Reserve and ensure it is being suitably treated.
3. Investigating the magnitude of fine sediment and other contamination inputs from existing land use such as the sawmill adjacent to Smacks Creek and lifestyle blocks.
4. Ensuring the development of an intact, well-vegetated riparian zone including on private land that adjoins the Styx River and its tributaries.

» The Styx River catchment has two culturally and ecologically significant megainvertebrates (freshwater mussel/kākahi and freshwater crayfish/kōura) that are very rare or absent from the more urbanised Christchurch catchments. We recommend a detailed survey of the distribution, abundance, and population structure of these species is undertaken in the Styx River. This will be needed to establish their current state and direct what can be done to protect them.

» The non-wadeable section of the Styx River mainstem is subjected to regular (3–4 times a year) weed harvesting. There is limited information on the impact of such activities on fauna and how any effects could be mitigated. Given the regularity of the activity and easy access to much of the lower Styx River, it would an excellent system in which to research the impacts of mechanical weed harvesting on fish, invertebrates, and macrophytes (native vs. exotic species). We recommend such a study is planned in co-operation with the CCC and funding sought.

A giant bully captured during the fish survey in the Styx River.

6 ACKNOWLEDGEMENTS

Thank you to EOS Ecology technical staff for their efforts with the field work, laboratory processing, and report formatting, and to Owen Southen for providing weed removal schedules.

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8 APPENDICES

8.1 APPENDIX I: SITE PHOTOGRAPHS

SMACKS CREEK | KAPUTONE CREEK

2008

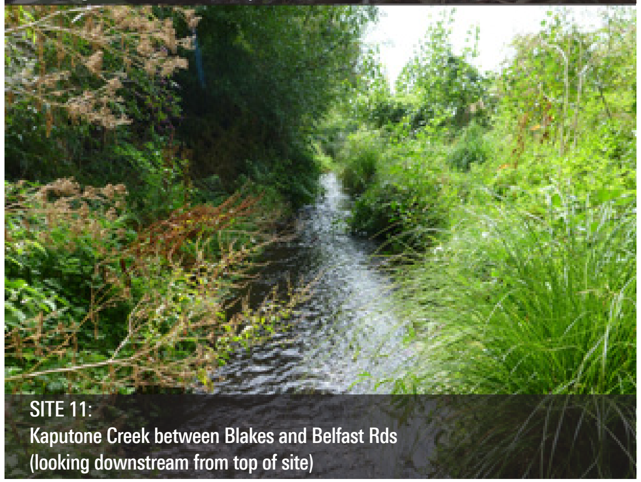
SITE 17:
Smacks Creek at Hussey Rd
(looking upstream from bottom of site)

SITE 11:
Kaputone Creek between Blakes and Belfast Rds
(looking downstream from top of site)

SITE 10:
Kaputone Creek at Ouruhia Reserve
(looking downstream from top of site)

2013

SITE 17:
Smacks Creek at Hussey Rd
(looking upstream from bottom of site)



SITE 11:
Kaputone Creek between Blakes and Belfast Rds
(looking downstream from top of site)

SITE 10:
Kaputone Creek at Ouruhia Reserve
(looking downstream from top of site)

HORNERS DRAIN	STYX RIVER (WADEABLE)	

2008

SITE 12:
Horners Drain at Hawkins Rd
(looking downstream from top of site)

SITE 18:
Styx River at Claridges Rd
(looking upstream from bottom of site)

SITE 16:
Styx River upstream of Styx Mill Reserve
(looking downstream from top of site)

2013

SITE 12:
Horners Drain at Hawkins Rd
(looking downstream from top of site)

SITE 18:
Styx River at Claridges Rd
(looking upstream from bottom of site)

SITE 16:
Styx River upstream of Styx Mill Reserve
(looking downstream from top of site)

STYX RIVER (WADEABLE)...continued

2008

SITE 15:
Styx River adjacent Styx Mill Dog Area car park
(looking downstream from top of site)

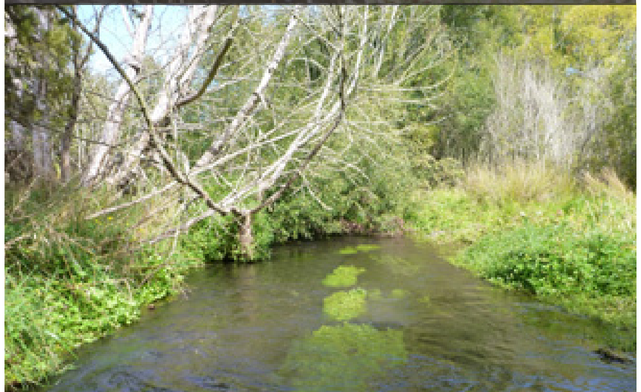
SITE 14:
Styx River at Styx Mill Conservation Reserve
(looking downstream from top of site)

SITE 13:
Styx River at Main North Rd
(looking downstream from top of site)

2013

SITE 15:
Styx River adjacent Styx Mill Dog Area car park
(looking downstream from top of site)

SITE 14:
Styx River at Styx Mill Conservation Reserve
(looking downstream from top of site)



SITE 13:
Styx River at Main North Rd
(looking downstream from top of site)

STYX RIVER (NON-WADEABLE)

2008

Not sampled in 2008

Not sampled in 2008

Not sampled in 2008

2013

SITE 50:
Not sampled in 2008

SITE 50:
Styx River at Marshlands Rd
(looking upstream from bottom of site)

SITE 49:
Not sampled in 2008

SITE 49:
Styx River at Richards Bridge
(looking downstream from top of site)

SITE 48:
Not sampled in 2008

SITE 48:
Styx River at Kainga Rd
(looking upstream from bottom of site)

8.2 APPENDIX II: HABITAT ATTRIBUTES

Habitat attributes of nine wadeable sites in the Styx River catchment surveyed in March 2008 and February 2012 and three non-wadeable site surveyed in April 2012. For site locations refer to Figure 1 and Table 1.

	SMACKS CREEK		KAPUTONE CREEK				HORNERS DRAIN	
	SITE 17		SITE 11		SITE 10		SITE 12	
	2008	2013	2008	2013	2008	2013	2008	2013
Surrounding land use	100% park/reserve	100% garden centre	100% fenced rural (horticulture)	50% unfenced rural (horticulture); 50% fenced rural (stock)	50% park/reserve; 50% lifestyle block	50% park/reserve; 50% lifestyle block	90% fenced rural (stock and horticulture); 10% residential (old)	100% fenced rural (stock)
Bank material composition	Earth (some rock and wood)	Earth (some rock and wood)	Earth	Earth (minor rock and wood)	Earth	Earth	Brick/concrete and wood	Wood
Riparian vegetation	Native trees, moss/ liverworts, some grass/ herb mix, ferns, shrubs, and rushes.	Native trees and shrubs, ferns, some low ground cover, unvegetated areas and rushes/sedges.	Exotic deciduous trees, grass/herb mix, unvegetated areas, with some low ground cover, ferns, and moss/ liverworts.	Grass/herb mix, low ground cover and exotic trees with some rushes/ sedges and mosses/ liverworts.	Grass/herb mix, low ground cover, and some exotic trees.	Grass/herb mix, low ground cover, lawn, and exotic trees.	Grass/herb mix, some impervious, exotic trees and shrubs, low ground cover and unvegetated areas.	Impervious and unvegetated with some grass/herb mix and native and exotic shrubs.
Canopy cover	25-50%	>75%	25-50%	5–50%	5-50%	<5%	50-75%	<5%
Substrate embeddedness	25-50%	25–50%	50-75%	50–75%	50-75%	50-75%	5-25%	25-50%
Habitat type (riffle:pool:run)	0:0:100	15:0:85	75:0:25	100:0:0	50:0:50	60:0:40	0:0:100	100:0:0
Aquatic vegetation and organic material cover	Algal mats: 40% Moss/liverworts: 20% *Potamogeton crispus*: 10% Terrestrial roots/ vegetation: 5% *Lemna*: 2% *Azolla*: 2% Filamentous algae: 2% *P. cheesemanii*: 2% *Rorippa*: 2% *Elodea*: 2% Detritus (leaf litter): 2% *Nitella*: 1% Woody debris: 1%	Algal mats: 75% *P. crispus*: 5% *Nitella*: 1% *P. cheesemanii*: 1% *Elodea*: 1% *Lemna*: 1%	Terrestrial roots/ vegetation: 25% Detritus (leaf litter): 15%	Filamentous algae: 70% *Nitella*: 5% *Ranunculus*: 1% Terrestrial roots/ vegetation: 2% *Lemna*: 1% Detritus (leaf litter): 1%	Terrestrial roots/ vegetation: 10% Detritus (leaf litter): 5% Moss/liverworts: 5% *Rorippa*: 2% *Nitella*: 1% Callitrichaceae: 1%	*Rorippa*: 60% Algal mats: 20% Terrestrial roots/ vegetation: 15% Filamentous algae: 5% *Nitella*: 5% *Ranunculus*: 2% *Lemna*: 2% Woody debris: 2% Moss/liverworts: 1% Detritus (leaf litter): 1%	Moss/liverworts: 25% *P. ochreatus*: 12% *P. crispus*: 8% Algal mats: 7% Detritus (leaf litter): 7% *Nitella*: 1%	Algal mats: 50% *P. ochreatus*: 30% *P. crispus*: 30% Moss/liverworts: 5% *Lemna*: 1% Detritus (leaf litter): 1%

	STYX RIVER (WADEABLE MAINSTEM)									
	SITE 18		SITE 16		SITE 15		SITE 14		SITE 13	
	2008	2013	2008	2013	2008	2013	2008	2013	2008	2013
Surrounding land use	90% lifestyle block; 10% residential (old)	90% lifestyle block; 10% residential (old)	95% park/reserve; 5% unfenced rural (stock)	50% park/reserve; 50% fenced rural (stock)	100% park/reserve	100% park/reserve	85% park/reserve; 15% lifestyle block	100% park/reserve	100% park/reserve	100% park/reserve
Bank material composition	Earth (minor rock)	Earth (minor rock)	Earth	Earth	Earth	Earth	Earth (minor wood)	Earth	Earth	Earth (minor rock)
Riparian vegetation	Mostly unvegetated with some ferns, rushes/sedges, native shrubs, moss/liverworts and exotic trees.	Rushes/sedges, native trees and shrubs, some grass/herb mix, moss/liverwort and exotic trees and shrubs.	Exotic trees and shrubs, some rushes/sedges, ferns and low ground cover.	Ferns and low ground cover, some grass/herb mix, and native and exotic trees and shrubs.	Grass/herb mix and low ground cover, some native and exotic trees and rushes/sedges.	Grass/herb mix, rushes/sedges and some native and exotic trees and shrubs.	Grass/herb mix, some low ground cover and exotic trees.	Grass/herb mix, some low ground cover, rushes/ sedges, native trees and shrubs and exotic trees.	Grass/herb mix, some low ground cover, rushes/ sedges, and native trees.	Grass/herb mix, some rushes/ sedges, and native and exotic trees.
Canopy cover	<5%	25–50%	50–75%	25–50%	5–25%	<5%	5–25%	<5%	>75%	5–25%
Substrate embeddedness	25–50%	>75%	25–50%	25–50%	<5%	5–25%	50–75%	25–50%	5–25%	5–25%
Habitat type (riffle:pool:run)	5:0:95	0:0:100	0:0:100	0:0:100	0:0:100	100:0:0	0:0:100	0:0:100	80:0:20	20:0:80
Aquatic vegetation and organic material cover	Algal mats: 10% Detritus (leaf litter): 10% *Rorippa*: 5% roots/vegetation: 5% Moss/liverworts: 3% *Lemna*: 1% Callitrichaceae: 1%	Algal mats: 5% *Rorippa*: 10% *Nitella*: 10% *Elodea*: 5% Terrestrial roots/ vegetation: 2% Woody debris: 2% *Lemna*: 1% Moss/liverworts: 1% Detritus (leaf litter): 1%	Detritus (leaf litter): 15% Moss/liverworts: 10% *Lemna*: 2% *Glyceria*: 2% *Elodea*: 2% *Rorippa*: 1%	Algal mats: 65% Terrestrial roots/ vegetation: 5% *Ranunculus*: 1% *Mimulus*: 1% *Rorippa*: 1% *Lemna*: 1% *Elodea*: 1%	*Rorippa*: 25% *Mimulus*: 10% *Elodea*: 7% Detritus (leaf litter): 5% *P. cheesemanii*: 5% *P. crispus*: 2%	Algal mats: 70% *Mimulus*: 15% Terrestrial roots/ vegetation: 10% *Ranunculus*: 1% *Rorippa*: 1% Filamentous algae: 1% *Lemna*: 1% *Elodea*: 1%	Terrestrial roots/ vegetation: 10% *P. crispus*: 5% Algal mats: 5% *Elodea*: 5% Detritus (leaf litter): 5% *Glyceria*: 3% *Rorippa*: 1%	Algal mats: 40% *Ranunculus*: 15% *P. crispus*: 10% *Rorippa*: 5% *Elodea*: 5% Terrestrial roots/ vegetation: 5% Moss/liverworts: 1% *Mimulus*: 1% *Lemna*: 1% *Azolla*: 1% Woody debris: 1%	*Mimulus*: 10% *Glyceria*: 5% *Rorippa*: 5% *Ranunculus*: 5% *P. crispus*: 5% Algal mats: 2% *Lemna*: 1% *Myriophyllum*: 1% Moss/liverworts: 1% Detritus (leaf litter): 1%	Algal mats: 60% *P. crispus*: 5% *Ranunculus*: 5% *Mimulus*: 5% *Rorippa*: 5% Terrestrial roots/ vegetation: 3% *Elodea*: 1% *Nitella*: 1% *Lemna*: 1% Moss/liverworts: 1% Callitrichaceae: 1% Woody debris: 1%

	STYX RIVER (NON-WADEABLE MAINSTEM)		
	SITE 50	SITE 49	SITE 48
	2013	2013	2013
Surrounding land use	50% fenced rural (stock); 50% park/ reserve	50% fenced rural (stock); 50% unfenced rural (stock)	50% fenced rural (stock); 50% unfenced rural (stock)
Bank material composition	Earth (minor wood)	Earth (minor wood)	Earth (minor wood)
Riparian vegetation	Grass/herb mix, some moss/ liverworts, rushes/sedges, and native and exotic trees.	Grass/herb mix, some moss/ liverworts, and exotic trees.	Grass/herb mix, unvegetated areas, exotic shrubs, some moss/ liverworts, and exotic trees.
Canopy cover	<5%	<5%	<5%
Substrate embeddedness	>75%	>75%	>75%
Habitat type (riffle:pool:run)	0:0:100	0:0:100	0:0:100
Aquatic vegetation and organic material cover	*Elodea*: 40% *Ranunculus*: 1% Terrestrial roots/vegetation: 2% *Rorippa*: 1% *Lemna*: 1% Detritus (leaf litter): 1% Woody debris: 1%	*Elodea*: 75% *P. crispus*: 5% Filamentous algae: 5% *Nitella*: 5% *Rorippa*: 3% Terrestrial roots/vegetation: 2% Woody debris: 2% Moss/liverworts: 1% *Lemna*: 1% *Azolla*: 1%	*P. ochreatus*: 70% *P. crispus*: 5% *Nitella*: 3% Moss/liverworts: 1% *Ranunculus*: 1% Callitrichaceae: 1% *Elodea*: 3% *Lemna*: 1% Detritus (leaf litter): 1% Terrestrial roots/vegetation: 1% Woody debris: 1%

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