Ecological monitoring of Christchurch City waterways: Styx River:

Round 3

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Final Report

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Two eyed inanga (whitebait) eggs from the lower Styx River, larger than life size (ca. 1 mm)

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Contents

1 Executive Summary

The Styx River catchment has undergone widespread landuse change over the last 20 years. This change has been from a predominantly rural catchment, to that with increasing proportions of residential and light commercial landuse. Attendant with landuse change there have been hydrological changes in the catchment, which are considered to be partly associated with catchment development, which include the loss of baseflow in the headwaters of both the Styx River mainstem, and its principal tributary, Kaputone Stream.

In the 3rd monitoring round of fish values in the city rivers, a series of investigations were undertaken on aspects of the fish ecology in the Styx River catchment. This indicated that, compared to previous surveys, brown trout spawning has shifted downstream, as a function of loss of utilised habitat in lower Smacks Creek. The loss of spawning trout habitat around the confluence of Smacks Creek warrants further investigation. However, the loss of spawning gravels in lower Smacks Creek is compensated by improving spawning habitat downstream of the Styx Mill Conservation Reserve, possibly due to the retirement of riparian and stream-bed access from grazing stock. Over the catchment, trout redd numbers in the winter of 2010 were the same as those recorded in 2005.

A brief fish survey in Smacks Creek last spring indicated some trout fry recruitment from the reaches in the vicinity, and upstream, of Gardiners Road. We consider that a denser riparian planting is required through the reach upstream of Gardiners Road to stabilise the banks and prevent woody material from entering the stream channel. Downstream of Gardeners Road, more overhanging bank vegetation through the Smacks Creek Esplanade Reserve may serve to reduce trout fry predation from the large eels which reside there.

This report introduces a novel type of survey, a boat-drift survey, for counting fish in the lower river downstream of Marshland Road. We consider that running such surveys over a defined and statistically meaningful distance of the lower river may provide an approximate assessment of the numbers of adult trout. The initial survey indicated that the lower river provides habitat for a low population of large brown trout, providing some angler amenity with access from Lower Styx Road.

A field verification was undertaken on the reported identification of redfin bully from the Kaputone River in the summer of 2006. This species is rare in the Christchurch area. However, no redfin bullies were found at the sites where they were previously identified, and we consider that the 2006 identification of redfin bully in the Kaputone Stream was a case of misidentification with the upland bully.

A re-survey of the previously reported inanga spawning habitat was undertaken in a reach between the Styx River tidegates and Harbour/Kainga road. Similar to previous surveys a high concentration of eggs were recorded immediately upstream of the Styx River tidegates, with smaller egg masses located a short distance upstream.

A number of further recommendations are made which elaborate on the issues raised in this summary.

2 Introduction and background

This report is the 3rd in a series of investigations into ecological issues pertaining to fish in Christchurch waterways. Earlier reports have dealt with specific components of the fish communities in the Avon River and Heathcote and Halswell Catchments (EOS Ecology Limited *et al.* 2005; Taylor 1997; Taylor 2005a; Taylor & Bray 2008; Taylor & Chapman 2007).

The Styx River catchment, which borders the northern periphery of Christchurch City, has undergone, and is still undergoing, rapid landuse change. These landuse changes are from predominantly rural to increasing proportions of residential and light commercial uses. Significant land areas affected are, for example, the Northwood, and Redwood Springs residential developments. More large-scale landuse changes are intended between Marshland Road and Grimseys Road. There has also been some rural landuse change to light commercial zones. For example, the SupaCentre on Marshland Road.

Without effective mitigation, catchment landuse change on a large scale can have adverse impacts on the aquatic ecology. Even with mitigation of many of these impacts, there is a growing scientific opinion that adverse impacts cannot be totally avoided, especially in regard to stormwater quality. There is an increasing body of information that effects of urbanisation include subtle gradual changes to the biota in waterways which receive urban stormwater runoff. This is particularly so, and more quantifiable, for the invertebrate fauna (Suren 2000). This gradually reduction in stream health, at least as reflected in the decline in the number and diversity of sensitive aquatic invertebrates, is termed ‘urban stream syndrome’.

It is potentially possible that fish communities would also be affected by landuse changes as profound and rapid as that is occurring in the Styx River catchment. Some of these effects may be due to food web relationships with the invertebrate fauna, upon which the fish depend on for food. Many freshwater fish are considered to be opportunistic browsers, with a degree of flexibility as regards their invertebrate diet, whereas others are more selective. Invertebrate prey differs in the ease in which they captured, and their calorific value, so changes in the invertebrate fauna, as suggested above, can lead to a reduction in the energy flow to fish predators, even if the compromised invertebrate fauna is not unpreferred by a particular fish species. Other effects of urbanisation are more direct, and include reduction in water clarity due to suspended sediment, and important issue for fish which are visual feeders, for example brown trout (Stuart-Smith 2004). When suspended sediment settles on the stream bed, then important substrate refuge for small fish is lost, for example, for bully species like the upland bully (Jowett & Boustead 2001). Settled sediment may also reduce the quality of the substrate for fish spawning, as fish like brown trout and the upland bully use the substrate as a spawning habitat. Recent research has also indicated that fish eggs, at least trout, but possibly other species, are much more sensitive to nitrate than previously thought (Hickey 2009).

In the past, the lower Styx River has had a valued brown trout fishery known for its accessibility for city-dwellers and good numbers of moderate-sized, but takeable trout (Teirney *et al.* 1987). Because of the value of this natural asset, aspects of brown trout ecology were considered as one of the values of the Styx River which should be monitored. There is no information on the state of trout numbers in the lower river. Smacks Creek has reaches utilised for trout spawning (Taylor 2005b), and provides juvenile trout recruitment to the fishery in the lower river. The tributary also has relatively high aquatic invertebrate diversity (in an urban stream context) and high stream health values (Taylor & McMurtrie 2003). The upper reaches of Smacks Creek is also subject to residential development, and it was considered that ecological values in this waterway should have priority for monitoring.

In contrast to Smacks Creek, the Kaputone Stream has long been regarded to fit more towards the bottom of the waterway health scale. Early studies indicated that the health was poor, and was infamously described as a ‘slum amongst waterways’, in relation to illegal rubbish dumping, pollution, and bankside herbicide spraying (Eldon & Taylor 1990). In the past, the stream was the receiving waterway for a host of contaminants (wool scours, abattoir waste water etc) sufficient to cause fish kills (Eldon & Taylor 1990), although the worst of these contaminant inputs have now ceased. Less publicised, but probably just as damaging, was the significant stock-accelerated erosion over a significant proportion of the middle rural reaches (Taylor 2005b). With the relatively reduction in stock numbers and contaminant loadings associated with the PPCS plant in Belfast, it is possible that, over time, the aquatic ecology of Kaputone Stream may show signs of recovery.

A recent survey on the Kaputone Stream reported the presence of redfin bully (*Gobiomorphus huttoni*) from two sites (Keesing 2007). The fishes of Kaputone Creek have been surveyed twice before; firstly as part of a Styx catchment-wide survey (Eldon & Taylor 1990), and subsequently the fish fauna of the upper creek upstream of the Main South Road was surveyed in 2004 (Taylor & McMurtrie 2004). In neither of those surveys were redfin bully recorded, nor in any other known survey of Christchurch rivers. Therefore, the identification of redfin bully in the Kaputone Stream may reflect a marked improvement in waterway health, but given that this species does not occur in other, more healthy, Christchurch waterways, a confirmation on the identification of this species was considered important.

3 Objectives

The objectives of this study are to compare and discuss aspects of fish ecology in the Styx River catchment. These are bulleted below in order of excecution:

- Confirmation of brown trout fry recruitment in Smacks Creek.
- Confirmation of a redfin bully population in Kaputone Stream.
- A census of brown trout numbers in the lower Styx River (March 2010).
- A check for inanga spawning activity along the tidal reaches of the lower Styx River (May 2010)
- Two brown trout redd surveys in the winter of 2010 (July, September).

4 Methods

4.1 Field methods

4.1.1 Georeferencing

A high- sensitivity GPS receiver was used to pinpoint the position of survey sites, trout redds, and other features of interest. Position averaging was used to reduce positional variation caused by atmospheric effects.

4.1.2 Smacks Creek trout fry recruitment

The fish communities in three reaches of Smacks Creek were electric-fished on 24th November 2009, with an emphasis on targeting emergent trout fry. By late November it was expected that most brown trout fry (i.e. juvenile trout) would have emerged from the redd gravels. The three reaches were selected on the basis that they had high numbers of trout redds during a previous trout redd survey (Taylor 2005b).

The selected reaches, in upstream to downstream order, were:

1. 130m upstream of Gardiners Road.
2. Adjacent to Redwood Aquatics (above Husseys Road).
3. Immediately upstream of the confluence with the Styx River, two electric fishing passes..

The locations of these reaches are depicted in Figure 1. Fishing was undertaken by two operators using a Kainga 300 packset electric fishing machine set on 200 volts DC. The electric-fishing operator fished downstream towards a fieldworker holding a stopnet.

All the fish collected were anaesthetised, identified, measured, and then released back into their resident habitat. At the site upstream of the Styx River confluence, two downstream passes were made with the machine, because of the large number of fish present. On the first pass, all of the fish seen were caught and placed in holding buckets. However, on the second sweep only trout were retained, and numbers of eels were counted, but not collected. At the other two sites, only one pass was made because the fishing efficiency was perceived as being higher there, and there were fewer fish. The fishing time and site dimensions are provided in Table 1, with site photographs provided in Figs. 2a-c.

Figure 1. The three surveyed reaches in Smacks Creek. The yellow pins indicate the upstream and downstream limits at each of the fished reaches.

Table 1. Details of Smacks Creek electric-fishing sites.

Site	NZMS 260 grid ref	Site length (m)	Area sampled (m^2)	Fishing time (minutes)
Upstream of Styx confluence	M35: 774-490	85	246.5	19 (sweep 1) 9 (sweep 2)
Adjacent to Redwood Aquatics	M35: 770-493	49	158	14
Upstream of Gardiners Road	M35: 767-494	47	96	6

Figure 2a. Smacks Creek upstream of the Styx River confluence, looking downstream.

Figure 2b. Smacks Creek at Redwood Aquatics, looking upstream

Figure 2c. Smacks Creek upstream of Gardiners Road, looking upstream

4.1.3 Kaputone Stream

An electric fishing survey was conducted on Kaputone Stream (on 15 March 2010) to confirm or refute the presence of redfin bully in this tributary. Redfin bullies were reported from two sites in the Kaputone Stream in the summer of 2006 (Keesing 2007), and these sites were re-surveyed using similar equipment to the 2006 survey (i.e. Kainga EFM300 packset), to check for the presence of this species. One site was at the Ouruhia Reserve near Guthries Road, and the second site was immediately above the Belfast Road culvert near Blakes Road (Table 2)(Fig. 3). Habitat photographs are provided in Figs. 4a, b. Eels were not collected at either site, but their presence was recorded. Other species were anaesthetised, identified, counted, and released.

Table 2. Dimensions of electric-fished reaches

Site	NZMS 260 grid ref	Site length (m)	Area sampled (m^2)	Fishing time (minutes)
Guthries Road/Ouruhia Reserve	M35: 818-518	84	277	14
Belfast Road (near Blakes Road) culvert	M35: 808-504	25	57.5	4

Figure 3. The two fished sites on the Kaputone Stream (ringed).

Figure 4a. The Guthries Road/Ouruhia Reserve sampling site

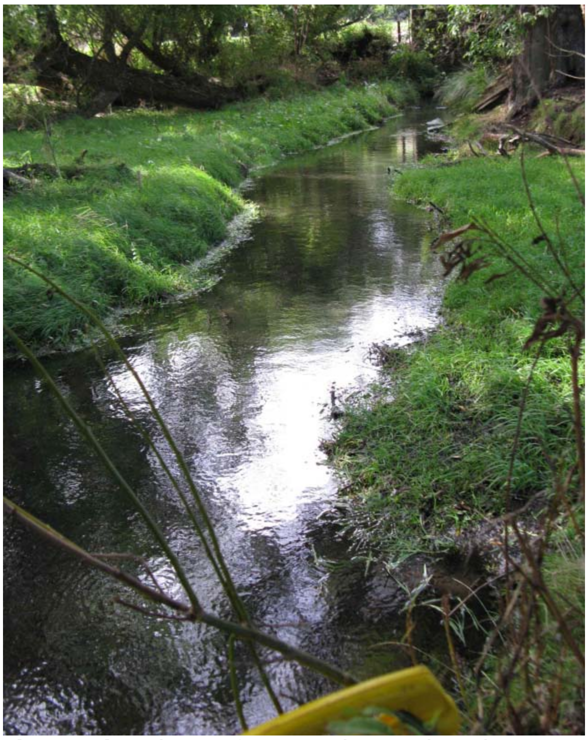

Figure 4b. The Belfast Road sampling site

4.1.4 Lower River Trout Survey

On the 18 March 2010, a census of observed trout were conducted along a 4.6km reach of the lower Styx River, from the Teapes Road bridge upstream to the Marshland Road bridge (Fig. 5). An earlier attempt to use a team of drift divers to undertake the survey was unsuccessful due to the reduction in water clarity caused by the disturbance of re-suspended bottom silt.

The survey reach meandered through a riparian tree canopy of willow, with a sub-canopy of flaxes and exotic grasses and *Carex* sp. The census was undertaken from a dinghy that was slowly motored upstream to Marshland Road and then the vessel allowed to drift downstream, whilst a repeat count was undertaken.

During the survey, an observer stood on the bow, and whilst wearing Polaroid sunglasses, counted observed fish. The estimated size class was recorded, and there position logged with a sensitive GPS receiver (Garmin GPSmap 60CSx). The size classes that fish were assigned to were: small <150mm F.L.; medium 150-300 mm F.L., and large >300mm F.L.

4.1.5 Inanga Spawning

On the 3rd and 4th May 2010, an inanga spawning survey was conducted in suitable riparian vegetation between Kainga Road and the tide gates. Methods are similar to previous surveys and described in Taylor and Bradshaw (2005), and was conducted over two low-tide events on the 4th and 5th May 2010. In brief, suitable riparian vegetation was parted down to soil level, by two field staff, and searched closely for inanga eggs. Where eggs were found, the locations were geo-referenced with a GPS receiver, and notes and habitat photographs taken.

Figure 5. The Styx River downstream of Marshlands Road, with the river course indicated in red. The 2-pass trout-census survey took place between the Teapes Road Bridge and the Marshland Road bridge (between the yellow and red pins).

4.1.6 Brown trout spawning survey

The trout spawning survey was conducted in a similar manner as previous years, although two surveys were undertaken this year, to ensure that all trout redds were counted. A potential deficiency with one-pass trout surveys, is that late spawning trout may spawn after the survey is conducted, therefore redds counts underestimate trout numbers, or, if a late survey is conducted, early redds may become hard to distinguish from the undisturbed substrate as periphyton begins to develop. The 1st early-season survey was undertaken on the 7th and 11th July, with the 2nd late-season survey conducted on 2nd September 2010. Surveys were conducted from mid-morning to mid-afternoon, under baseflow conditions when bottom visibility was at its best.

The survey commenced on the mainstem at the confluence with the Redwood Springs springhead, downstream of the railway bridge. The survey extended to approximately 120 m upstream of the Smacks Creek confluence (red line in Fig. 6). The Smacks Creek survey extended from the mainstem confluence, and progressed upstream to Wilkinson Road (green line in Fig. 6). A straight drain 150 m west of Cavendish Road was also surveyed over its confined boxed section (i.e. for 84 m) north of Styx Mill Road (blue line in Fig. 6).

Waterways were surveyed by foot in an upstream direction, with the location of redds and suitable spawning gravels logged onto a GPS receiver. Surveys were conducted with the stream at baseflow, and between 10 am and 4 pm, when the sun was sufficiently high above the horizon, minimising water-surface glare. Polaroid™ sunglasses were used to improve the detection of trout redds and fish. Records and waypoints were kept regarding the location of redds, the size and number of observed trout, and aspects of riparian management which could affect trout spawning.

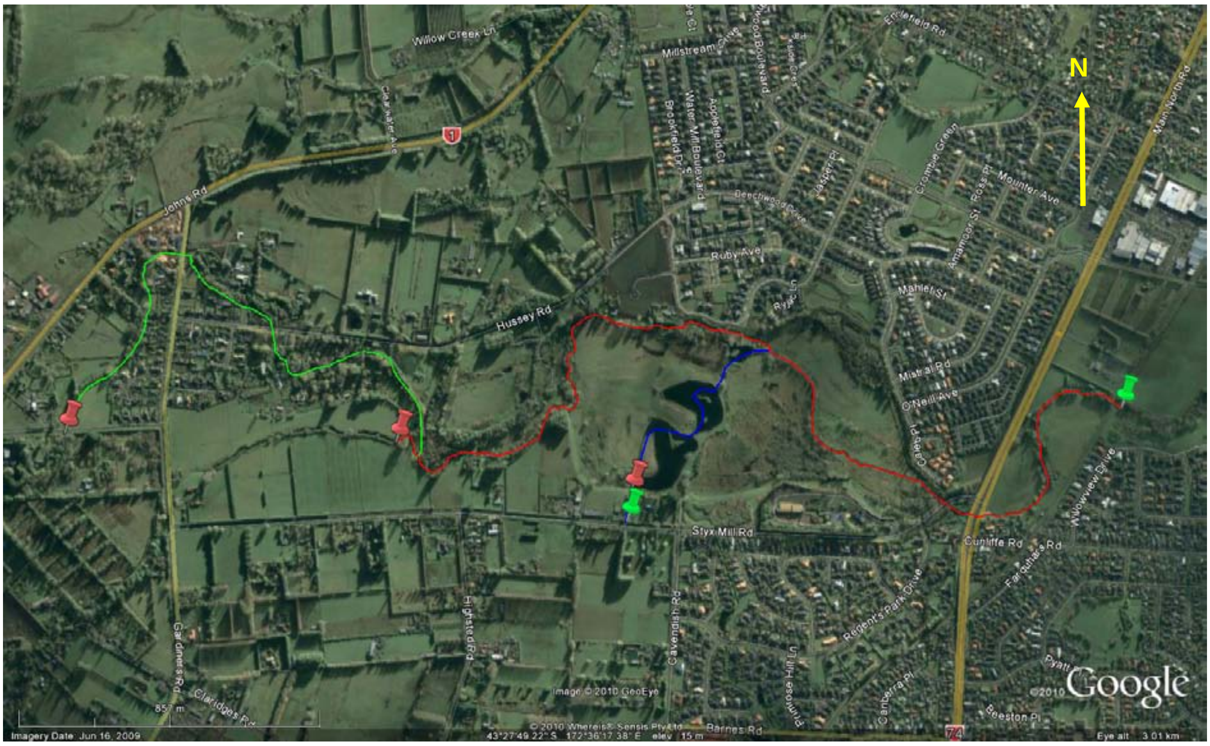

Figure 6. Extent of trout redd survey in Google Earth, waypoints from each survey already formatted.

4.2 Analytical methods and approach

Older GPS data was converted to Google Earth format (*.txt and *.gpx to *.kmz) Distancing data was derived from Google Earth software. SYSTAT 12 was used to derive the dit plot and modes.

5 Results

5.1 Smacks Creek fish community

The catch from each of the three survey sites are tabulated below (Table 3). Trout fry catch rates were relatively low, with the highest recorded upstream of the Styx River confluence, and a lower number upstream of Gardiners Road. In the reach near Redwood Aquatics, trout fry were sparse. Trout fry ranged in size from 32 mm to 43 mm (Fig. 7).

The catch rate for the two upstream sites – the site adjacent to Redwood Aquatics, and the site upstream of Gardiners Road – is combined and graphically portrayed with the catch rate obtained from the downstream site near the Styx River mainstem (Fig, 8). Catch rates from the upper Smacks Creek have declined over time, but the relative dominance of trout and longfin eels in the catch is still present. In contrast, the catch in the lower Smacks Creek was dominated by shortfin eels, but trout fry numbers were also higher there than in the upstream reach. There is no earlier data from the lower Smacks Creek to compare this information.

A single adult brown trout was recorded from upstream of the Styx River confluence (Fig. 9). Shortfin eels were found at each of the three sites, but most common at the site near the Styx River. Low numbers of large longfin eels were captured from each of the three sites.

Table 3. Smacks Creek fish catch results.

Site	Species	Abundance (1st pass, 2nd pass)	Number per 100 m^2	Length, or length range (mm)
Immediately upstream of the Styx confluence	Brown trout adult	1	0.4	320
	Brown trout fry	8, 2	4.1	32-41
	Upland bully	2, 0	0.8	45-46
	Longfin eel	2, 0	0.8	530-530
	Shortfin eel	19, 0	7.7	112-440
	Unidentified eels, 2nd pass	15	6.1	Not measured
At Redwood Aquatics	Brown trout fry	1	0.6	42
	Common bully	1	0.6	43
	Longfin eel	3	1.9	430-500
	Shortfin eel	1	0.6	320
Upstream of Gardiners Road	Brown trout fry	3	3.1	34-40
	Shortfin eel	2	2.1	230
	Longfin eel	1	1.0	485

Figure 7. Trout fry from Smacks Creek, illustrating the range of captured sizes.

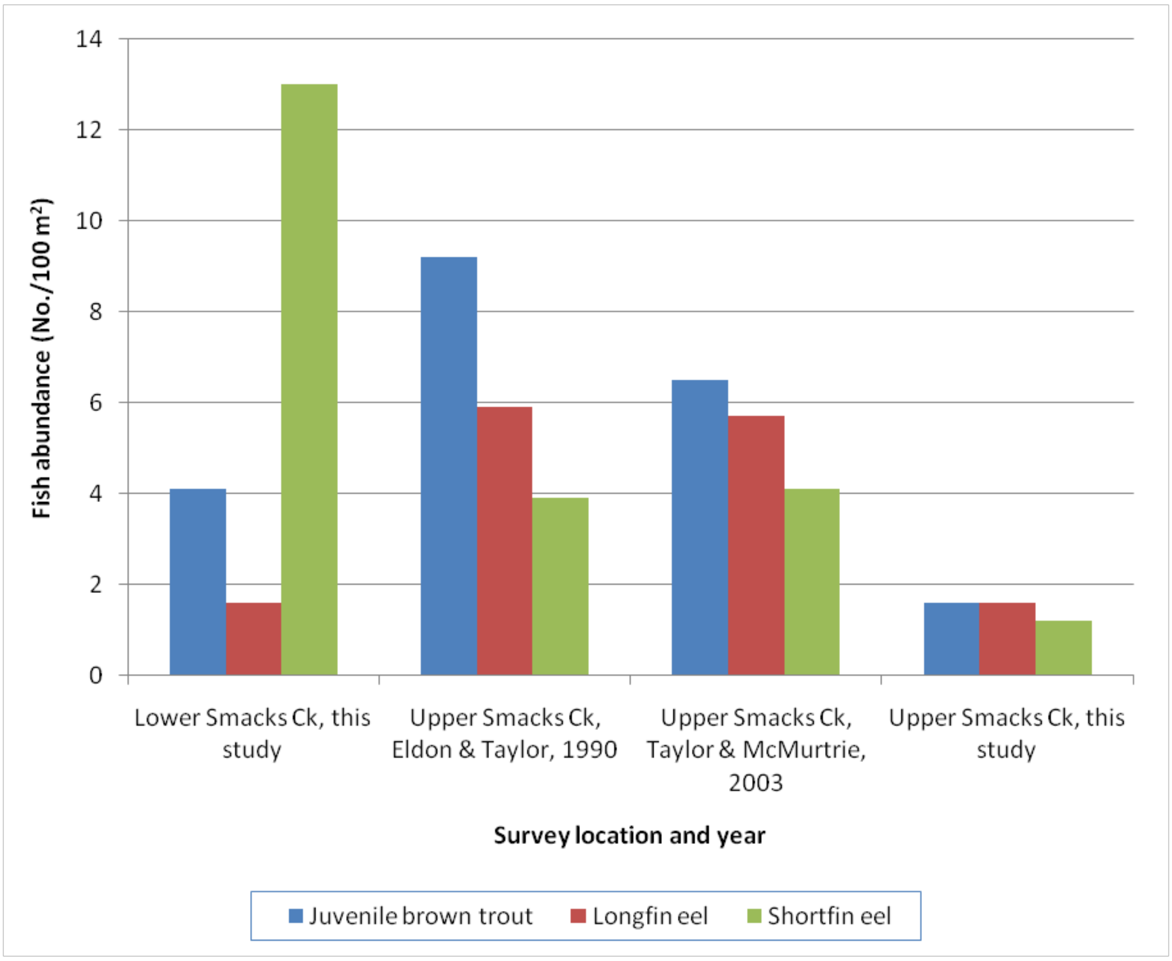

Figure 8. Fish catch in the Smacks Creek, upstream of Husseys Road. Catch data from this study is compared to catch rates from tow other studies using similar fishing techniques. Data is based on total catch, therefore statistical variation cannot be estimated.

Figure 9. The single well-conditioned adult brown trout fished from Smacks Creek. Upon recovery, this anaesthetised fish was returned to its resident habitat.

5.2 Kaputone Stream fish community

Only common bully (*Gobiomorphus cotidianus*), upland bully (*Gobiomorphus breviceps*), and inanga (*Galaxias maculatus*) were collected from the Guthries Road/Ouruhia Reserve site and only common bullies were recorded from the Belfast Road site (Table 4). No redfin bullies were recorded in the catch. Eels were recorded from both sites, but were not identified in the field. The physical habitat at both sites was silted, and regarded as wholly unsuitable as redfin bully habitat (Fig. 10).

Table 4. Sampling results from Kaputone Stream. No data = n.d.

Site	Species	Catch abundance	Number per 100 m^2
Guthries Rd/Ouruhia Reserve	Common bully	41	14.8
	Upland bully	3	1.1
	Inanga	3	1.1
	Unidentified eels	Not counted	n.d
Above Belfast Road	Common bully	6	1.1
	Unidentified eels	Not counted	n.d

Figure 10. The streambed at the Ouruhia Reserve site was covered by silt and filamentous algae.

5.3 Lower river brown trout survey

The locations of trout noted in the lower river are depicted in Fig. 11, and their details provided in Table 5. A total of 18 positively identified trout were observed travelling upstream, with approximately 26 trout observed while drifting downstream. Two large dead trout was seen on the bottom of the river, although the cause of the death could not be surmised. Only one trout was categorised as small. Also observed was a large shoal of small fish, which may have been one of inanga or smelt.

The distribution of observed trout was clustered, with three groups of observed trout downstream of the Marshland Road bridge (0m-830 m downstream distance), in the straight reach distant from the Lower Styx Road (1670 – 2230 m), and the river's re-approach to this road (4000 – 4411 m)(Fig. 11).

Table 5. Tallies of Brown Trout observed in the lower Styx River.

Upstream Travel				Downstream Travel			
Waypoint	**Number of fish**	**Size class**	**Comments**	**Waypoint**	**Numbe r of fish**	**Size class**	**Comments**
1	1	Large	700-800mm	12	1	Large	
2	1	large		13	1	Large	
3	4	large	Dead	14	1	Medium	
4	1	medium		15	1	Large	
5	1	large	>600mm	16	1	Large	
6	1	large		17	1	Large	Dead
7	1	large		18	1	Large	
8	1	large		19	2	Large	
9	1	Medium		20	1	Medium	
10	1	Medium		21	1	Large	Dead (same as waypoint 3)
11	1	Small		22	1	Medium	
32	3	Medium		23	1	Large	>600mm
33	1	Large	>600mm	24	12	Medium	? mullet
Total trout	**18**			25	19	Medium	? mullet
				26	~30	Small	?inanga
				27	1	Large	>600mm
				28	1	Large	>600mm (same as above?)
				29	7	Medium	
				30	2	Medium	
				31	2	Medium	
				Total trout	**26**		

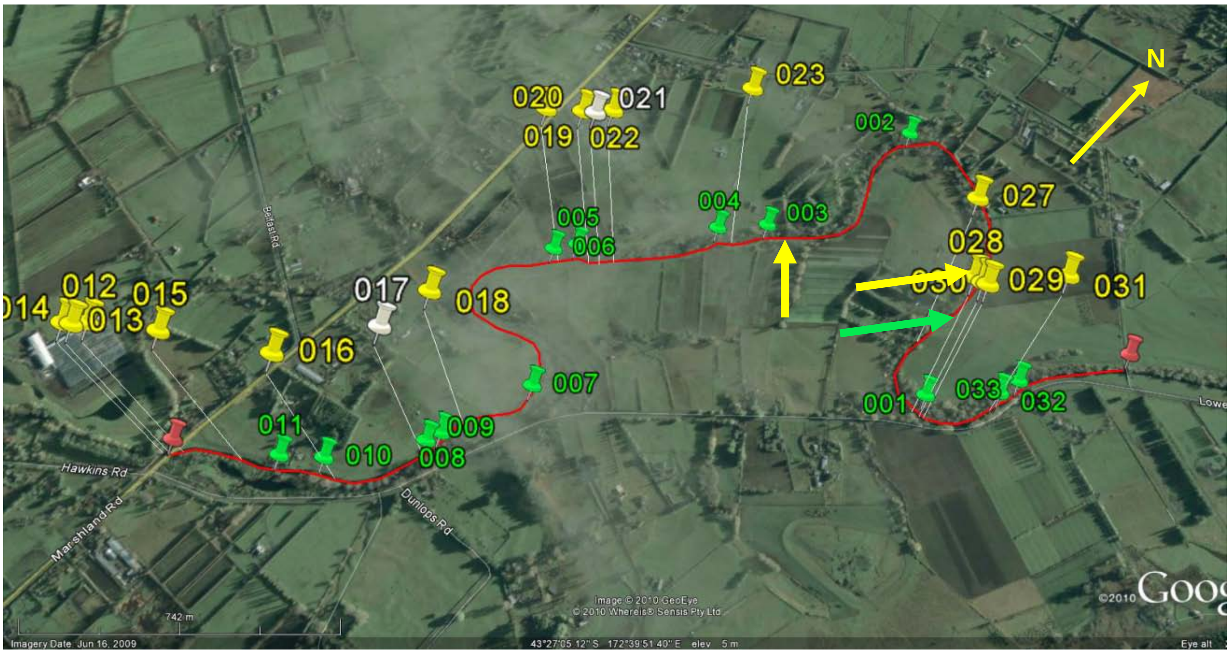

Figure 11. Locations on the lower Styx River where trout were recorded. The red line indicates the river course. The green pins denote trout observed while travelling upstream, and the yellow pins indicate the locations of trout recorded while travelling downstream. The white pins = dead trout, yellow arrows = yellow-eyed mullet shoals, green arrow = inanga school.

Live trout were noted at 33 locations, but some of those would have been repeat sightings. Only one observed trout was classified as small (i.e. < 150 mm F.L.).

Two large shoals of 12 and 19 fish each were sighted which might have been yellow-eyed mullet (wpts 24, 25 in Table 5, and arrowed in Fig. 11). Mullet are known to be present in that reach of the river (N.Z. Freshwater Fish Database). They have been deleted from the trout census, as have the suspected inanga school . The remaining numbers of live trout recorded were: 17 when working upstream, and 23 when working downstream. One of the latter was almost certainly counted twice, because the trout had a tendency to swim off rapidly downstream on our approach. Therefore, there was a mean number of 19.5 trout in the surveyed reach, most of which were in the large (>300mm long) category, and several were very large. Over the 4.6 km surveyed, this count equates to 4.2 trout per kilometre.

5.4 Trout spawning survey

There were five main trout spawning reaches in the Styx River. These are graphically depicted in Fig. 13, and were:

1. the upper Smacks Creek in the vicinity of Gardiners Road (Reach 1)
2. Smacks Creek and Styx river reaches within 200 m of the Smacks Creek confluence (Reach 2)
3. a reach within the Styx Mill Conservation Reserve (Reach 3)
4. a long reach in the vicinity of the Main North Road (Reach 4),
5. and a short reach in a boxed drain near Styx Mill Road (Reach 5)

In App. I (Fig. i-v), close-up graphics are provided for each of these reaches, with an overlay of the redd distribution from the last (2005) survey (Taylor 2005b). The late-season (i.e. August) 2005 survey covered the same river reaches as in 2010.

The upper Smacks Creek (Reach 1) was almost totally unutilised in 2010, with only one redd each recorded upstream and downstream of Gardiners Road (App. I, Fig. I). The reach downstream of the City Firewood yard still contains wood chip debris which is probably from that source (Fig. 12). However, the debris may have entered the channel prior to the yard being fenced in 2007.

Figure 12. Woody debris in the channel of Smacks Creek, approximately 95 m downstream of the City Firewood Yard (photo 11/7/2010).

For Reach 2, in the vicinity of the Smacks Creek confluence, the reach has become less utilised for spawning trout over time. Only one redd was excavated this season, compared to 9 in 2005, and 5 in 2000 (Table 6, App. I, Fig. ii). Four partially excavated redds were recorded just downstream of the confluence during the early survey, but these had not been completed when the reach was revisited in September. At the time of this survey, former spawning gravels in the most downstream reaches of Smacks Creek were obscured by a thin layer of periphyton (Fig. 14), with slower reaches totally silted with a thick layer of decaying leaf litter.

In contrast, numbers of redds in Reach 3 were similar to previous surveys in 2000 and 2005, although redd distribution appeared more clumped and truncated especially in the more upstream reach of Reach 2, with numbers of partially excavated redds which were not completed, or washed out by the time of the second survey. Like Reach 2 , spawning gravels may be being compromised at this location (App. I, Fig. iii).

Reach 4, the long, most downstream reach on the Styx River would appear to have become more productive in respect to trout redd numbers (Table 6)(App. I, Fig. iv). The numbers of redds from Reach 4 was higher in 2010 than in 2005, due partly to the utilisation of the reach downstream of the Main North Road. This reach between the railway bridge and the Main North Road was not used by trout for spawning when it was checked in 2005. Our results also indicate that the section of Reach 4 upstream of the Main North Road was more utilised than 10 years ago, with a more uniform distribution of redds over time (Fig. 15).

Reach 5, a remnant boxed drain reach within the Styx Mill Conservation Reserve, had about the same level of utilisation in 2010, with 3 redds, compared to 4 redds in 2005 (App. I, Fig. v). This drain is better described as a modified waterway, as it appears to possess perennial flow. The waterway was not surveyed during the winter 2000 survey, although 9 redds were reported from the drain during the winter of 1989 (Eldon & Taylor 1990). However, the Styx Mill Conservation Reserve had not been developed in 1989, and the drain spawning habitat probably extended much further downstream than the remaining 81 m.

Taking the catchment as a whole, there has been a reduced utilisation of the upper reaches of the Styx River catchment, and a greater utilisation of the lower reaches, although the total number of redds was the same in 2010 as in 2005. If the longitudinal distribution of trout redds from the three surveys are superimposed, the downstream shift in the modes are apparent (Fig. 16).

Table 6. Total number of fully excavated trout redds from the 5 spawning reaches in the Styx River catchment. See Figure 12 for the location of spawning reaches.

	Trout Spawning Reach						
Year	**1**	**2**	**3**	**Between 3 and 4**	**4**	**5**	Totals
2000	1	5	15	2	6	n.d.	29
2005	5	9	14	3	12	4	47
2010	2	1	13	1	27	3	47
Totals	**9**	**15**	**72**	**6**	**45**	**7**	**123**


1
2
3
4
5
N
stop
stop
start
Johns Rd
Hussey Rd
Glen Oaks Drive
Mill Boulevard
Ruby Ave
Jasper Pl
Talbot Rd
Crombie Green
Mounter Ave
Ross Pl
Amamoor St
Mahler St
O'Neill Ave
Main North Rd
Saracen Ave
Mistral Rd
Willowview Drive
Styx Mill Rd
Farquhars Rd
Highsted Rd
Cavendish Rd
Claridges Rd
Gardiners Rd
Canberra Pl
Beeston Pl
Barnes Rd
840 m
Image © 2010 GeoEye
© 2010 Whereis® Sensis Pty Ltd
©2010 Google
Imagery Date: Jun 16, 2009
43°27'55.05" S 172°36'20.71" E elev 15 m
Eye alt 2.93 km

Figure 13. The five principal trout spawning reaches on the Styx River (ringed) with the 2010 redd distribution indicated. Yellow pins = redds present during the early season (June), and red pins = redds present during late season (September). Reach 4 was utilised by early spawning fish, whereas spawning occurred later in Reaches 2 and 3.

Figure 14. The single, small, completed trout redd recorded from Reach 2, in the lower Smacks Creek (ringed). Much of the substrate had a thick layer of periphyton and filamentous diatoms.

Figure 15. Trout redd distribution from three trout spawning seasons upstream of the Main North Road; blue = 2000, white=2005, red/yellow = early/late 2010 spawning surveys.

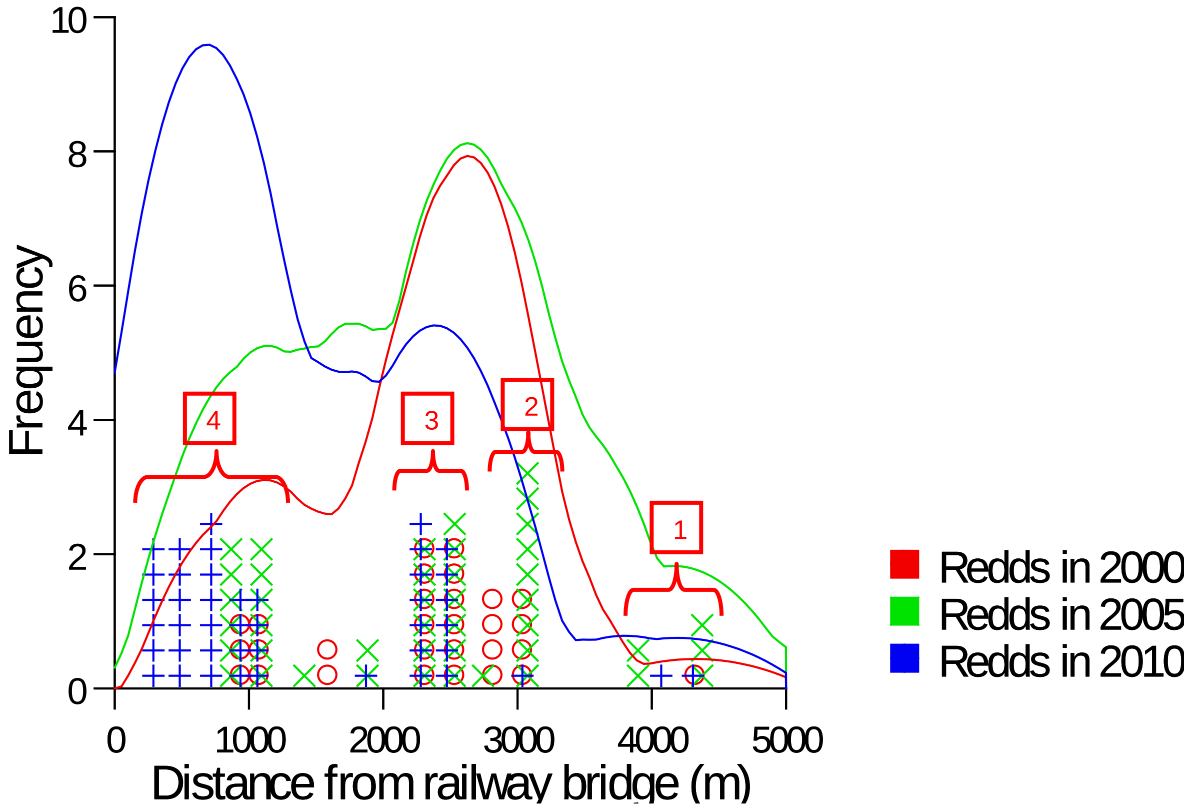

Figure 16. Dit frequency histogram indicating the temporal shift in the longitudinal distribution of fully-excavated trout redds along the course of the Styx River and Smacks Creek. The reaches relating to each of the modes are indicated. Note the minimum survey distance in 2000 was 900 m.

5.5 Inanga Spawning in the lower river.

In May 2010, similar to previous years, inanga eggs were concentrated near the tidegates, especially on the true right bank, with several eggs also recorded about mid-way on the true left (western) bank (Fig. 17). The grassy vegetation utilised by the spawning inanga is shown in Fig. 18a, with a close-up of the main egg masses in Fig. 18b. The eggs were of a similar stage and had eyed.

Figure 17. Red pins = egg searches yielding a negative result, and the green pins where inanga eggs were found.

Figure 18a. Two egg nests (yellow arrows) on the true right tank near the tide gates. The eggs from these habitats are shown in Fig. 18b.

Figure 18b. A multitude of well-developed inanga eggs (which appear as white spheres, arrowed) adhering to the root hairs of tidally submerged grasses.

6 Discussion

6.1 Smacks Creek fish community

Smacks Creek has long been noted for is value for both invertebrates and fish (Taylor & McMurtrie 2003). The reach of Smacks Creek between Gardiners and Husseys Road was found to have a diverse invertebrate fauna in 2003, with six caddisfly species, and the common mayfly *Deleatidium* . Such mayfly/caddisfly communities are increasingly rare within the Christchurch Area, and more consistent with that of similarly-sized rural waterways. While an update on the invertebrate community was beyond the brief of this study, we are aware the invertebrate community is monitored by the voluntary Living Laboratory Monitoring Group, and invertebrates' sensitive to water quality are still present at this location.

In terms of fish values, the Gardiners-Husseys Road reach, and Smacks Creek generally, has been known to support native fish values and trout spawning (Eldon & Taylor 1990; Taylor 2005b; Taylor & McMurtrie 2003). In this study, for the two upper Smacks Creek sites, we recorded a similar fish fauna as in previous studies from Smacks Creek, with the catch numerically dominated by small trout and longfin eels. This is the pattern observed in the earlier studies (see Fig. 8), although catch rates of all fish were markedly lower in the later studies.

The general decline in catch rate is considered to be due to decreasing fishing pressure across the studies. The 1990 study involved a high-powered generator machine, 4 personnel, two fishing passes, a large fished area (305 m^2), and a stopnet. The 2003 study also used a downstream staked stopnet, but the population estimate was based on one fishing pass over 94 m^2, and a pack-pack powered machine of lower power than the 1990 fishing unit. The recent study was based on one fishing pass over 304 m^2, a backpack fishing machine, but without a downstream stopnet. The downstream stopnet would be useful for capturing fleeing trout. Thus, it is considered that trout numbers have declined in the upper Smacks Creek, but possibly not to the extent reflected by these numbers. A standardisation of fishing pressure and technique would assist in drawing conclusions about temporal changes in fish populations over time.

At a localised habitat level, shortfin eels tend to be associated with reaches which contain more silt, in which this species take refuge during the day. In the 2003 Smacks Creek study (Taylor & McMurtrie 2003), four reaches with distinct physical characteristics were selected, and the highest numbers of shortfin eels were found in the reach with deep (mean = 8.6 cm depth) sediment. In sections with more exposed gravel (70-80% cobble or gravel), shortfin eels were almost totally absent.

There is little fish data on lower Smacks Creek. Other than this study, there is only a NZFFDB record of longfin eels being identified from a fyke net downstream of Husseys Road (NZFFDB Rec # 28345). Fyke nets are quite selective for eels. Shortfin eels were much more abundant in the reach near the Styx River confluence, and this may be related to its more down-river location, and higher levels of silt and diatom cover present.

An important ecological role for Smacks Creek is to provide refuge for juvenile trout (fry, and parr) before they develop and enter the recreation fishery in the lower river. Therefore, fish migration routes are important between the spawning and rearing grounds in Smacks Creek, to the maturation habitat in the lower river. This point was made in the 1990 report, where an absence of trout redds upstream of Redwood Aquatics was attributed to the lack of fish passage (Eldon & Taylor 1990). It is our understanding, although this has not been rigorously assessed, that fish passage through the pond network is now possible, and that trout from the lower river can now spawn upstream of Redwood Aquatics. It was noteworthy that a number of large longfin eels were captured during the Smacks Creek survey, as they were in 2005. The large eels would be effective predators on young trout, and the provision of cover for fry would be important for maintaining the quality of the rearing habitat for trout.

Another issue in the upper catchment, is organic pollution sources from the City Firewood yard (upstream of Gardiners Road), which has been the source of wood chips and other woody waste in the past (Taylor & McMurtrie 2003). This material had accumulated in the slower-flowing reaches downstream of Gardiners Road, modifying the physical habitat for invertebrates and fish. A recommendation of the 2003 report was that the waterway be fenced and planted, and this was ultimately enforced by Environment Canterbury Compliance staff (Figs. 19a,b). However, the woody material is still present, and it is unknown if it is new wood waste which is finding its way into the channel, or its of past origin but is very slow to rot down.

Figure 19a. Photo 8th August 2005. Sawdust and chips entering the channel.

Figure 19b. Photo 2 Sept 2010. Recent riparian fencing and planting to prevent sawdust from entering Smacks Creek. Some improvement to the riparian fencing and sparse planting on the (true) right bank would be beneficial to instream habitat by intercepting loose wood chip material.

Another important reach which is clearly changed since our 2003 study was the reach downstream of the City Firewood yard, between Gardiners and Husseys Roads. This riparian zone of this reach has been changed due to the removal of the heavily-shading willow tree canopy, and the development of a canopy of native trees. This has caused more sunlight exposure to the stream channel, inducing some minor increase in periphyton growth (Fig. 20). This is expected to lead to a change in the invertebrate fauna towards algal-piercing and grazing species.

These two reaches which straddle Gardiners Road would benefit from ecological enhancement. The Smacks Creek Esplanade Reserve requires more overhanging vegetation to provide refuge areas for trout fry to evade eel predation. Shading of the habitat is important for this reach, and the retention of north bank shade trees was recommend in the earlier report on this reach prior to the reserve's development (Taylor & McMurtrie 2003). We re-iterate here the importance of shading and recommend the installation of medium-height (height > 2m) native trees along the north bank to preserve instream values. However, stream-side seated areas could be installed to provide public amenity along this attractive stream.

We accept the work that City Firewood has undertaken to protect instream values, although the riparian fencing along the south (true right) bank requires a more robust structure if the sawdust piles are to remain at this location. The riparian planting needs to be denser to support the steep bank, and inhibit the movement of woody material within the banks from entering the stream channel.

Figure 20. The removal of large shading trees and overhanging vegetation on the north bank has led to markedly more sunlight exposure to Smacks Creek. This has facilitated the growth of waterfern, duckweed, and emergent soft herbs (e.g. monkey musk) along the margins.

6.2 Trout spawning in the Styx River – temporal trends

The following sections discuss changes in the five principal trout spawning reaches in the Styx River catchment, working in an upstream to downstream direction. That is, from the redds located in Smacks Creek upstream of Gardiners Road, downstream to those located downstream of the Main North Road. Previous data is drawn from the initial winter 1989 study, followed by the three GPS-based surveys in 2000, 2005, and 2010.

6.2.1 Smacks Creek (Reaches 1 & 2 in part)

Smacks Creek was subject to a trout spawning survey in June 1989, and just one redd was recorded downstream of Willowbank Reserve (Eldon & Taylor 1990). At the time, the low redd count was considered to be due to two factors. First, the development of the ponds at Willowbank Reserve caused the loss of significant spawning gravel. This conclusion was based on information that, in the 1950's, prior to the Reserve's pond development, the reach occupied by Willowbank was an important trout spawning reach (Eldon & Taylor 1990).

The second factor considered for the low redd count was that control structures within the reserve were preventing or inhibiting trout migration (Eldon & Taylor 1990), although this was not investigated thoroughly. At the time, the downstream boundary fence did pass through the water channel (pers. Obs), and was of a small enough mesh size to inhibit trout passage. This was thought to lead to local stocks of trout either side of the barrier, a phenomenon considered to take place in the upper Avon catchment, where impassable weirs restrict trout passage (Eldon & Kelly 1992). However, a check on fish passage in 2005 showed that the instream fencing material had been removed (Taylor 2005b), and, in that season, Smacks Creek appeared relatively productive in terms of the number of completed redds, including upstream of the Willowbank Reserve.

This season (2010) trout redd numbers in Smacks Creek were again low, as in 2000, although the presence of several fry upstream of the City Firewood Yard in spring 2010, indicating some successful egg development from the few redds located upstream of Gardiners Road. Thus, we consider that habitat quality constraints are now restricting trout spawning in Smacks Creek, and access problems are likely to be secondary. Alternatively, sufficient trout spawning habitat is available for the adult trout population in the reaches downstream.

Higher numbers of captured fry were located near the Styx River confluence in November 2010, and this reach used to have a concentration of trout redds, especially in 2005. However, only one trout redd was recorded from this reach during the winter of 2010, and this contradiction may be due to the gradual downstream movement of trout fry with development. Based on trout redd counts, it would appear that the utilisation of this reach for trout spawning looks variable over time, as does most of Smacks Creek, at least in recent years (App. I, Fig. ii). This may be due to variation in the quality of the spawning gravels at that location. The 1990 report talks of the gravels being otherwise suitable, except for presence of clogging silt and filamentous algae. In 2010, the reach was described as having a layer of silt and filamentous diatoms. It is possible that the nutrient level downstream of the Willowbank Reserve is elevated, due to unrestricted public feeding of fish. If nutrient levels are elevated, than this has potential to increase primary production in the reach downstream, although most of the downstream reach is heavily shaded by trees, and production would be light-limited. In this context, recent overseas research has also indicated that trout eggs have a higher chronic sensitivity to nitrate than previously assumed (Hickey 2000). This assumption was based on trout having a fairly tolerant response to acute sensitivity to nitrate, but this would not appear to be the case for trout eggs (Hickey 2000). A recent study on the water quality within redds from local rural and urban rivers indicated that nitrate levels could be a problem in spring-fed rural catchments with agricultural landuse (Taylor & Burdon 2010).

However, it is unknown whether a female trout excavating a trout redd (i.e. a hen fish) would be sensitive to nitrate levels, or other aspects of water quality. However, we consider it quite possible. For example, trout have preferences to the physical environment in which redds are excavated, and it is possible that water quality cues may provide behavioural stimuli. For example, olfaction in the salmon group is highly developed to the point that the water chemistry of the natal stream can be distinguished from other waterways nearby.

Under the circumstances, we consider it prudent to obtain water quality samples from trout spawning reaches to see if utilisation, or egg survival, can be co-related to water quality (e.g. nitrate, biological oxygen demand, dissolved oxygen and ammonia), to check that water quality is not limiting trout reproduction and recruitment. Over the last three winters, Aquatic Ecology Limited has developed and manufactured a large number of intra-gravel probes used for obtaining water samples from brown trout redds. They were modified from probes used successfully on American salmon redds. These probes have been used recently to undertake pioneering studies on water quality and hydraulics in New Zealand trout redds in local streams (Houdayer 2010; Taylor & Burdon 2010).

6.2.2 Styx Mainstem (Reaches 2 in part, 3, 4)

There are two main spawning reaches on the Styx River which extend downstream from the Smacks Creek confluence. In this document these reaches are classified as reaches 2 and 3. In the past, both of these reaches have proven to be well utilised by spawning trout in excavating redds. However, numbers of redds during the 2010 survey were markedly less than those recorded previously from the more upstream Reach 2, near the Smacks Creek confluence (Fig. 21). For Reach 2, a group of four partially excavated redds were reported immediately downstream of the confluence during the early survey in July 2010, but there were still recorded as uncompleted during the 2nd survey in September. Further, an old redd from a previous season, was found at that location. Redd numbers in Reach 3 were nearly the same as previous surveys, although there was a perceptible trend of a truncation of redd distribution at the upstream end of Reach 3, and a clustering of redds, and a high proportion of partially excavated redds which were not completed. We consider that issues of spawning gravel quality could be affecting the integrity of Reaches 2 and 3, and is worthy of further investigation.

The increase in redd numbers in Reach 4 has largely compensated for lower redd counts in upstream reaches, Reaches 1 and 2. The riparian management along a high proportion of Reach 4 has improved over the years. In 1999 and 2000, much of the spawning reach upstream of Styx Mill Road was accessible to beef stock, and they regularly forded the river through the shallow spawning gravels (Ross 1999; Taylor 2005b). Further most of the reach downstream of the Main North Road was accessible to stock. By 2005 the spawning reach upstream of Styx Mill Road had been fenced from stock (see Fig. 8 in Taylor 2005b), although stock could still access the reach downstream of the Main North Road. By 2010, after about 8 years of no stock access, the spawning reach upstream of Styx Mill Road was bordered by small trees and long grass, and all of the stock on the northern bank of the river downstream of the Main North Road were removed or fenced from the channel. However, some stock access and stock-accelerated bank erosion is present on the south (true left) bank.

There is previous history of trout spawning downstream of the Main North Road, but they were not recorded during the winter 1989 survey, though local residents spoke of some annual trout spawning just downstream of the Main North Road Bridge (Eldon & Taylor 1990). The reach from the Railway bridge to the Main North Road was also checked in 2005, and no redds were reported. Our finding, therefore, of good numbers of trout redds over a long reach of river is therefore a welcome and compensatory change from the decline in redd numbers reported from the upper catchment.

This increase in utilisation in Reach 4 is likely to be directly attributable to lower stocking levels and better fencing. This increase in utilisation of this downstream reach for trout spawning in graphically illustrated by the increase in the mode in Fig. 16. A recent field experiment demonstrated that water quality, and trout egg survival, within artificial trout redds in reaches fenced from cattle was significantly higher than those in partially unfenced, or totally unfenced reaches (Houdayer 2010).

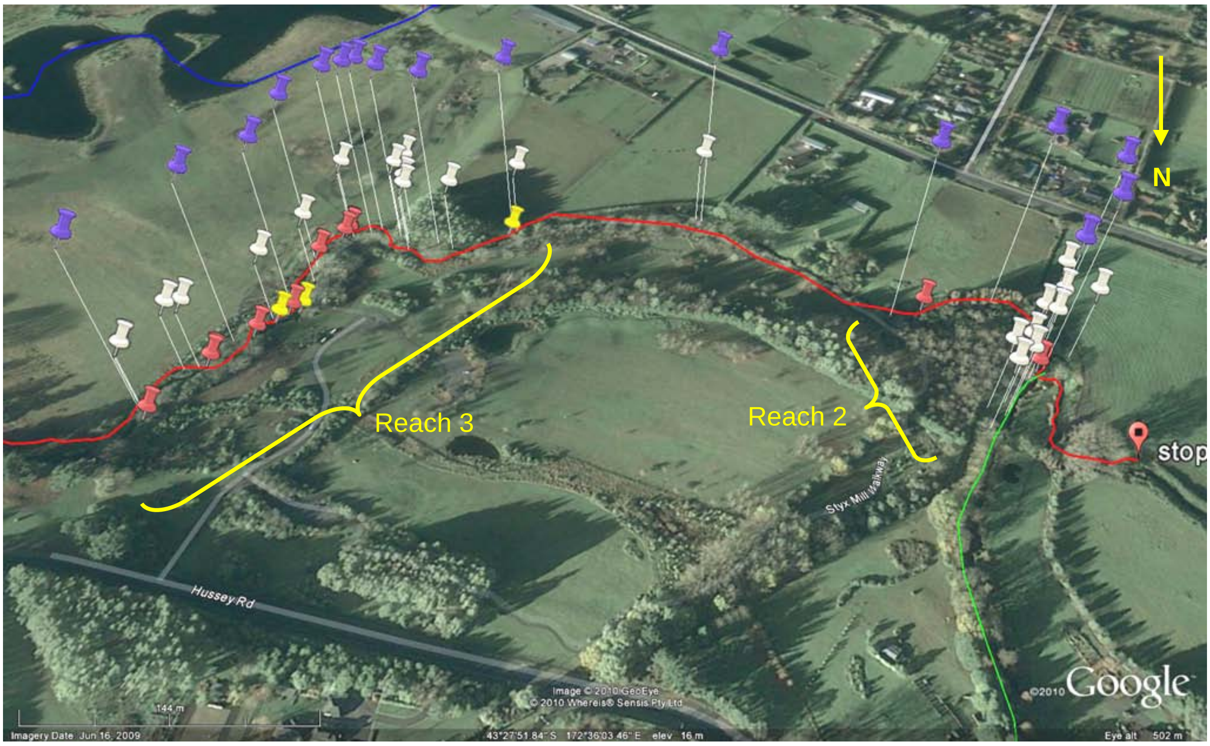

Figure 21. The locations of brown trout redds on a 800 m reach of the Styx River (red line) downstream of the Smacks Creek confluence (green line). Blue pins=2000 redd survey, white pins = 2005 redd survey, red/yellow pins = 2010 redd surveys). The map is inverted.

6.2.3 Unnamed boxed drain – Styx Mill Conservation Reserve

It is considered that this waterway relates to one described in the inaugural Styx River fish report under 'lateral drains" in Taylor and Eldon (1990), where it was described, prior to the development of the SCHR ponds, as "enters the mainstem upstream of Cavendish Road", and which is referred to as "First Lateral drain" in Table 6 of that report. In the winter of 1989, a total of nine redds were counted from this drain, although it is clear that a good portion of the trout spawning habitat in the downstream reaches has been modified into pond habitat. This trout spawning reach was not surveyed in 2000, but was surveyed in 2005 and in 2010 (see App. I, Fig. v), and it is apparent that this drain has low-level consistent use.

6.2.4 Comparison of spawning reaches and habitat suitability with early surveys

It is apparent that some loss of trout spawning habitat has occurred over the decades. For example the upper reaches of the mainstem, near Claridges Road, was utilised by some trout during the winter 1989 survey (3 redds *in* Eldon & Taylor 1990). However, owing to siltation, no trout spawning habitat, nor redds were recorded, when the reach was checked in the winter of 2005 (Taylor 2005b). Further, in that season, the most upstream 200 m reach was dewatered. It was considered futile to re-survey this reach, because headwater gravels tend to remain permanently silted owing to their lack of flushing capacity.

Based on physical descriptions, the Styx River mainstem between Gardiners Road and the confluence of Smacks Creek appears to have changed little. Near the Smacks Creek confluence, "promising" gravel was reported in 1989, but no redds were reported. In 2005, a single trout redd was reported from this reach, but none were recorded in 2010.

The 1989 report pre-dates GPS technology, and the distribution of trout redds between the Smacks Creek confluence and the Styx Mill Road bridge is not described in detail, probably owing to the lack of definable geographic features along its course. However, it is apparent that the focus of trout spawning activity was broadly similar to what has been reported during the more recent surveys. It is also clear that in the winter of 1989, stock access to the trout spawning grounds was less apparent, and the condition of the spawning gravel was considered 'good' with riparian stands of gorse providing cover for trout (Eldon & Taylor 1990). The redd count between the Smacks Creek confluence and Styx Mill Road was 55 redds, significantly higher than what has been recorded since, and with a grand catchment total of 64 redds.

The next trout survey was conducted by Fish and Game in 1999 (Ross 1999), followed by another survey the following winter (Taylor 2005b). Both of these surveys report of significant damage by stock trampling and bank erosion along the mainstem spawning reach, and redd counts were decreased there by 50% in the 2000 season. A field experiment at the time indicated that sedimentation rates in artificial redds, in the middle and lower reaches of the reach between the Styx Mill Conservation Reserve and the Railway Bridge, were just within acceptable limits within the reserve and severely impacted towards the Railway Bridge, and stock-accelerated erosion of the banks would have exacerbated this trend (Dolphin 2000).

By 2005, stock access has been eliminated in the reach between the Styx Mill Conservation Reserve and the Styx Mill Road (Taylor 2005b), with a doubling of the number of reported redds from this reach (Reach 4). This last winter (2010), the number of redds in Reach 4 that were upstream of Styx Mill Road was the same as 2005 (12 redds). The decreased redd counts in the Smacks Creek area (Reach 2) were largely compensated by the resumption of trout spawning downstream of the Main North Road. Overall, the Styx River catchment redd count (47) this year was the same as 2005, and much higher than the 2000 total of 29. As sediment inputs decrease, trout spawning habitat improves, then trout fry recruitment should lead to a large trout population, with a subsequent further increase in spawning activity.

The physical spawning habitat in upper Smacks Creek, was poor based on the 1989 description, which, while claiming "very good" gravel was present, if was overgrown with filamentous algae (Eldon & Taylor 1990). However, the upstream habitat appears to have generally improved, as has fish access, so that the upper reaches (i.e. Reach 1) now supports limited trout spawning. It is hoped that impact mitigation measures through the City Firewood reach, and the Smacks Creek Esplanade Reserve will enhance further spawning there. However, trout redd numbers have fallen in the lower reach of Smacks Creek (Reach 2), with many abandoned partial redds excavated this year. Water quality issues may be a problem, which is a water quality investigation in this reach is recommended.\

The 'first lateral drain', or Reach 5, had a moderately high utilisation in 1989, but there suitability for trout spawning has been markedly decreased due to development of the ponds in the Styx Mill Conservation Reserve. Since then a number of redds have been recorded in the 80 m remnant downstream of Styx Mill Road, and there is no evidence that the habitat quality has been compromised.

Kaputone Stream was considered to provide no trout spawning habitat in 1989, and this was also the case when we re-surveyed the catchment in 2005 (Taylor 2005b). However, Kaputone Stream has potential for improvement, should the reduction of stock activity at the Silver Fern holding paddocks lead to reduction in stock-accelerated erosion along the banks of the Kaputone Stream. Therefore, it would be prudent to re-survey the middle reaches of the Kaputone Stream during the next spawning survey of the Styx River, to establish if trout spawning is taking place then.

6.3 Lower river brown trout survey

To the best of our knowledge, passive fish-observation surveys have not been conducted on the Styx River, although the waterway possesses clear water at baseflow. We suspected that trout population densities would be low and therefore a long survey reach would be required to obtain meaningful fish counts. We initially trialled a team of three divers, but the cold water, and the reduction of water clarity by the disturbance of bottom silt made this technique impractical. However, using the boat seemed to be a practical and economic alternative.

In an assessment of the accuracy of drift-dive estimates, researchers using Nelson rivers concluded that raw drift-dive counts provide a useful index of relative abundance of measuring temporal changes in fish abundance over a standardised reach. However, a large proportion of the trout population may not be seen where fish cover is high. We concluded that a boat survey, when an observer has bank-to-bank visibility offers a safe alternative to drift-diving, and provides a means of replicating survey results. Other significant advantages include fieldworker safety, and the facility to use GPS positioning.

It has been found that drift diving records only about 25-50% of the actual trout population, because fish under the cover cannot be seen and are not counted (Young & Hayes 2001). Our count is likely to have been similarly under-represented, although, like drift-diving, repeat boat-drift surveys over the same reach should allow a relative assessment as to the size structure and abundance of the trout population. Moreover, using a powerful spotlight, it would also be possible to use the technique on still summer nights to enumerate the eel population, which are a nocturnal species. Similar to the trout, there is no data on the number and size of mature eels in the lower river.

However, there are no earlier census data with which to make a comparison with our estimate (4.2 trout/km), and it is difficult to compare these data with surveys from other rivers. However, this would put it in the lower end of the range of 27 New Zealand river reaches where trout were counted by drift-diving (Jowett & Hicks 1985), on a par with the upper Kakanui River, which had the third-lowest density recorded in that study.

6.4 Kaputone Stream fish community

The only bully species that we collected from Kaputone Stream were common bully and upland bully. Redfin bullies were not collected and are unlikely to be present in the stream. This is because it is unlike the known habitat for the species, which is typically rapidly-flowing stony streams (McDowall 1990). Tony Eldon described it as inhabiting "…low altitude waters, where it favours stable rough-cobbled streams of medium velocity. The less stable smooth-cobbled waters of the eastern South Island are not really redfinned bully habitat" (Eldon 1989). A study in South Westland, where it was recorded at 80 sites, found that the habitat of the species usually had gravel or cobble bed (Taylor 1988). In contrast, at both sites in Kaputone Creek the stream bed consisted of fine sediment, and the water velocity was slow (see Fig. 10). In addition, the species is rare in Canterbury, and Eldon was unable to find any on Banks Peninsula where it had previously been recorded at times (Eldon 1989). It has subsequently been recorded again from some of those Banks Peninsula site; Charteris Bay Stream, Okains Bay Stream, and Aylmers Stream (pers. obs. M. Taylor), and they are currently the only sites where it is known to exist in Canterbury.

The fishes of Kaputone Creek have been surveyed twice before; firstly as part of a Styx catchment-wide survey (Eldon & Taylor 1990), and the fish fauna of the upper creek upstream of the Main South Road was subsequently surveyed in 2004 (Taylor & McMurtrie 2004). In neither of those was redfin bully recorded. One of the sites that Eldon and Taylor surveyed in 1990 was the same as one that we fished (Guthries Rd/Ouruhia Reserve). The list of species that they recorded during that survey was similar to those we did – inanga, common bully and upland bully – plus shortfin and longfin eels. In addition, the densities of common bully and upland bully that we recorded were similar to those recorded by them; 14.8 compared with 13.1 per 100 m^2, and 1.1 compared with 1.3 per 100 m^2, respectively. It appears likely that the species which had been identified as redfin bully in a recent study (Keesing 2007) was in fact, upland bully.

6.5 Inanga Spawning survey

After an unsuccessful search to locate inanga eggs in 1990 (Eldon & Taylor 1990), inanga eggs were found in 2005, and in 2007 (Taylor & Bradshaw 2005; Taylor & Chapman 2007). The egg masses found in 2010 on the true right bank were in approximately the same location as those found during the earlier surveys. Over the three successful surveys, no inanga eggs have been found on the seaward side of the tidegates, nor further inland than Harbour Road.

The concentration of eggs very close to the tidegates suggests that spawning inanga may be cueing on the interface of tidal seawater and freshwater. There are plans to develop a tidally influenced saltwater/freshwater lagoon area which bypasses the tidegates as part of the Waimakariri Regional Park (Gregory Byrnes; Environment Canterbury, pers. comm.). It is intended that such an area will be ecologically enhanced to facilitate inanga spawning.

7 Recommendations

AEL recommends the following:

1. That the planting along the reach through the City Firewood Yard be augmented this coming autumn to stabilise the slopes and inhibit further transfer of woody material into the channel. The fencing through the City Firewood needs be improved between the stream and the sawdust piles.

2. That shading through the Smack Creek Esplanade Reserve be developed on the North Bank, and that more overhanging vegetation cover be provided for fish refuge.

3. That an investigation be undertaken on intragravel water quality in trout redds in the Styx River, especially Smacks Creek. Water quality parameters of key interest would be nitrate, dissolved oxygen, and biological oxygen demand.

4. That during the next trout spawning survey of the Styx River, that the Kaputone Stream be checked for habitat suitability.

5. That drift-boat surveys continue to be used to monitor stocks of trout in the lower river, and be trialled to assess its suitability for the enumeration of eel populations.

8 Acknowledgements

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10 Appendix I

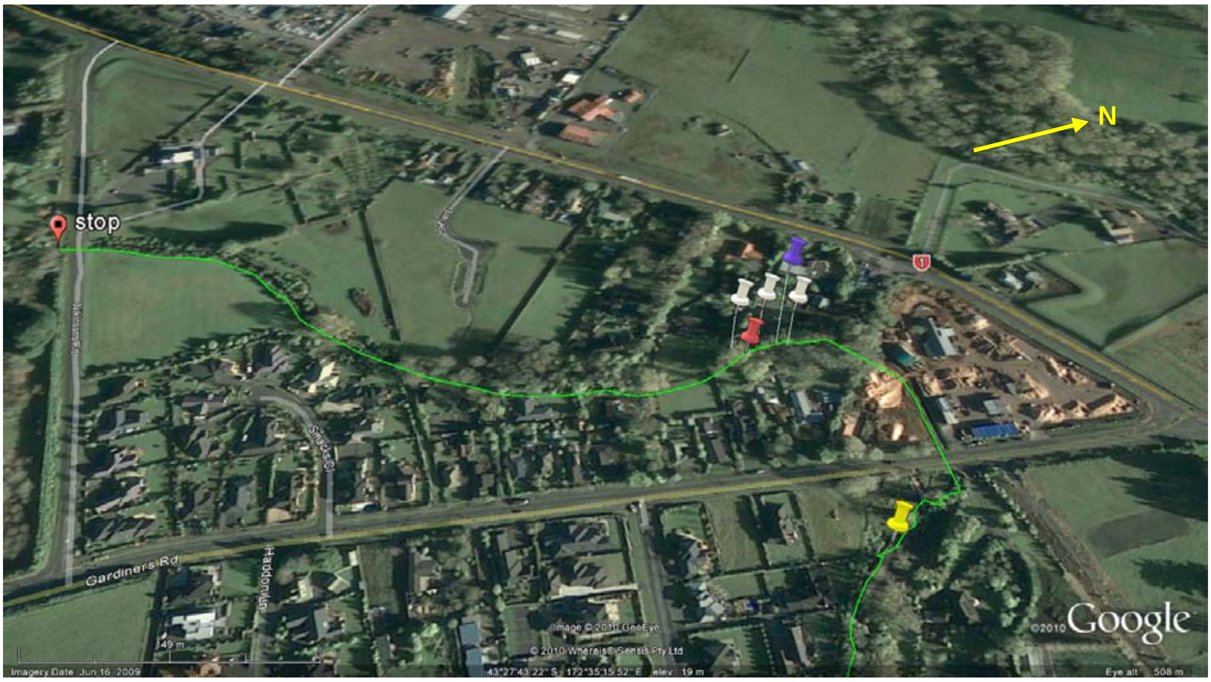

Figure i. The upper reaches of Smacks Creek (Reach 1), green line = water course, white pins = 2005 redds, Yellow pins = early season (June) 2010 redds, red pins = late season (September) 2010 redds, white pins=late season (August) 2005 redds, blue pins = season 2000 redds.

Figure ii. Reach 2 near the Smacks Creek confluence in the Styx Mill Conservation Reserve. Red river course = Styx River mainstem, green water course = Smacks Creek. Red pin = late season (September) 2010 redds, white pins=late season (August) 2005 redds, and blue pines = 2000 redds. Redds in the upper Smacks Creek (Reach 1) can be seen in the top right corner.

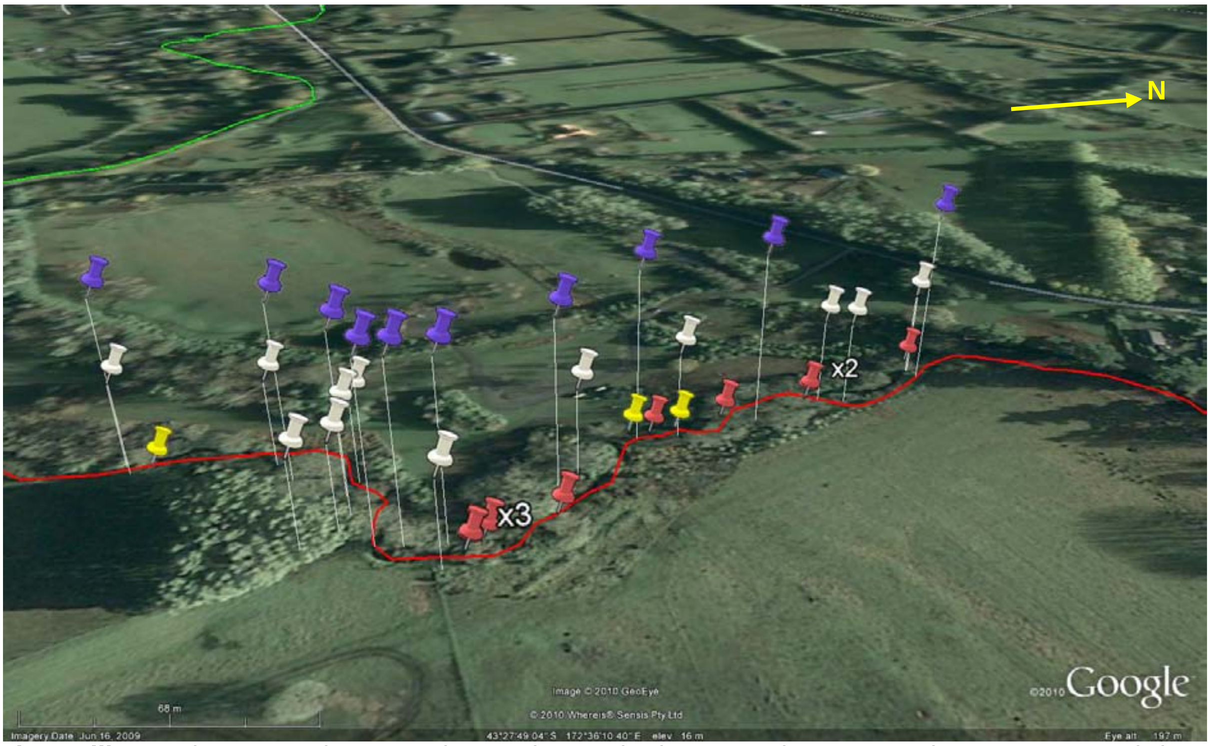

Figure iii. Reach 3 along the Styx River mainstem in the Styx Mill Conservation Reserve. Red river course = Styx River mainstem, green water course = Smacks Creek. Red pin = late season (September) 2010 redds, white pins=late season (August) 2005 redds, and blue pines = 2000 redds. Labelled pins indicate the number of adjacent redds.

Figure iv. Reach 4 along the lower Styx River redd distribution 2005 and 2010 (). Yellow pins = early season (June) 2010 redds, red pins = late season (September) 2010 redds, white pins=late season (August) 2005 redds, and blue pines = 2000 redds.

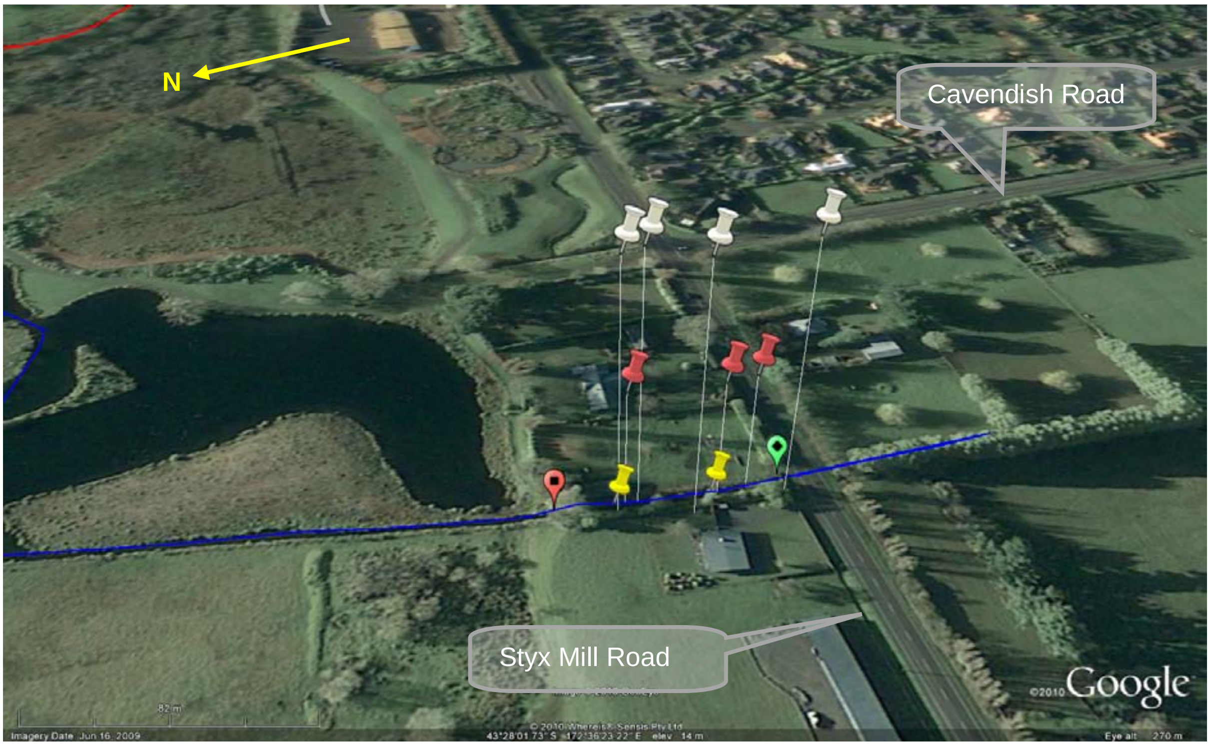

Figure v. Reach 5, a boxed drain west of Cavendish Road utilised by spawning trout (Reach 5). Yellow pins = early season (June) 2010 redds, red pins = late season (September) 2010 redds, white pins=late season (August) 2005 redds.