Fish Values of the Otukaikino River; 2012

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Mark Taylor
Winsome Blair

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The lower reaches of Plantation Creek, Otukaikino River Catchment

Aquatic Ecology Ltd.
PO Box 3254
Christchurch 8140
Telephone/ Facsimile (03) 366-4070
Email: info@ael.org.nz

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1 Executive Summary

This document reports on the first fish monitoring survey undertaken on the Otukaikino catchment on behalf of the Christchurch City Council. This work was composed of the November 2011 monitoring of four previously surveyed sites in the Clearwater development area, three sites in the North Boundary Stream sub-catchment, and four sites in the upper Otukaikino catchment. A variety of physical habitat parameters were also reassessed.

Of note there was a detectable increase in the proportion of sand and silt coverage over the sites generally, and some of this may be due to seismic activity in the catchment following the September the 4th 2010 earthquake.

This survey indicated that the Kaikanui Stream, in the Clearwater Development Area, had eroded significantly over the past decade, but that it still supported a population of lamprey ammocoetes and provided some trout spawning utility. Comparing fish numbers, eel numbers, mostly shortfin eels, were significantly reduced in 2012. At the North Boundary Stream sites, and the upper Otukaikino sites, shortfin eel numbers were also lower than previously. Some reduction in upland bully numbers were noted, but this may reflect seasonal differences between the two surveys.

In the 2012 winter, the catchment upstream of the Groynes was subject to a trout redd survey of the same reaches surveyed during the winters of 2002 & 2003. A redd is the gravel nest made by spawning female trout in the stream gravels.

Based on raw numbers, the 2012 redd count was 47% less than that during the 2002/03 winters. However, unknown to the fish survey team, a number of hen fish were trapped downstream of the survey area, stripped of eggs, and transported to the top of the catchment. This work was undertaken by the North Canterbury Fish and Game Council. Allowing for the effective loss of these redds, and a minor adjustment for a unsurveyed minor tributary, the effective decline in trout spawning activity would have been in the order of 17% less than the 2002/03 winter. However, this trout redd comparison excludes the potentially productive spawning reaches of the upper North Boundary Stream and Stopbank Creek, essentially upstream of the Clearwater Development. Access to this sub-catchment was denied to us during the winter months, although access was granted for the summer fieldwork.

Recommendations are made in respect to better liaison between local government agencies in respect to activities which would compromise environmental monitoring activities, remediation work on Plantation Creek, and specific trout spawning reaches, and further monitoring of lamprey, and trout spawning activity in North Boundary Stream. For the sake of the fishery, it is also recommended that North Canterbury Fish and Game Council return some trout parr or fingerlings back into the fishery.

2 Catchment Description

The Otukaikino River, to the north of Christchurch City, is of rural character, and the northern tributaries are fed directly by shallow groundwater from the near-by Waimakariri River. The catchment is rather ill-defined by ground topography, but would be in the order of 1600 Ha (16 km^2). The main groundwater source for the river is on the private property of “Peacock Springs” (Fig. 1).

Figure 1. The principal groundwater source of the Otukaikino River, entering a disused quarry pond on the property of Peacock Springs (28/8/2003).

Downstream of Peacock Springs, and the Isaac Salmon Hatchery, the Otukaikino gains further surface flow from groundwater, and follows a linear path eastwards adjacent and parallel to McLean's Island Road. Landuse downstream of Peacock Springs and the Hatchery is low intensity dryland sheep grazing, and this landuse is maintained though Isaac's property, and then Shipley's land. The main river enters the Clearwater development approximately 5 km downstream. Through Isaac's land, the watercourse is fenced but lacks tree canopy cover. However through Shipley's land, the main river is lined heavily with mature willow, and other introduced trees and shrubs, and the willow in places, is beginning to choke the channel, especially upstream of the boundary with Clearwater. In some locations on Shipley's land, the willow is being removed on the true left bank, and native trees planted by teams of Periodic Detention workers (Fig. 2).

Downstream of the Shipley land, the Otukaikino River flows through the Clearwater development. This development is composed largely of a large golf course, low-density residential land, and associated service buildings and car parks. Further, a series of large groundwater-fed excavated ponds have outlet outflows into the mainstem, although the riparian zone is largely lined with mature willow trees. Here too, luxuriant willow is beginning to choke the channel, but these are in the process of being cleared in the worst areas. Downstream of Clearwater, the main river enters the Groynes recreational area administered by the Christchurch City Council (CCC). The catchment adopts a park-like setting, although the character of the river remains the same, and is thickly clad in willow, but with pockets of native plantings. For much of its length, stock access is denied by fencing.

Figure 2. The clearing of large willow trees on the true left bank of the Otukaikino River (Shipley's Land, i.e. Island Farm). The riparian zone is now being replanted in native trees and shrubs.

3 Objectives

The objectives of this survey are to:

- Undertake a resurvey of fish values of the ecological monitoring sites in the upper Otukaikino (inaugural survey January 2003)
- Undertake a re-survey of trout spawning activity in the Otukaikino Catchment (last surveyed, August 2002, August 2003)

4 Background information on aquatic ecology

There are two historic Marine Department reports which studied the ecological relationship between eels and trout in the Otukaikino River, and their invertebrate prey (Burnet 1968; Burnet 1969). Fowles completed a MSc. thesis on invertebrate fauna in the Otukaikino downstream of Haul Road and upstream of the current Clearwater area, recently after the river channel had been realigned (Fowles 1971).

Further reports include an early report on fish and fishery values in the Clearwater area, prior to its full development, when algal blooms in the lakes were an issue (Jellyman 1994). This small study predated the development of the Clearwater, but considered in general terms the impact of many of the development options which have since been implemented. A report on the management of the waterways in the Clearwater development was prepared for Clearwater Resort Ltd, including planting proposals, and esplanade widths (Boffa Miskell Ltd 2000). A second NIWA report was prepared the following year, which considered the ecological impact of the diversion of some of the East Stream waters into a Clearwater lake (Bonnett & Jellyman 2001).

Further ecological information on the upper Otukaikino catchment was obtained in pursuit of consenting requirements for the development of a proposed rowing lake, Lake Isaac (McMurtrie *et al.* 2003), which involved obtaining information on trout spawning activity during August 2002 in the catchment upstream of Clearwater, followed by an aquatic invertebrate and fish survey in the upper catchment in January 2003. Additional work was undertaken the following year in respect to a land zoning variation, with a trout spawning survey in the Clearwater area in August 2003 and an evaluation of selected sites (Taylor & McMurtrie 2004). A preliminary water resources assessment for the re-zoning was also undertaken in 2003 (Pattle Delamore Partners Ltd 2003).

5 Methods

5.1 Field methods

5.1.1 Summer survey

A total of 11 sites were re-assessed in the Otukaikino catchment based on a previous inaugural field survey. The original 7 upper-catchment sites were surveyed in January 2003, whereas the four sites in the Clearwater Development were assessed in August 2003.

The survey was undertaken during settled weather, between 9 November 2011 and 17 November 2011. The survey period occurred nine months after the M6.3 earthquake on February 22 2011. For purposes of convenience, we have used the old site numbers from that survey, and these sites are depicted in Fig. 3. At 10 of the 11 sites, every endeavour was made to fish the same reach as previously surveyed. This was relatively easy in the field, due to the accurate GPS fixes obtained at the downstream margins of each site during the 2003 survey, and the use of site photos. However, the 2003 site on East Stream, which was particularly depauperate, was not re-surveyed exactly, but a shallow riffle, a short distance upstream was surveyed instead. A stop net was used at sites where it had been used previously.

Nine of the 11 sites were shallow (mean free-water depth < 0.5 m), and all were surveyed using an EFM Kainga 300 machine. For this study, a voltage setting of 200 - 300V was employed, the minimum level required to achieve an effective electric field for capturing small fish with a current of 300-400 mA. Electric fishing serves only to briefly (approx. 3 seconds) render fish unconscious to facilitate their capture in nets for identification. Overall conditions for fish capture using electric fishing were adequate, owing to the suitable, but low water conductivity, high clarity, and swift water currents. The machine incorporates a timer, which allows the effective fishing time and effort to be recorded. All fish were anesthetised, identified, and measured in the field, before being released unharmed into their resident habitat.

Habitat Assessment

A number of habitat parameters were estimated for each fished site. These included mean flow depth (free-flowing water, macrophyte and sediment), wetted width, and maximum depth within the surveyed channel length. Substrate embeddedness, substrate composition, riparian bank composition, and fish cover were also assessed. Substrate embeddedness is the degree (expressed as a percentage) to which the large substrate particles are buried into the fine substrate material (i.e. sand or silt). Thus, cobbles about a third buried into surrounding silt is considered to be 30% embedded, while a silty stream bed is considered to be 100% embedded (App. I, Fig. i). The overall substrate composition (expressed as a percentage of stream bed area) was visually estimated using modified Wentworth substrate particle sizes. The substrate coarseness index was computed from the substrate composition from each site. The wetted habitat area of each site was approximated by using the mean width (based on three or more transects depending on within-site variation) multiplied by the length of the fished channel.

The composition of the riparian border (i.e. grass, scrub, native etc.) is expressed as a percentage of the two riparian margins extending out to 15 m from the water’s edge. Fish cover is the amount of refugia provided by aquatic macrophytes, instream debris, overhanging bank vegetation, undercut banks, or overhead shade (i.e. directly above the stream bed). These cover components are estimated separately along three equidistantly spaced sectors along each reach, and measured or assessed as a proportion of stream width. The percentage area of the bed with adequate substrate cover (i.e. particles > 60 mm) is then weighted by embeddedness. These cover components are calculated and summed to provide an estimate of total available fish cover.

5.1.2 Winter Trout Spawning Survey

A slow-walk survey was conducted in an upstream direction, visually assessing the river substrate for disturbance caused by trout spawning activity. Substrate visibility was significantly improved by the use of Polaroid® sunglasses, and visibility in the mainstem and tributaries was rated as good to excellent. If possible, surveillance was conducted from the banks, but fencing, dense riparian vegetation, and visibility restraints meant much of the channel through residential land was surveyed in-channel. Photographs of some partially excavated redds, full redds, and brown trout were taken with a digital camera fitted with a polarising filter. A 12 channel GPS (Global Positioning System) receiver was used for geo-referencing trout redds, survey sites, and habitat features.

The 2012 survey dates of surveyed reaches locations are tabulated below, along with the comparisons from 2003 (Table 3). Generally, survey times were about the time of the first survey, in mid-to-late August. An initial late May survey in Clearwater proved to be too early with fish seen but no redds, so this survey was repeated in September, as it was clear that spawning was a little late this year. South Boundary was chocked with willow in 2003, and as this was a similar situation in 2012, therefore no trout spawning survey was conducted in that silted waterway.

Access was denied to fieldworkers for the productive trout spawning reaches in the upper Boundary Stream, due to a dispute between the landowner and Environment Canterbury.

Table 3. Trout Spawning Survey dates in the Otukaikino Catchment.

Reach	Previous Survey	This Survey
Mainstem lower (u/s groynes thru Clearwater)	12/8/2003	30/7/2012, 3/8/12
Mainstem (u/s Clearwater to Peacock Springs)	15/8/2003	10/8/12, 20/8/12, 22/8/12
Kaikanui Stream (Clearwater)	15/8/2003	29/5/12, 18/9/12 (Double pass)
East Stream (Clearwater)	15/8/2003	29/5/12
North Boundary Stream (Clearwater)	14/8/2003	29/5, 18/9/12 (Double pass)
North Boundary Stream (to Greywacke Road)	15/8/2003	Access across property denied
North Boundary Stream, Stopbank Creek (upstream of greywacke road)	10-11/8/2002	Access across property denied
Shinglepit Creek	15/8/2002	22/8/2012
South Boundary (Clearwater)	14, 21/8/2003	Not surveyed
Stillwater (western trib only)	15/8/2003	10/8/2012
Plantation Creek	15/8/2003	10/8/2012

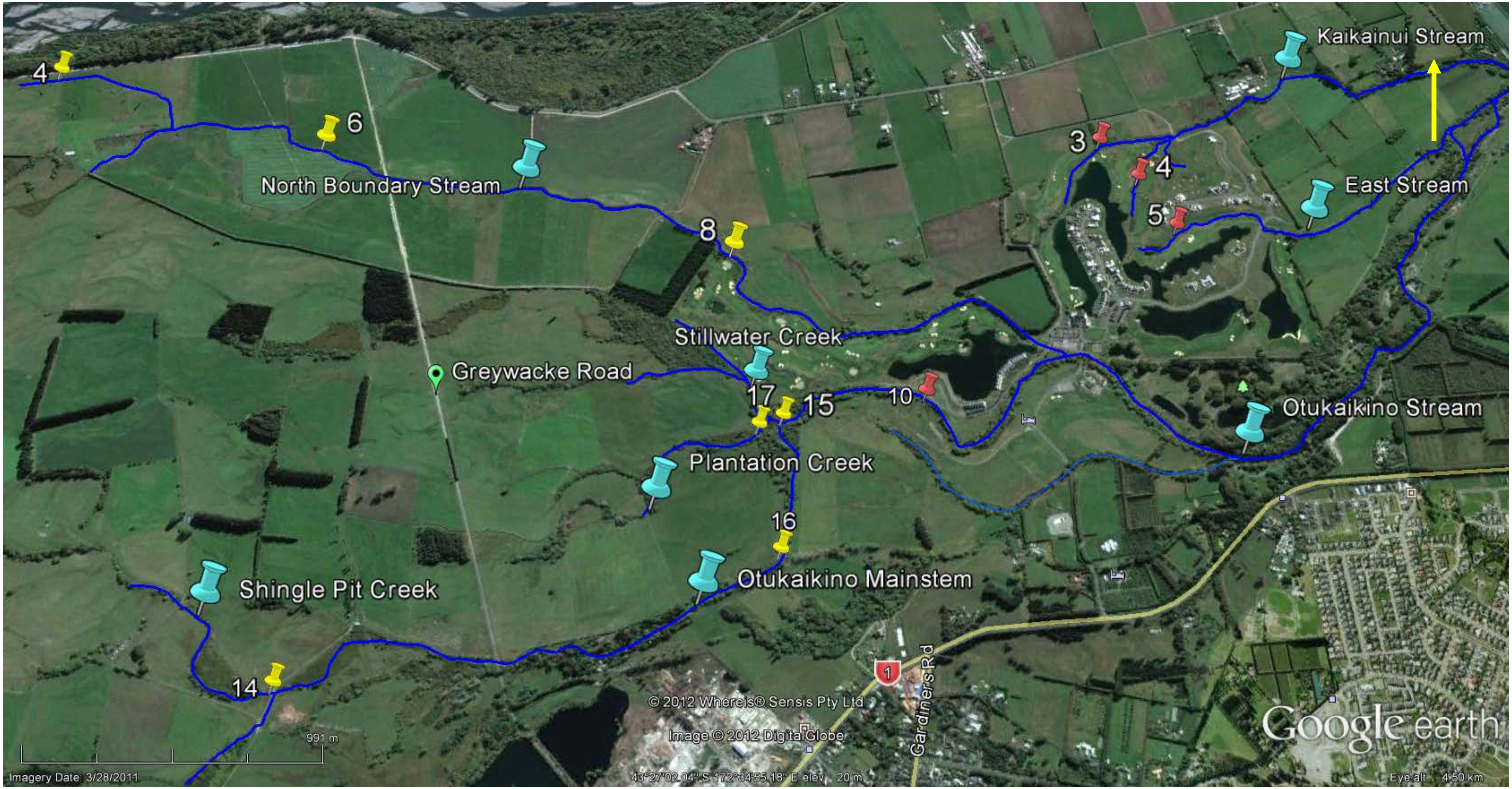


Figure 3. Google map of the 4 Clearwater Resort sites (red pins) and 7 upper catchment sites (yellow pins) sampled in the Otukaikino catchment during the summer season. Blue line = water path, yellow arrow = north. The site numbers relate to the site number from the original survey.

6 Results

6.1 Temporal changes in physical habitat and fish communities

Site photographs of all the monitored fish sites are presented in Apps. II-IV, with site locations and physical habitat attributes tabulated in App. V.

6.1.1 Clearwater Development Area (Lower Otukaikino, Kakanui Stream, East Stream)

An aerial map of the location of the four surveyed sites in the Clearwater Development Area is presented below (Fig. 4). The locations of all fish monitoring sites are tabulated in App. III. With the exception of East Stream, the basic physical habitat attributes of the three re-surveyed habitats are presented below for the purposes of comparison (Fig. 4), with site photographs presented in App. II. Figs. i (a,b).

Figure 4. The four re-fished sites (red pins = Sites 3, 4, 5, and 10) within the Clearwater Development.

Kaikanui Stream, northern tributary, Site 3

Between the sampling periods of 2003 and 2011 the average width of the habitat on the northern tributary of the Kaikanui Stream increased markedly (65% increase) from 2.3 m to 3.8 m (Fig. 5). The physical changes in this monitoring site are apparent in the site photos (App. II, Fig. i(a, b). Mean free-water depth (distance between water surface and the macrophyte or sediment layer), had decreased slightly, although the point of maximum depth had increased. The sediment depth in 2003 was approximately 11 cm, but in 2011 the soft sediment was much deeper, with a mean depth of 66 cm.

Over time there has been an increase in overhanging bank vegetation, emergent plants, and some detrital matter, leading to a modest increase in fish cover, but substrate refuge remained low (Fig. 6). Possibly due to the amount of soft sediment, the abundance of juvenile lamprey (ammocoetes) had increased, with a reduction in both longfin and shortfin eels (Fig. 7). No juvenile brown trout were caught at this site in 2011, despite some recorded in August 2003. The site does not appear to provide habitat for the upland bully, either in 2003 or in 2011.

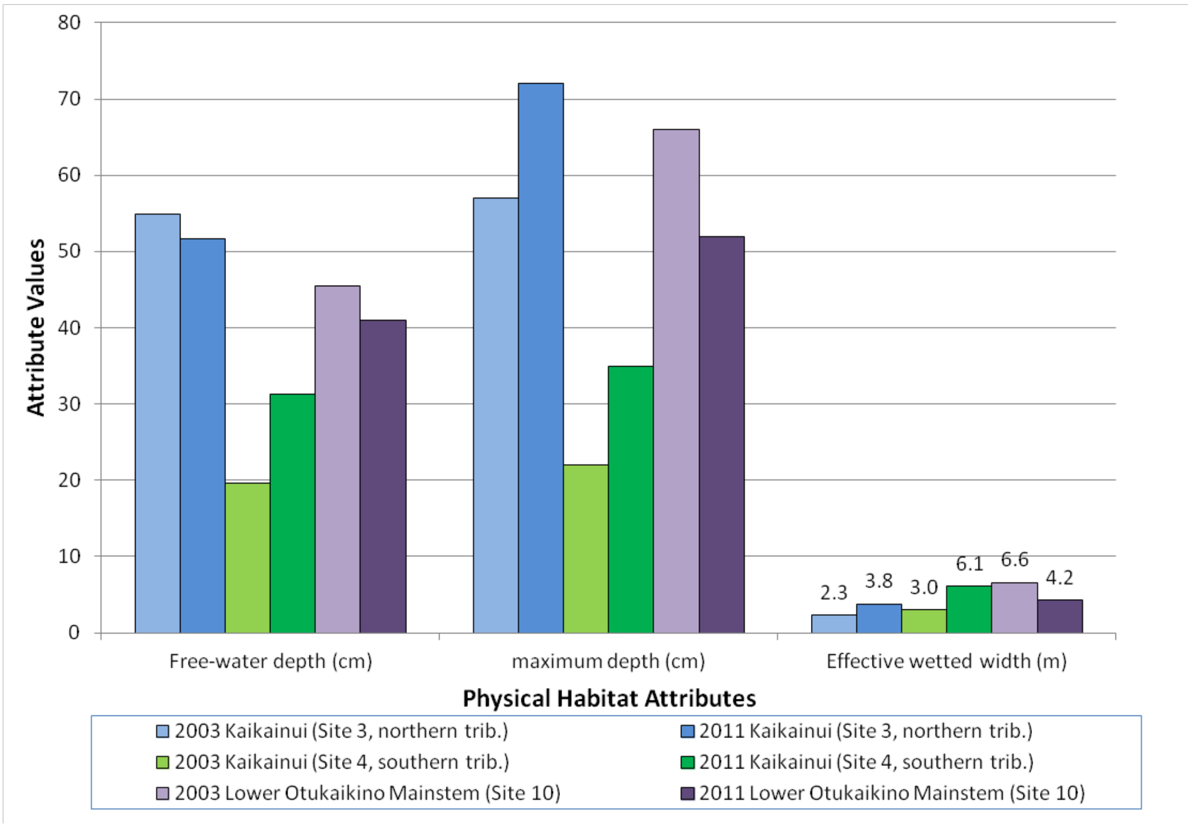


Figure 5. Changes in physical attributes of the 3 re-surveyed sites within the Clearwater precinct. Numerals denote wetted width. The East Stream sites are not comparable and omitted from these comparisons.

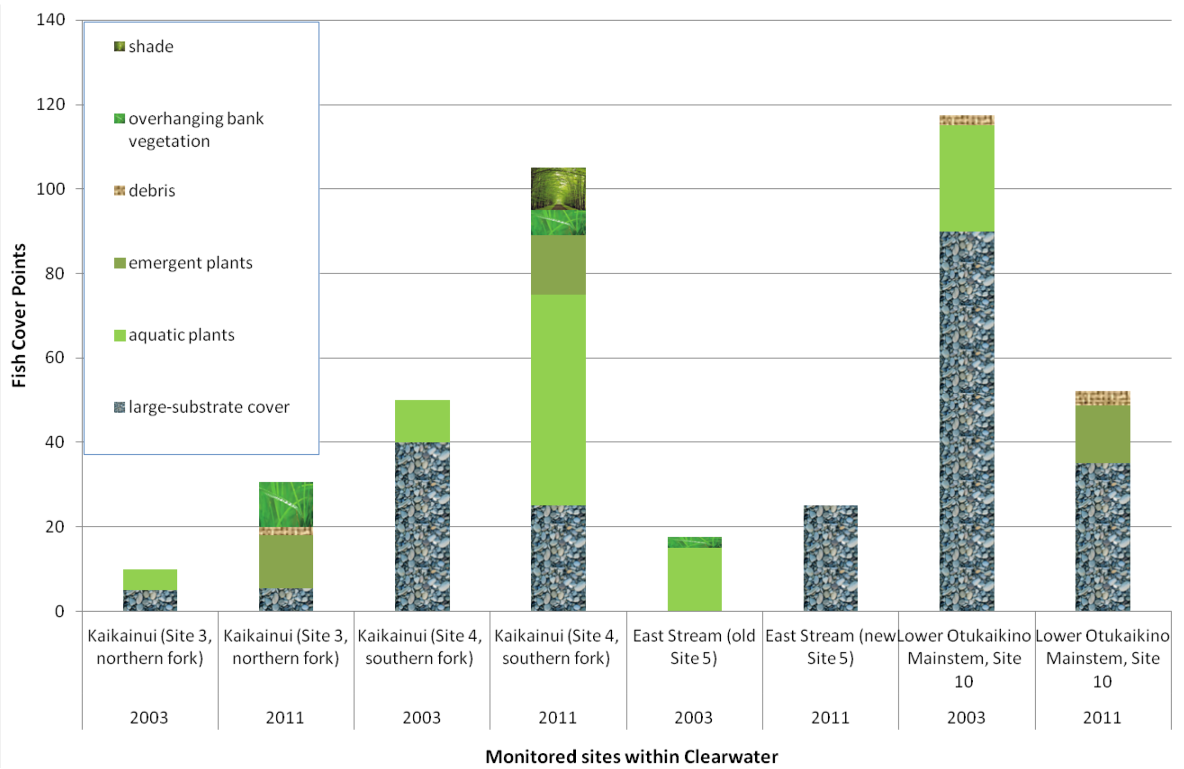


Figure 6. Temporal comparisons of fish cover across four monitored sites in Clearwater from 2003/ 2011. There is no valid 2003 comparison to "new Site 5".

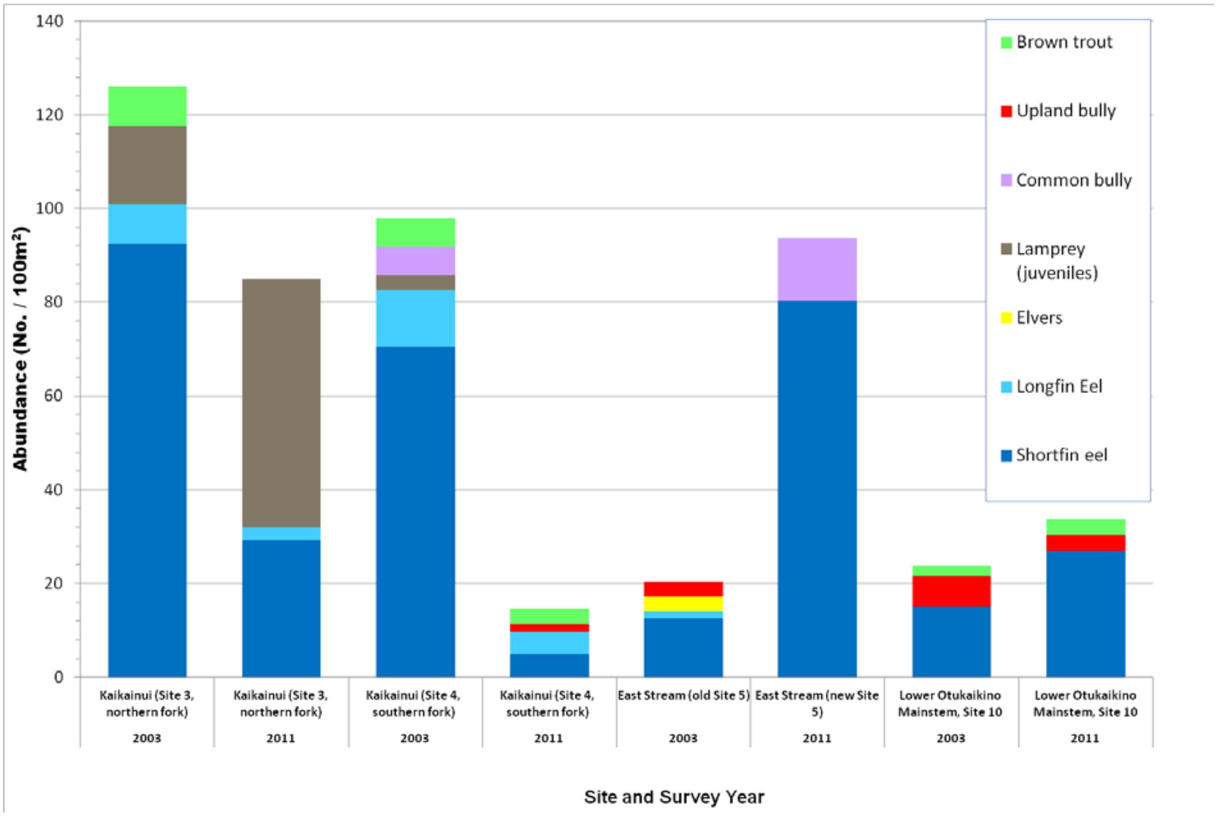


Figure 7. Electric-fished catch abundance for re-surveyed sites in the Clearwater area.

Kaikanui Stream, southern tributary, Site 4

The southern tributary in the Kaikanui Stream illustrated an increase in mean ‘free-water’ depth, and maximum depth over time (Fig. 5). Similar to the northern tributary three was a notable increase in width, with width more than doubling from 2.97 m to 6.13 m. The mean soft-sediment depth, in 2011, was 1 cm, compared to negligible sediment depth in 2003, and there was a consequent decrease in large-substrate cover (Fig. 6). Vegetative fish cover in the southern tributary, likes its northern tributary had increased, with increased macrophyte, marginal emergent macrophytes, and overhead canopy cover from small trees (App. II, Fig. ii (a, b)).

Captured-fish abundance has decreased by over 80%, largely due to significant decrease in the shortfin and longfin eel catch (Fig. 7). The reduction in eels is possibly because of escapement in the emergent weed which has developed at this site. A single ammocoete was recorded from the section in 2003, but while none were identified in 2011, little significance can be placed on that omission. Two common bullies were recorded in 2003, and while none were caught this year, a single upland bully was captured. A single trout fry, and a trout parr was recorded in 2011, compared with two parr last survey.

East Stream, Site 5

This site is close to the original 2003 site, but does not replicate it. The decision not to re-survey the exact same location was because the ponded original site location was considered unsuitable to support significant fish diversity, and therefore insensitive to temporal changes. Therefore a new monitoring site was established a few metres downstream, which was shallower and comprised a riffle-type flow (App. II, Fig. iii (a, b)). Of course, physical habitat comparisons between the two habitats are meaningless, and therefore not portrayed in Fig. 5. However, the fish cover characteristics of the two sites are contrasted in Fig. 6, with the older 2003 site, exhibiting a low level of macrophyte refuge and shading. In contrast, the new Site 5 provides only a modest degree of substrate refuge as riffle habitat.

The biodiversity of the relocated Site 5 was lower than the older 2003 counterpart, as no brown trout were recorded from the riffle, but overall fish abundance was much higher (Fig. 7). Shortfin eels dominated the fauna, in common with all of the Clearwater Area sites, with some juvenile eels (elvers, probably shortfin eels) found amongst the stony substrate. This stony habitat was the only site where elvers were recorded, and along with common bully, were the only two fish species found at this site.

Lower Otukaikino Mainstem, Site 10

The Lower Otukaikino mainstem showed a decrease across all physical habitat attributes, with a decreased water depth, maximum depth, and the channel was markedly narrower than in 2003 (App. II, Figs. iv(a, b)). The decreased depth may reflect a decrease in baseflow. The sediment depth at this site was recorded at 0.3 cm in 2011, but sediment depth was not recorded in 2003. Fish refuge from aquatic and emergent macrophytes was broadly similar across the two surveys, although with a marked decrease in large-substrate cover (large stones) from 90 cover points to 35 cover points. In 2011, about half of the surveyed habitat had a layer of silt obscuring the previously entirely stony substrate.

Actual shortfin eel and brown trout numbers were much the same in 2011 as 2003, with the increase in fish per unit area due to the narrower channel fished (Fig. 7). The number of upland bullies captured decreased slightly from 3 to 1, although this fish was gravid. A single brown trout fry was recorded in August 2003, compared to a single counterpart recorded in 2011.

6.1.2 Synopsis of results from the Clearwater Development Area

Kaikanui Stream has suffered further significant erosion since our site visit in 2003, but its population of lamprey ammocoetes has been maintained. In addition, low numbers of brown trout fry across the Kaikanui and Otukaikino suggests some successful recruitment. The lower Otukaikino mainstem site had clear signs of sediment deposition, but little change in fish fauna was evident. Upland bullies remain sparse in the waterways around the Clearwater development, and the November results suggest recent successful fry recruitment.

6.1.3 North Boundary Stream subcatchment

North Boundary Stream, as a 1st order tributary termed stopbank creek, rises close to the Waimakariri River mainstem, approximately 50 m south of the south bank levee. The flow in North Boundary Stream is hydraulically linked to that of the Waimakariri River. North Boundary Stream flows over a greywacke bed composed of coarse and fine gravel, and flows for a distance of approximately 4.8 km to its confluence with the Otukaikino mainstem. The North Boundary Stream catchment has historically been used for dryland sheep farming and beef production, but in recent years, agricultural intensification has occurred with pivot sprayer irrigation being introduced, and increased stock numbers. Further a small area of the North Boundary Stream catchment has been converted from forestry to irrigated pasture, which is discernible from comparison of the aerial photos from 2005 and 2011 (Figs. 8a, b).

Two of the 3 fished sites (Sites 4, 6) in the North Boundary Stream subcatchment were initially surveyed in January 2003. At that time, the methodology for quantifying fish cover had not been developed, and a generally lower level of habitat assessment was undertaken. However, Site 8, just within the Clearwater Area boundary, was surveyed in August 2003 with a higher level of detail in respect to habitat assessment, and which can be compared to our 2011 results.

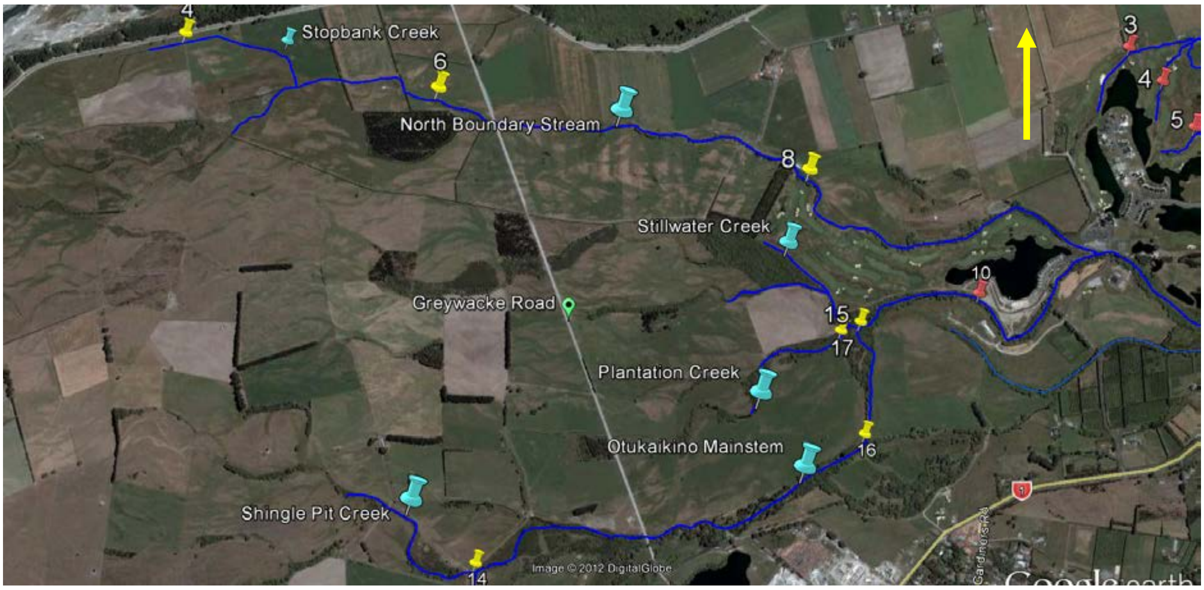


Figure 8a. The 7 re-surveyed sites (yellow pins) in the upper Otukaikino catchment (imagery 2005).

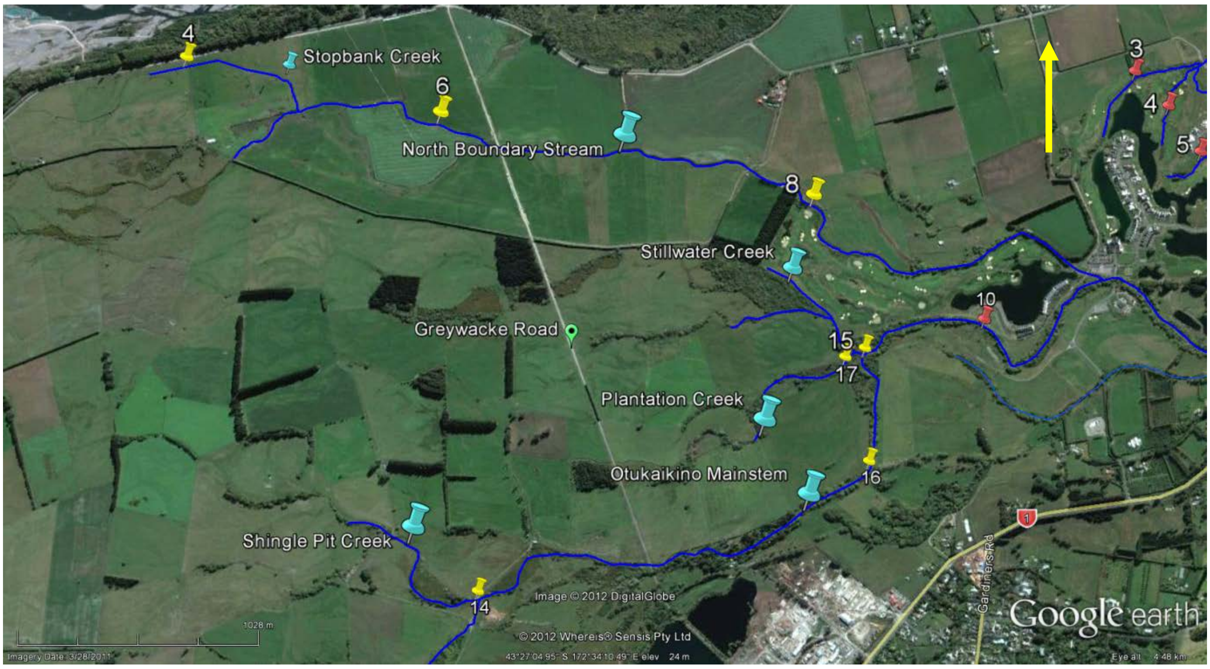


Figure 8b. The 7 re-surveyed sites (yellow pins) in the upper Otukaikino catchment. Site 8 is just within the Clearwater Development Area (Imagery 28 Mar 2011).

North Boundary Stream, Stopbank Creek, Site 4

Site 4 is the most upstream surveyed site on North Boundary Stream, and has widened noticeably since surveyed in 2003 (1.8 m to 2.6 m). This increase in width is depicted graphically (Fig. 9) and in the photograph record (App. III, Figs. i (a, b)). While stock access was clearly possible in 2003, grazing pressure was low, as indicated by the length of riparian vegetation at the time the photograph was taken (App. III, Fig. i(a)). In 2003, the stream had beds of macrophytes present (*Potamogeton sp.*), with fish cover along the margins and with some overhanging grass and sporadic gorse.

In contrast, the 2011 photograph (App. III, Fig. i (b)), not only depicts the wider channel, but that one of the banks has been damaged, possibly as a consequence of recent stream cleaning operations. No plant cover was present along the margins, and the channel, while wider, was more uniform in respect to depth (Fig. 9). Fish cover in 2011 was composed of coarse substrate with some aquatic plants, and a minimum of marginal emergent plant growth (Fig. 10).

The fish species fauna in North Boundary Stream is composed of four species; in order of overall catch abundance there are upland bully, shortfin eel, brown trout, and longfin eel (Fig. 11). In respect to Site 4, all of the brown trout, from both 2003 and 2011 visits, were 0+ year class from spawning during the previous winter. However, the spring (November) 2011 trout fry were smaller (mean length= 35.3 mm) than the summer 2003 trout (mean=71.8 mm), reflecting growth over the 59 julian days between survey dates. Shortfin eel, and upland bully numbers have reduced substantially at this site, although one upland bully was noted as gravid, and two juveniles (lengths = 31, 32 mm) were recorded. Cover was not quantified during the 2003 summer survey, but photographic evidence would suggest that this could be due to reduction in marginal cover.

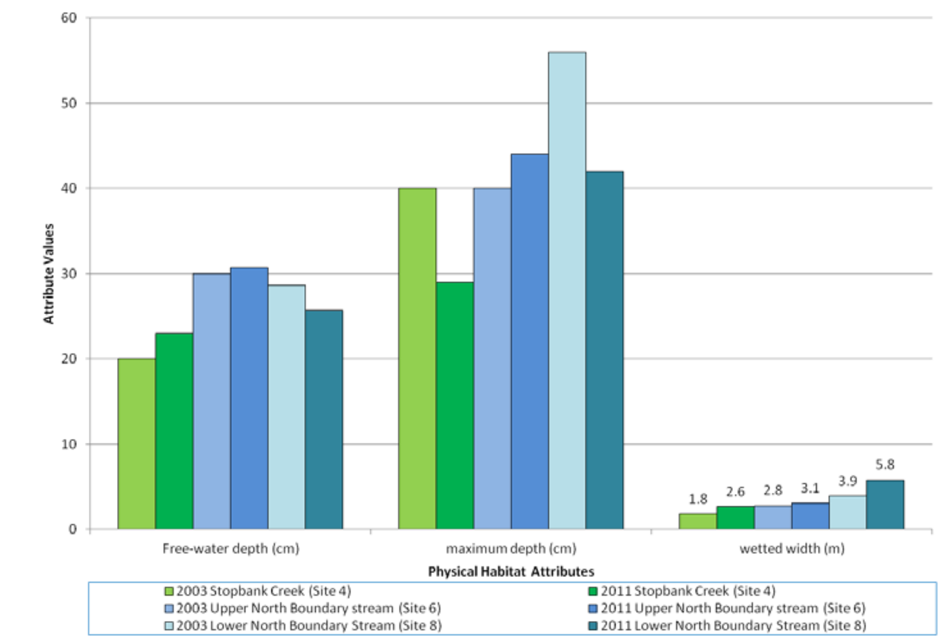


Figure 9. Physical habitat changes in the three surveyed sites on North Boundary Stream. Mean and maximum depths for the 2003 dataset are only approximate.

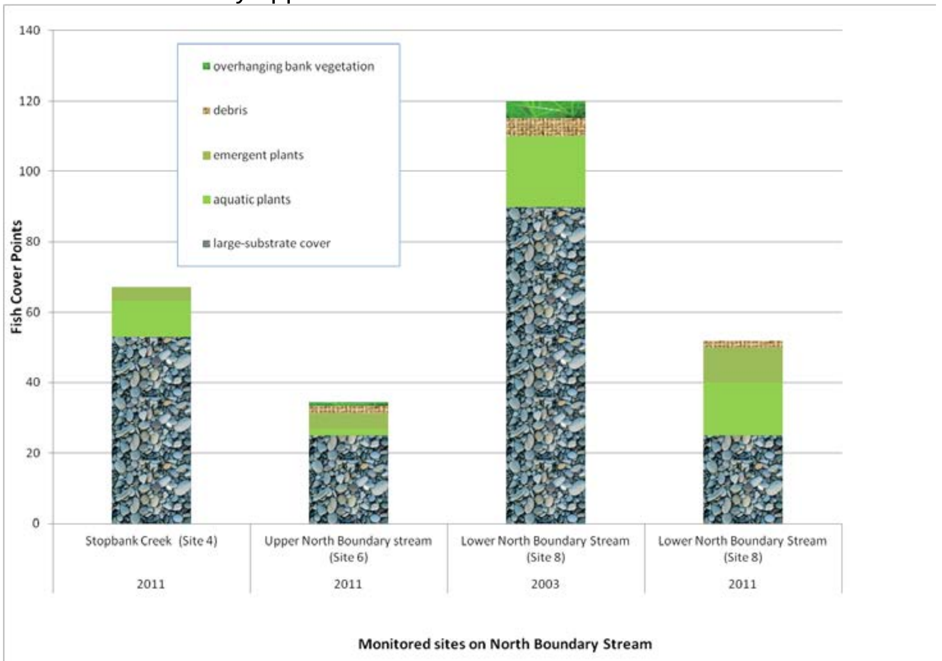


Figure 10. Quantified fish cover points from the three monitored sites on North Boundary Stream. Fish cover was not quantified in January 2003 for Sites 4 and 6.

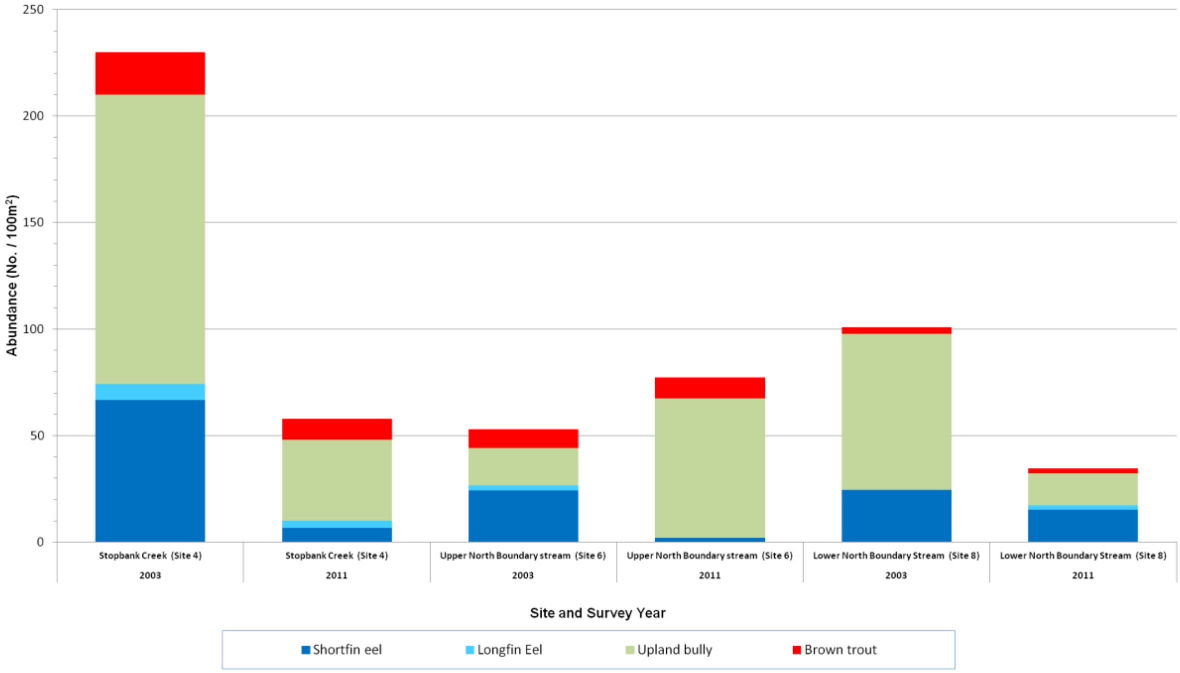


Figure 11. Changes in fish abundance at the three monitored sites on North Boundary Stream.

North Boundary Stream, Site 6

Similar to Site 4 on Stopbank Creek, Site 6, in the upper reaches of North Boundary Stream has experienced some bank erosion with a slight (11 %) increase in wetted width, although there was no little perceived difference in mean water depth, or maximum depth (Fig. 9). In 2003, the site was clearly accessible to stock (App. III, Fig. ii (a)), whereas in 2011, the waterway had been recently fenced on the true right bank, with the true left bank under crops and cleared of riparian gorse thickets (App. III, Fig. ii (b)).

The loss of the gorse thickets, and some associated in-channel gorse debris, equates to the loss of some fish cover. In addition, the substrate composition in 2003 was coarser than in 2011. The 2003 field notes stipulate that larger-size substrate (small cobbles and large gravel) formed 100% of the substrate, whereas in 2011, the large-substrate cover was assessed at only 25%, with the bulk of the substrate composed as fine gravel.

Fish abundance at this site was higher overall, especially upland bullies (Fig. 11). Some of upland bullies were quite small (min length 32 mm), suggesting recent recruitment. Similar to Site 4, several (4) brown trout fry were also caught at this site in November 2011, significantly smaller (mean length 33.9 mm F.L.) than their 2003 counterparts obtained later in the summer (Jan 2003)(mean length 64.8 mm F.L.). There is no indication of a temporal decline in trout abundance at this site, and this habitat still provides spawning and rearing habitat for brown trout and upland bullies.

North Boundary Stream, Site 8

Unlike the two upstream sites, this site was surveyed in the winter of 2003, but is bordered by the Clearwater golf course on one bank and rural land on the other. This habitat has changed significantly, as depicted in the Google™ aerial photos (Figs. 12a, b). Based on Google™ aerial maps, the riparian trees were removed in 2010, with the site quite open in November 2011 (App. III, Figs. iii(a, b)). The reduction in tree cover is reflected in the riparian composition data between the two surveys, with 30% willow tree on the true left (north rural) bank absent in 2011 (AEL raw data). In compensation, the proportion of grass in the Clearwater (south) riparian zone (12 m) has increased from 10% in 2003 to 25% on the Clearwater side with the fairway approaching the water's edge, with 50% of the north rural bank riparian zone now composed of stock feed.

Probably as a consequence of the riparian zone changes, erosion had occurred with a reduction in channel mean depth and maximum flow depth, but a 49% increase in channel width (see Fig. 9). Fish cover has reduced from 120 cover points in 2003, to only 52 cover points in 2011, due to the increase in fine gravel (Fig. 10). However, there was only a slight increase of fines (from 0% to 5%), and 10% embeddedness. The most significant contribution to the reduction in fish cover was due to the loss of coarse substrate refuge (i.e. coarse gravel particles and cobbles), and reduction in aquatic plant cover, and overhanging bank vegetation.

Overall fish abundance was substantially lower in 2011 than in 2003, especially for upland bullies (Fig. 11), but the 2011 upland bullies were large with two gravid females recorded. Shortfin eel numbers were slightly lower in 2011 as well, but a single longfin eel was also obtained during the recent survey. One brown trout, a yearling, was captured at this site in 2003 and a single fry obtained in 2011.

Figure 12a. Site 8, illustrating, the heavily vegetated banks of the North Boundary Stream in April 2004.

Figure 12b. Site 8 quite open, with some poplar tree just upstream of section. Google imagery 28/3/11.

6.1.4 Synopsis of results from the North Boundary Stream subcatchment

A marked increase in wetted width in the North Boundary Stream catchment, especially in Stopbank Creek and the lower site (Site 8). All three monitoring sites illustrated significant changes in riparian vegetation and adjacent landuse. One of the three monitored sites has comparative fish cover data from the two survey assessments, and this site exhibited a marked reduction in this attribute over time.

Overall, there has been a marked decrease in fish abundance across the three monitored sites, with substantial reductions in upland bullies and shortfin eels. However, the presence of both gravid upland bullies, and juveniles would suggest the stream still provides spawning and rearing habitats for these native fish. Longfin eels are less abundant in 2011 than in 2003. Brown trout numbers were about the same, but seasonal effects complications the interpretation of temporal changes in abundance. This is because November sampling (i.e. 2011) you would expect more fry, whereas in January we would expect fewer but larger fish due to attrition through natural mortality. Therefore, all things being equal, we would anticipate higher trout numbers in 2011, but this was not apparent in this dataset.

6.1.5 Upper Otukaikino River mainstem, Plantation Creek, and Shingle Pit Creek

These four sites are situated on catchment waterways within the boundary of 'Island Farm', which has been owned for many years by the Shipley family. Landuse appears to be largely low intensity sheep grazing. In contrast to North Boundary Stream, and its tributaries, changes in the riparian zone are less apparent, and three of these sites have retained their heavily vegetated riparian vegetation.

Sites 15 and 16, on the upper Otukaikino River mainstem, along with Site 17, on Plantation Creek were originally surveyed in September 2003. Plantation Creek is a tributary of the Otukaikino River, which, for most of its length, possesses a densely vegetated riparian zone. This zone is composed of thick willow canopy, which is encroaching into the water channel, and a dense understory dominated by exotic adventives (broom, gorse, blackberry).

During the previous summer, in January 2003, a small tributary of the Otukaikino River, "Shingle Pit Creek" was sampled (Site 14). Shingle Pit creek is a short winding waterway of approximately 1400 m, of which the upstream third is willow-chocked ephemeral channel. Directly downstream of Site 14, Shingle Pit Creek joins the Otukaikino River mainstem, and the habitat is protected by thick undergrowth and a willow canopy.

The following sections provide a summary of the physical habitat and fish fauna changes from each of these four monitored sites.

Upper Otukaikino, Site 16

Wetted widths in November 2011 were similar to those recorded in 2003 (Fig. 13), but the mean and maximum water depths, were slightly less than that recorded in September 2003. This may reflect seasonal differences in groundwater level and baseflow.

The substrate embeddedness of this site had increased from 20% in 2003 to 55% in 2011 (AEL raw data), which is manifested in a sharp decrease in substrate cover for fish, albeit with some compensatory willow tree canopy growth on the true right bank (App. IV, Figs. i (a,b), Fig. 14)). The fish catch at this site was much less (Fig. 15) than in 2003, with a marked reduction in upland bully numbers, and to a lesser extent, shortfin eels. An adult brown trout was seen at this site in 2011, whereas a rainbow trout fry (not indicated in Fig. 15) was identified in 2003.

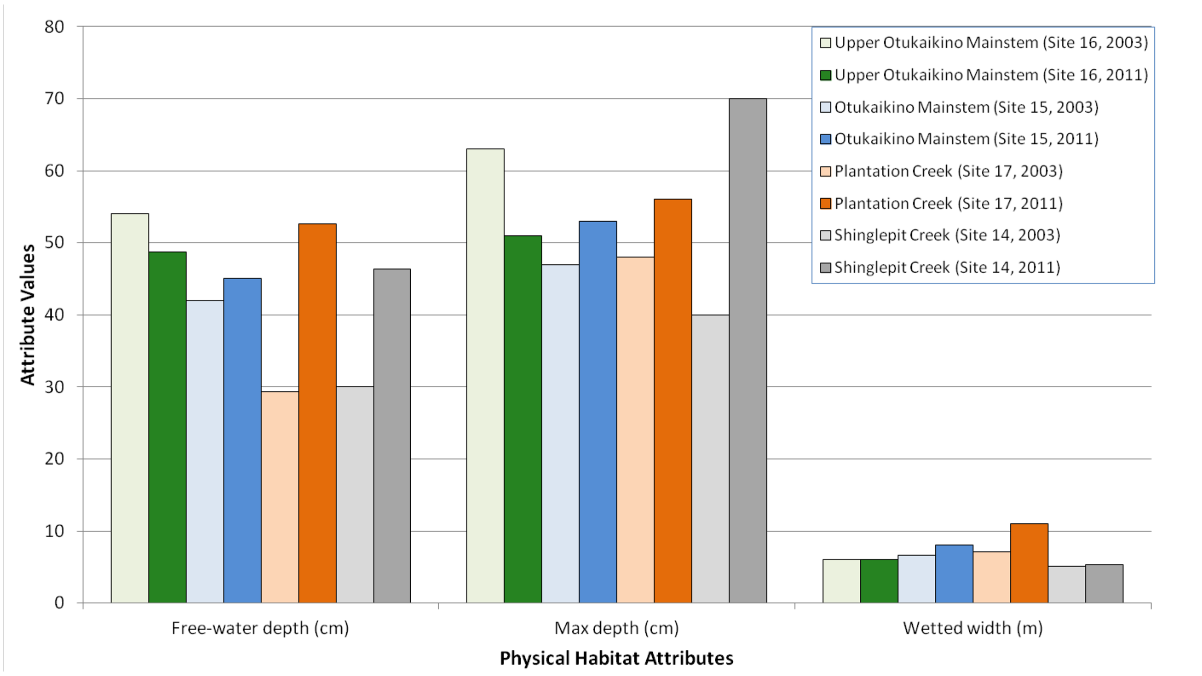


Figure 13. Physical habitat changes in the four surveyed sites on the upper Otukaikino catchment. Mean and maximum depths for the 2003 dataset are only approximate.

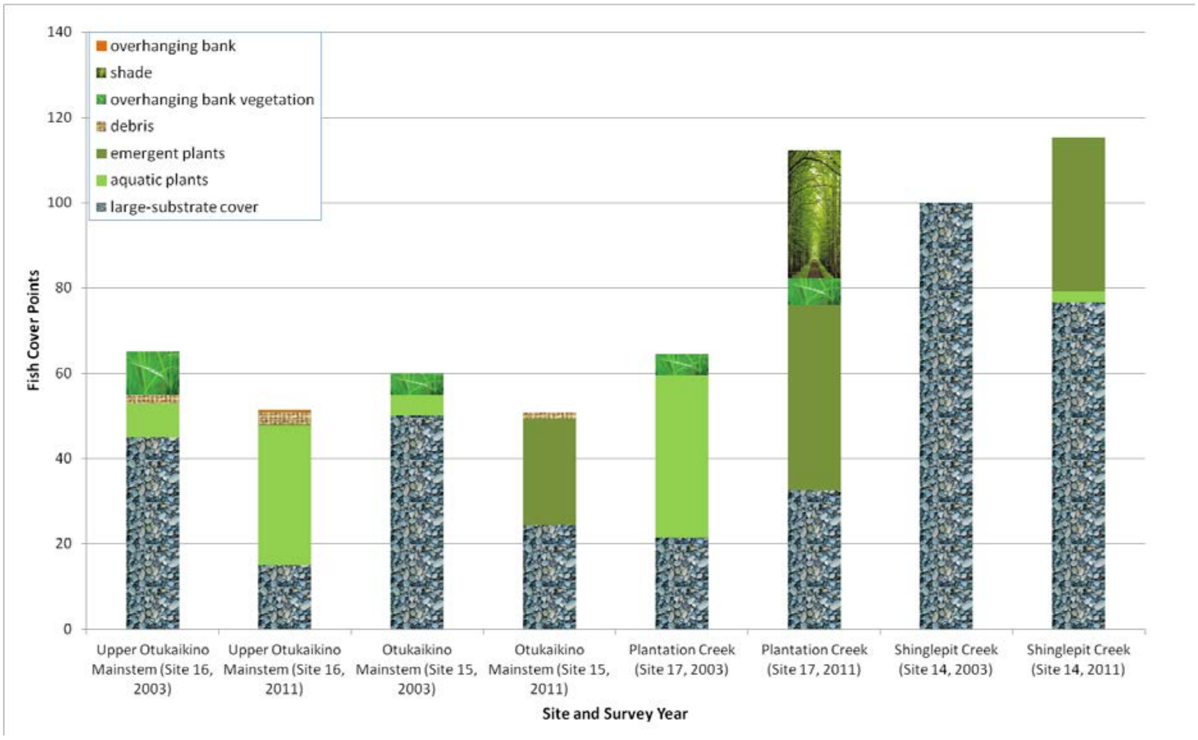


Figure 14. Quantified fish cover points from the four monitored sites on the upper Otukaikino River catchment, 2003 and 2011.

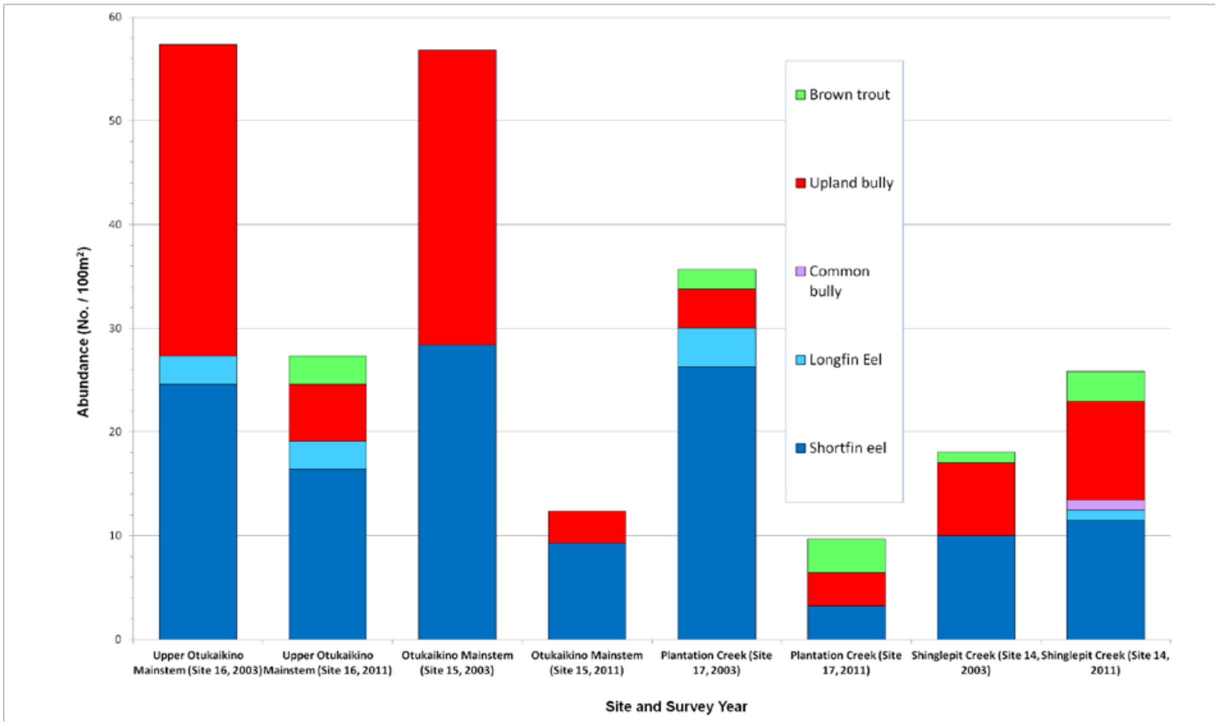


Figure 15. Changes in fish catch abundance at each of the four monitored sites in the upper Otukaikino Catchment, 2003 & 2011.

Upper Otukaikino, Site 15

Site 15, on the upper Otukaikino River, had changed dramatically in appearance between site visits, as depicted in the site photographs (App. IV, Figs. ii (a, b)). However, despite the ingrowth of surface-emergent plants, the wetted width, and water depths had changed little (Fig. 13). Similar to the upstream site (Site 16), there was a marked reduction in substrate cover, but with a compensating growth of emergent cover mentioned previously (Fig. 14). Levels of coarse-substrate embeddedness at this site had increased from 20% to approximately 75%, with the proportion of sand covering the bed increasing from none in 2003 to 36% in 2011. Similar to the upstream site (Site 16), there was a marked reduction in populations of upland bullies and shortfin eels in this habitat (Fig. 15). In fact, only a single adult upland bully was obtained at this site in 2011.

Plantation Creek, Site 17

This Plantation Creek site is close to Site 15, and also close to the confluence with the Otukaikino River. Similar to Site 15 on the mainstem, the site was characterised by luxuriant ingrowth of emergent soft herbs, in this case, largely monkey musk (App. IV, Figs. iii (a, b)). The section exhibited a marked increase in mean channel depth and maximum depth, as measured within the flowing mid-section of the channel (Fig. 13). The wetted width had also increased substantially, although the emergent marginal vegetation made the wetted margin quite ill-defined.

Similar to Site 15, the marginal surface-emergent herb bed (monkey musk) formed a larger proportion of the fished habitat, although a greater proportion of the bed was considered to have suitable large-substrate cover (Fig. 14). The fish catch, compared to that in 2003, was much reduced at this site, entirely due to the relatively poor catch of shortfin eels (Fig. 15). This result may be an artefact of much of the wetted area being unfishable with an electric fishing machine, but nevertheless constituting an aquatic habitat where shortfin eels would reside. Therefore, we consider that the shortfin eel catch may have been seriously underestimated at this site. Upland bullies were low in number in 2003 as they were in 2011.

Shingle-pit Creek, Site 14

In 2011, the Shingle-pit Creek site was of similar wetted width to the January 2003 data, but the mean flow, and maximum depth was greater in 2011 (Fig. 13). However, this may be due to seasonal effects, because groundwater levels could well have been lower in January 2003. Fish cover at the site was high, both in 2003 and 2011, with an increase in emergent and aquatic vegetation refuge in 2011 (Fig. 14)(App. III, Fig. iv(a, b)). In 2011, the fish population in Shingle-Pit Creek was higher in terms of biodiversity and number (Fig. 15), with a common bully being positively identified at this site. Large (74 mm T.L.) gravid upland bullies were obtained from this site, as were brown trout fry, suggesting spawning habitat facility for both species.

6.1.6 Synopsis of results from the Upper Otukaikino catchment

It was evident that some bed sedimentation had taken place at both sites in the mainstem of the upper Otukaikino, which was associated with a decrease in available fish cover, and a reduction in the numbers of upland bullies, and a reduction in shortfin eel numbers. However, the reduction in the number of shortfin eels could also be linked to the difficulties in fishing amongst the luxuriant marginal weed beds, which were not present in 2003. There was evidence of successful trout and upland bully spawning in Shingle-pit Creek.

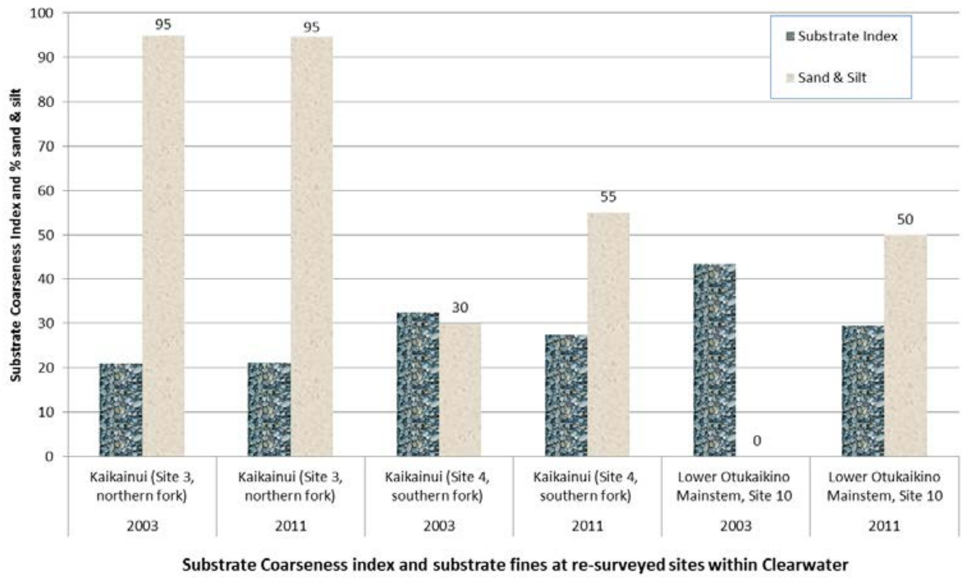
6.2 Temporal changes in substrate index, substrate embeddedness, and percentage sand/silt.

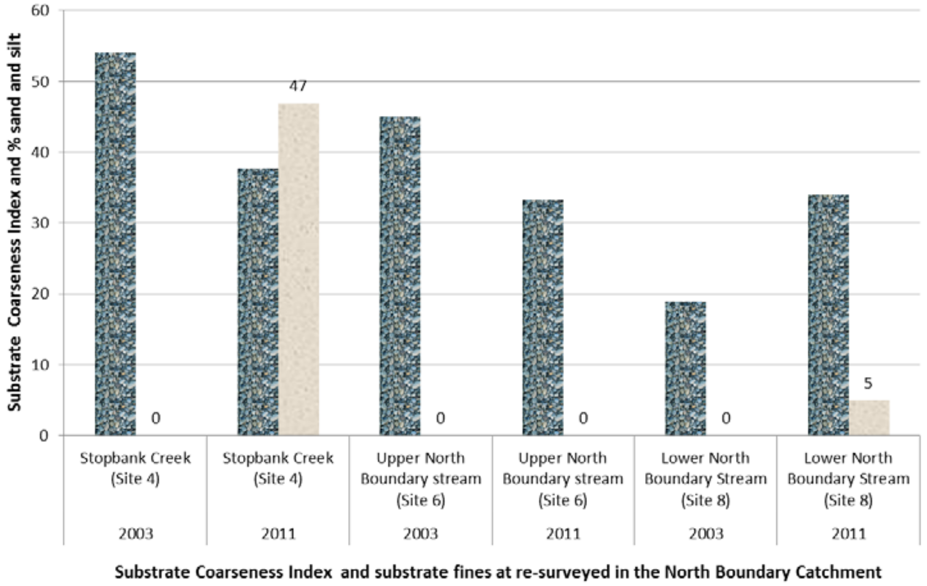
Over the 10 sites which had been re-surveyed, thus excluding Site 5 (East Stream), which was not surveyed exactly at the same physical habitat, there was a decrease over time in the substrate (coarseness) index from 33.6 to 30.65. There was also a marked increase in the proportions of sand and silt at many, but not all sites (Figs. 16). Substrate embeddedness also increased from 34.9% to 42.9%.

In respect to the three Clearwater Area sites, there were substantial increases in the combined sand and silt percentage over the bed at two of the sites, with a decrease in substrate coarseness at the same habitats. For the North Boundary habitats, there was a marked increase in the proportion of fines at the Stopbank Creek site, at the top of the North Boundary stream subcatchment. The other sites portrayed slight decreases in substrate coarseness but without any fines, with the exception of Site 8, where some increase in fines was observed. Amongst the four Otukaikino sites, the two mainstem sites exhibited increases in the habitat area obscured in fines, but which did not affect the substrate coarseness evaluation. The Shingle-pit Creek site had trapped some sediment amongst the marginal herbs, increasing the overall proportion of sedimentation at that site. For Plantation Creek, there was an apparent slight increase in substrate coarseness, and decrease in silt and sand cover at this weedy site.

These variates differed significantly from normal distributions, and failed to normalise despite the application of two commonly used transformations (ln + 1, square root + 1). Therefore these variates required recourse to non-parametric statistics (pair-wise approach (Sign test, Wilcoxon), and a test for a general change in mean value across all sites (Mann Whitney U test). Across all sites, the less powerful non-parametric tests did not indicate a significant change in substrate index or embeddedness across past-present pairs of sites.

There were also marked changes in the proportion of the substrate covered with sand or silt particles (Fig. 16). It is possible for the substrate index, a measure of overall substrate coarseness, to only weakly reflect marked changes in fine sediment, depending on the proportions of intermediate-size particles. The non-parametric pair-wise test on change in the percentage of sand and silt covering the bed of the 10 resurveyed sites was borderline significant at the 95% level ($p=0.05$, Sign test), but insignificant for the alternative pair-wise Wilcoxon test ($p=0.07$).





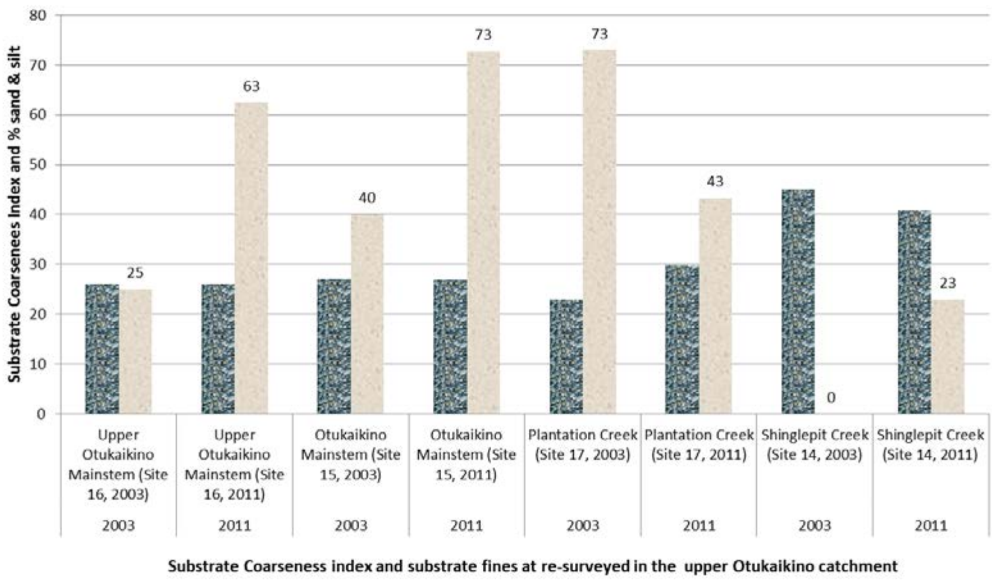


Figure 16. Temporal changes in the Substrate Coarseness index and the proportion of silt and sand from resurveyed sites in the Otukaikino catchment.

6.3 Temporal changes in trout spawning distribution

Google Earth™ overlays of the trout spawning surveys in winter 2002 & 2003, and the winter 2012 survey are provided in App. VI, Figs. i-iii. There have been marked reductions in the recorded numbers of trout redds in the major spawning reaches of the catchment; North Boundary Stream, Stillwater Creek, Plantation Creek, and most of the mainstem reaches, as indicated in the frequency histogram (Fig. 17, reach descriptions in Table 4).

A total of 169 redds were counted over separate reaches in 2003 & 2004, compared to 90 redds in the winter of 2012. However, as discussed later, the operation of a fish trap on the Otukaikino River, unbeknownst to AEL or CCC, led to the removal of 47 ripe female trout (hens) before they reached the spawning grounds. The trap was installed in 20 March – 9th August near the footbridge in the Groynes, and the stripped trout transported to the reach downstream of the hatchery in the headwaters of the Otukaikino. Assuming that these 47 hens would have been detectable, and that a late survey of East Stream would have yielded several (say 3) redds in suitable habitat, the adjusted redd count would be in the order of 140 redds, a reduction of approximately 17%. However, it is clear that the level of reduction in redd numbers varies over the reaches, with the biggest reductions are in Stillwater Creek, Plantation Creek, North Boundary Stream, and three of the mainstem reaches. The changes in redd distribution throughout the study area are briefly described in the following sections.

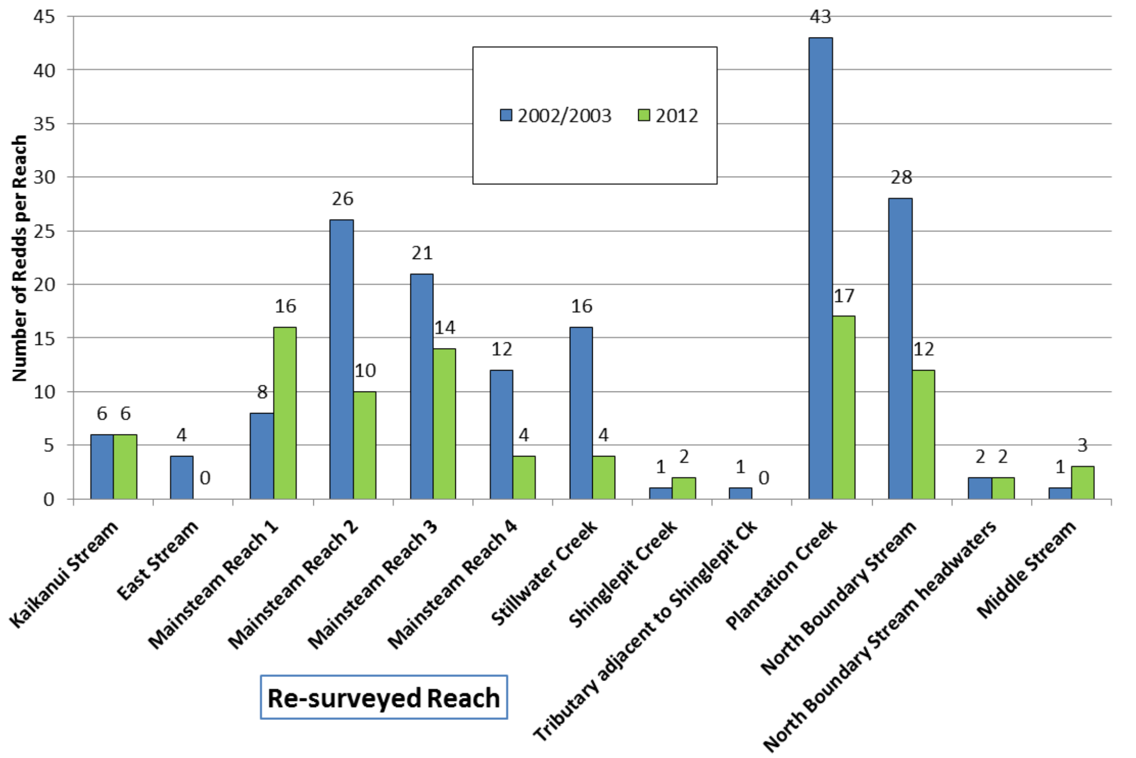


Figure 17. Changes in recorded trout redd numbers over re-surveyed reaches of the Otukaikino River catchment. Table 4 (below) provides the mainstem reach descriptions used in this figure. Numerals represent actual numbers of fully excavated redds.

Table 4. Reach descriptions used in Figure 17.

Reach Description	Reference in Fig. 17
Mainstem to North Boundary confluence	Mainstem Reach 1
Mainstem: From North Boundary confluence to Plantation/Stillwater Creek Confluence	Mainstem Reach 2
Mainstem: Plantation/Stillwater confluence to Shingle-pit Creek confluence	Mainstem Reach 3
Mainstem: Upstream Shingle-pit Creek confluence to Peacock Springs.	Mainstem Reach 4

6.3.1 Clearwater Area tributaries; Kaikanui Stream and East Stream

These small waterways, which rise on Clearwater land, had a limited number of redds in 2003. In 2012, only the Kaikanui Stream had several well-distributed redds that were equal in number to those in 2003 (App. VI, Fig. i). No redds were located in the East Stream in late May 2012, but good spawning gravel was present at the same upper reach location as 4 redds were in 2003. However, East Stream was inadvertently not surveyed for redds in late August. However, we consider that the headwater of this waterway still has potential for trout spawning, and some would have been recorded if the late survey had been conducted.

6.3.2 North Boundary Stream

North Boundary Stream, and its tributary Stopbank Creek, were a major trout spawning environment when surveyed in the winters of 2002 and 2003. No data comparison is possible for the productive Stopbank Creek, and most of upper North Boundary Stream because we were denied access to this tributary during winter 2011.

However, it was possible to re-survey the middle and lower reach of North Boundary Stream, where it flows adjacent to the Clearwater golf course fairway, and this was surveyed twice (early-season, late-season), with all redds being recorded during the later survey on 18 September 2012.Redd counts decreased from 28 in 2003 to 12 in 2012 (Fig. 18). The distribution of trout redds in 2012 was quite different compared to 2003. In 2012 redds were dispersed more in the central portion of this reach, whereas, in 2003 the lower and upstream 1/3s were more heavily utilised.

Short headwater tributaries of North Boundary Stream were accessible in late August 2012, and the number of redds in these waters (Fig. 17, upper North Boundary Stream, Middle Stream) was slightly greater than in 2003. Landuse around these tributaries was low intensity dryland sheep grazing, and the waterways were characterised by stable banks and vegetated banks.

Figure 18. The trout redd distribution on the lower North Boundary Stream. Waypoints "R" indicate 2003 trout redds, with red squares equate to 2012 redd distribution.

6.3.3 Otukaikino mainstem reach 1 (Groynes upstream to Boundary Stream confluence)

This reach was well populated with redds, with redds aggregated in the same locales as those found in 2003 (App. V, Fig. i). The banks along the lower reach of the Otukaikino mainstem, were protected by a dense riparian border of mature willow, some of which is being removed and replanted with native trees and shrubs. Recorded redd numbers in 2012 well exceeded those in 2003 over this reach. Over its length, the watercourse alternates between flat runs and riffle type flow, and redds were generally concentrated in smooth-flowing water, at the upstream margins of the riffle-type flow. All redds, with the exception of one, were conspicuous and appeared freshly excavated (Fig. 19).

Figure 19. A fresh excavated trout redd, and an adjacent partial excavation in the Otukaikino River, downstream of the Clearwater Avenue Bridge.

6.3.4 Otukaikino mainstem reach 2 (Boundary Stream confluence upstream to Stillwater Creek/Plantation Creek confluence

In this reach, 2012 redd numbers were less than those counted in 2003, although the river was quite difficult to survey by foot in places due to the ingrowth of willow trees into the deep channel. There was a conspicuous absence of redds in the upstream half of this survey reach. Towards the western end of the lake (Fig. 20a), a reach which previously contained trout redds in 2003 had become choked with willow trees, and the bed had become silted (Fig. 20b).

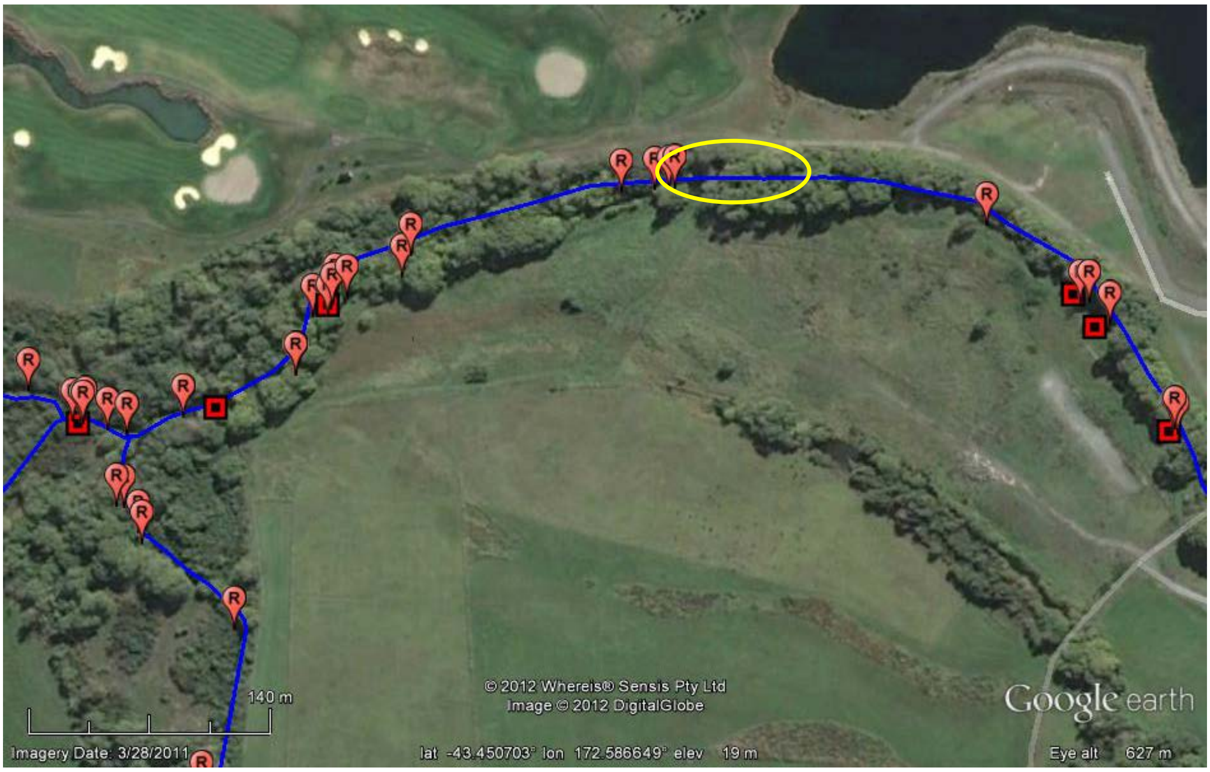


Figure 20a. The ringed area where significant willow ingrowth has jeopardised a trout spawning reach in the Outkaikino River. Waypoints "R" indicate 2003 trout redds, and red squares equate to the locations of redds in 2012 redds.

Figure 20b. The silted willow-choked reach which was formerly used for trout spawning, as ringed in Fig. 20a.

6.3.5 Otukaikino mainstem reach 3, Plantation Creek confluence to Shingle-pit Creek confluence

The distribution of trout redds for mainstem reaches 3 and 4 are provided in App. VI, Fig. ii. Reach 3 is actually in two surveyed sections (3a, 3b), separated by a section which has not been surveyed downstream of Greywacke Road (red ring in App. VI, Fig. ii). This unsurveyed reach flows through, in part, a residential property, and the channel is impounded by a weir. It is considered, although not known for certain, that this unsurveyed section is unsuitable for trout spawning. This unsurveyed reach was not considered in either the 2003 or 2012 survey. In addition, a short (300 m) deep reach along reach 3b, immediately downstream of the Shingle-pit Creek confluence, was well utilised in 2012, although not surveyed in 2003 (App. VI, Fig. ii).

Generally the 2012 redd distribution followed the distribution in 2003, although there were no redds within 400m upstream of the Stillwater Creek confluence, compared to 9 in 2003. This depauperate section of reach 3 is depicted as a red ring in App. VI, Fig. iii. Light grey earthquake sands were found throughout reach 3, and the true left (north) bank was being cleared of willow and replanted in native trees and shrubs (Fig. 21). Overall, comparing the same surveyed sections of reach 3 from the 2003 and 2013 surveys, trout redd counts were well down on their 2003 tallies, a reduction from 21 redds to 14 (Fig. 17).

Figure 21. Looking downstream at a sandy reach of the Otukaikino mainstem (reach 3). The willow was being cleared on the left bank prior to planting in native foliage.

6.3.6 Upper Otukaikino River mainstem, Shinglepit Creek to Peacock Springs (reach 4)

Comparison of redd counts over the same surveyed reaches in Reach 4 indicated a much lower utilisation of the upper reach downstream of Peacock Springs, with a reduction from 12 fully excavated redds to just 4 (Fig. 17, App. VI, Fig. ii). This reduction excludes a short well-utilised reach which was only surveyed in 2012 (reach b, App VI, Fig. ii).

Upstream of a silted duck pond, the channel narrowed, and while in 2003 in consisted of relatively clean greywacke gravels, in 2012, the gravel was slightly embedded with fines, and the channel over-filled above the normal baseflow (Fig. 22). The channel was also unfenced along the south (true right) bank and the pasture closely grazed. However, the banks are stabilised by the high proportion of greywacke boulders through the soil profile. Based on collated field observations, it was unknown how the trout spawning habitat along this reach has changed since the survey in 2003.

Figure 22. The flooded reach of the upper Otukaikino (Reach 4).

6.3.7 Stillwater Creek, Plantation Creek, Shingle-pit Creek

The distribution of redds in Stillwater and Plantation Creeks, during the 2003 and 2012 surveys, are depicted in Fig. 23. These two waterways demonstrated the greatest reduction in trout redds, and both channels of these channel are becoming increasingly overgrown with willow, and access along the channel was very difficult, with some heavily-choked reaches un-negotiable and un-surveyable. While this mean some redds may not have been detected, heavily choked reaches were heavily silted, and were unsuitable for trout spawning in any case. The same access issues plagued the 2002 survey, although the willows would have grown significantly worse in the interim.

Stillwater Creek has suffered a significant loss of redds in the downstream reach of the surveyed reach, with 3 fully excavated redds in the upstream reach, and one near the confluence with Plantation Creek. Over the reach which had a concentration of redds in 2003, only 2 trial redds were found in 2012, and the reach was reported as being silted in the more recent survey (Fig. 24).

Plantation Creek also suffered a significant reduction in redds, from 43 well-distributed redds in 2003, to just 17 redds (60% reduction) in 2012. Of particular interest was the utilisation of a new stony-based diversion channel excavated in late 2010, but before the September earthquake, where a number of redds were located (Fig. 25). The old channel of Plantation Creek, which contained 5 redds in 2003, now lacked surface flow.

'Shingle-pit' Creek is a short waterway which rises from a spring on Island Farm, and in 2012 two redds were located in the lower reach near the main farm (Island Farm) road. This is in a similar location as a redd was located in 2003. Most of the upstream reach is wide and silted and confers no potential for trout spawning. Another tributary adjacent to Shingle-pit Creek has, in 2012, no potential for trout spawning, despite one redd being located in the lower channel in 2003 when habitat was more suitable.

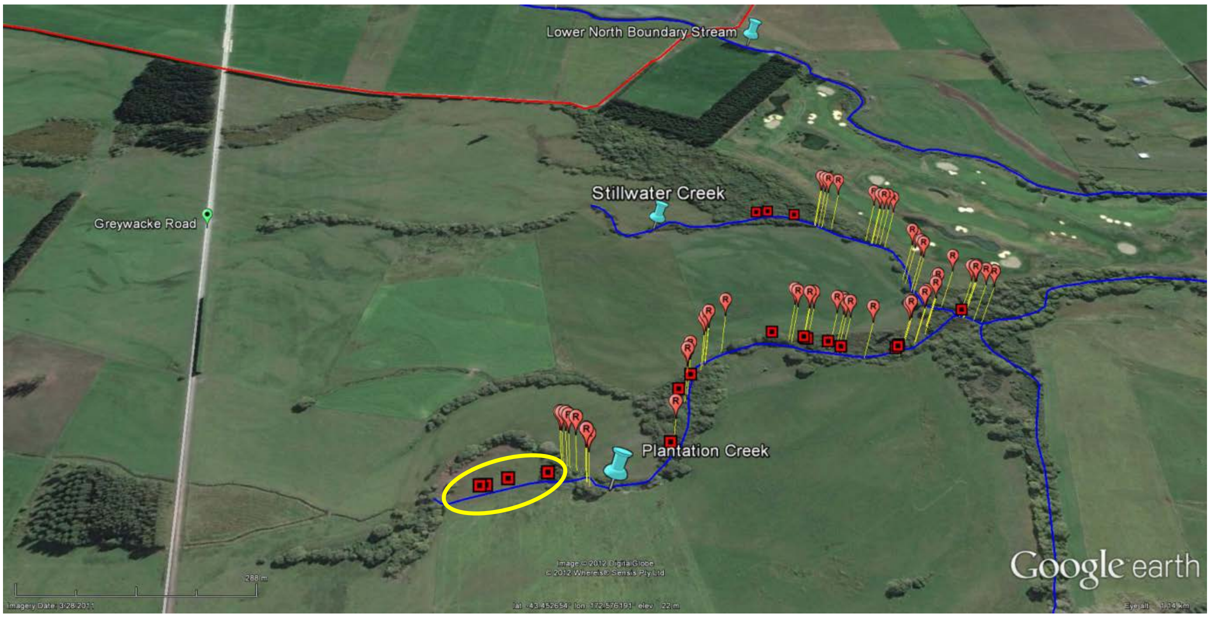


Figure 23. Waypoints "R" indicate 2003 trout redds, and red squares equate to the locations of redds in 2012 redds. The yellow ringed area indicates where a new channel has been cut since 2003, and which was well utilised for trout spawning in 2012. Redd location in neighbouring channels have been supressed for reasons of clarity.

Figure 24. Looking downstream at a silted weedy reach which used to provide trout spawning habitat in 2003.

Figure 25. A new straight diversion channel, in the upper reaches of Plantation Creek, was relatively well utilised by spawning brown trout.

7 Discussion

7.1 Temporal changes in fish habitat and distribution

7.1.1 Operation of fish trap on the Otukaikino River

We were disappointed to learn, in November 2012 that North Canterbury Fish and Game had extended the operation of an installed salmon trap in the Otukaikino River right through the winter brown trout spawning season (Dirk Barr, NCFG, pers. comm.). If the 47 hen fish were allowed to enter the survey area and spawn, and we counted them all, and allowing for several uncounted redds in East Stream, a natural reduction of 17% may not be that ecologically significant if we assume that the hatching rate is satisfactory. This is because most trout fry die before reaching maturity, therefore a reduction in trout redds or ova production of 17% does not equate to a loss of adult trout in the same proportion. Clearly, though, a large number of trout ova were removed from the population so the actual loss of ova production would be in the order of 44%, which is much more ecologically significant. Using the average number of eggs from brown trout eggs from the Selwyn River (1718 ova in Hardy 1963), the loss of eggs from the catchment is over 80000.Therefore to maintain the fishery, the release of several thousand brown trout parr back into the Otukaikino River, possibly in the groynes reserve, would redress the balance left by the removal of ova. These parr could come from the North Canterbury Fish and Game hatchery. A new purpose fish trap is expected to be installed in March 2013, but the operational details are not yet known.

It is expected that a proportion of the 47 female trout trapped in the Groynes would otherwise have constructed redds and spawned in the upper catchment. This may explain why we saw no trout redds around Clearwater in late July, as the female trout were being trapped and stripped. It is probable that some down-river trout could have migrated upstream after the trap was lifted on 9th August and constructed redds before our late surveys commenced around Clearwater in mid-September.

However, our late July and early August (3/8/12) survey of the lower Mainstem through the upper section of the Groynes and the reach downstream of the Clearwater Avenue Bridge would have been affected. We found, however, that 2012 redd numbers in this Clearwater Avenue Bridge reach (Reach 1) were higher than in 2003.

Based on my observations over several projects, there is little spawning gravel downstream of the installed fish trap, with all spawning and rearing habitat (e.g. pools, and deep runs) upstream of the trap. Therefore it is quite possible that most of the brown trout population in the upper Otukaikino River could spawn and rear upstream of the trap. In contrast, mature Chinook salmon migrate upstream from the sea, and the trap would be effective at trapping the entire run, which was NCFG initial intention. NCFG are installing a permanent fish trap into the Otukaikino River for next winter (Dirk Barr, NCFG, pers. comm.), and it will be clearly necessary for CCC to consider the operation of this facility in respect to monitoring future trout spawning seasons, and the interpretation of the results.

7.1.2 Clearwater Development Area

Kaikanui and East Streams

A prediction of increased bank erosion in the Kaikanui Stream, expressed in the earlier Clearwater report, has proved to be true (Taylor & McMurtrie 2003). The 2003 field notes for Site 3 on the Kaikanui Stream report extreme bank erosion, and predict that the channel would be twice the width in a few years if the banks are not stabilised. While not quite twice the width, the 65% width increase points to significant erosion, and in 2011 bank erosion was still apparent, and the stream substrate possessed a deep bed of soft sediment. Despite the increase in soft-sediment depth, numbers of shortfin eels were lower in both of the Kaikanui Stream sites (Sites 3, and 4).

The 2003 field notes were useful in pointing out that the bank profile had been inappropriately over-steepened for the bank type, and the steep banks were not consolidated with riparian vegetation. In 2011, the steep true right bank was anchored with mature flax. Whereas the opposite bank was terraced with some protection from soft herbs. Based on our observations it would appear the worst of the bank's erosion has taken place, as the developing vegetation begins to consolidate the banks.

The Kaikanui Stream, a waterway which rises from a spring on Clearwater, continues to form habitat for the juveniles of the southern lamprey (*Geotria australis*). These juveniles, or ammocoetes, are filter feeders on microorganisms, and form burrows in silty areas along waterways (McDowall 1990). However, the adults are thought to spawn in gravels (Kelso & Glova 1993), and in Canterbury waterways generally, including in Clearwater, they appear to be located in stable trout spawning streams with both spawning gravel and some marginal silt.

In the latest review of the conservation status of freshwater fish Allibone *et al.* (2010), lamprey hold a national conservation status of "declining", although this status is qualified that data is "poor". There is no discussion on the mechanisms for the species decline in Allibone *et al.* (2010), but McDowall (1990) considered that it may be due to a loss of forested small streams, which are undoubtedly less common through land development. However, we have found good numbers of ammocoetes in developed catchments in mid-Canterbury where flow-stable waterways where trout spawning gravels and marginal silt are both present. Such stable springfed streams in Canterbury may form a breeding reservoir for this species. Given the conservation status of this species, we recommend that the Kaikanui Stream, in the Clearwater development, continue to be monitored for its value for lamprey.

A marked decline in eels from the two Kaikanui Stream was of interest, and several hypotheses were postulated: unsuitable habitat changes or perturbation, reduced recruitment from the sea, or reduced fishing efficiency. The amount and variety of fish cover had improved at both sites, and water depths appeared quite adequate for both the shortfin and longfin eel. In East Stream, a short tributary of the Kaikanui rising on Clearwater, there were a number of elvers caught, suggesting ongoing eel recruitment, but fishing efficiency may have been reduced. Site 4, in particular, but also Site 3 had significant rafts of floating herbs. These habitats are preferred by shortfin eels, but are notoriously difficult to fish with electric fishing machines, as the catch remains electro-narcotised amongst the weed, and often escape detection.

Clearly, the Kaikanui mainstem has suffered in the past from siltation due to lack of bank stability, and this is detrimental to species sensitive to siltation. However, some spawning gravel still exists, and the same number of trout redds were recorded in 2011 as during the winter of 2003. We recorded a small number of juvenile trout in the headwaters of this waterway, both during the winter trout spawning surveys and the summer site fishing. The presence of redds and juvenile trout demonstrates that the Kaikanui Stream still provides a useful role in trout production for the Otukaikino catchment, in addition to Kaikanui Stream's role for lamprey spawning and ammocoete rearing mentioned above.

As the 2003 data suggests, the upper Kaikanui catchment does provide habitat for trout spawning. While redds were not recorded early in the season, the early survey predated the lifting of the fish trap in the Groynes. The later survey did not include East Stream, but good spawning gravel was present in the headwater reach, the same as in 2003. Thus we expect that, like the Kaikanui, the East Stream tributary still provides potential for trout spawning.

Otukaikino River Mainstem from the Groynes upstream to the Clearwater boundary

The fish fauna at Site 10, in the Otukaikino River adjacent to the most western lake, differed little to that in 2003, although the channel was narrower. Throughout much of the Clearwater development, the mainstem of the Otukaikino has suffered from willow tree ingrowth, which modifies the local hydraulics. In addition to modifying the local aquatic habitat, and its fauna, the ingrowth compromises trout spawning reaches, by facilitating siltation. The clearest example of where significant willow growth had coincided with trout spawning reaches was depicted in Figs. 20a, b. Losses of specific trout reaches though willow ingrowth may explain the decrease in the number of redds, but it is also possible that redds otherwise found in the larger, more downstream reaches, would have been affected by the operation of the trap.

Generally, the Otukaikino mainstem, especially downstream of the Clearwater Avenue bridge, was in good order, with little seismic sand, and stable banks. Upstream of Clearwater Avenue, some former trout spawning gravel has become chocked with willow ingrowth, but it was evident that some willow clearing was taking place which will remediate siltation. Using the redd distribution for this survey, and the 2002/2003 surveys, it may well be possible for CCC to advise on reaches which coincide with trout spawning reaches, so that they may be cleared as a matter of priority.

7.1.3 The Otukaikino mainstem upstream of Clearwater

Other areas of the mainstem possessed sandy beds that could not be attributed to willow tree ingrowth, or stock-accelerated erosion. For example, the results from Site 15, and 16, near the mainstem's confluence with Plantation Creek, exhibited substantial increases in substrate embeddedness, and reductions in upland bully and eel abundance (see Fig. 15). The statistical evaluation of site parameters related to sedimentation suffered from lack of statistical power, this is because the distribution of differences could not be normalised satisfactorily, so a non-parametric approach was required to assess the paired difference in substrate indices. A non-parametric approach transforms the variates (the difference in embeddedness values obtained during the two surveys), into ranks and the magnitude of the changes is lost. However, across all sites, there was some evidence that there is a general decrease in substrate coarseness and a statistically significant increase in the percentage of sand and silt within the habitats.

Upland bully abundance has been experimentally demonstrated to decrease with increased substrate embeddedness, and for abundance to increase when embeddedness was decreased (Jowett & Boustead 2001). It is interesting to compare the results for Sites 15 and 16 with a site on the Heathcote River which was fished a few months before the February 2010 earthquake, and a few months later (Taylor & Blair 2012), with an increase in upland bully occurred between surveys. These upland bullies were associated with an area of streambed 'heave' where the bed was thrust upwards exposing a patch of clean gravels. This patch of clean gravels was also used for refuge by numerous juvenile elvers. In contrast, most of the fished area, previously a silt-free gravel riffle, had become obscured with sand (mean sediment depth = 2cm), and bluegill bully abundance had substantially decreased at both this site, and another bluegill habitat further upstream (Taylor & Blair 2011). Bluegill bullies do not appear to be present in this region of the Otukaikino River, but the point is that seismic effects are both species and habitat specific. Therefore upland bullies which occupied previously stony habitats are likely to be affected more than those that adopted habitats in soft-bottomed habitats in the first instance. In particular, upland bully spawning grounds, which tend to spawn on the underside of stones could be adversely affected. Reassuringly, we found gravid upland bullies at Site 8 on North Boundary Stream,

We suspect that the source of these fines are a result of seismic activity within the catchment, as the build-up of fines also occurred in reaches with no stock access, and no obvious anthrogenic activities. The headwaters of the Otukaikino carry very little bedload even at high flow (pers. obs.). Some evidence for the disturbance of the bed is evident from the aerial photograph of the catchment on the 3rd September 2010 UTC time (4 September local time) which shows the turbidity in the Clearwater lakes and waterways (Fig. 22a) from the 7.3 M earthquake. However, no further seismic disruption was evident on the aerial photograph approximately 2 days after the aftershock on February 22nd (Fig. 22b), despite other city rivers remaining turbid and elevated on that date. During the February earthquake, an observer reported sand being ejected from discrete locations of the Avon River bed, and the sand being transported and dispersed downstream (Perry Royal, pers. comm.). It is likely that a similar mechanism occurred in the Otukaikino catchment.

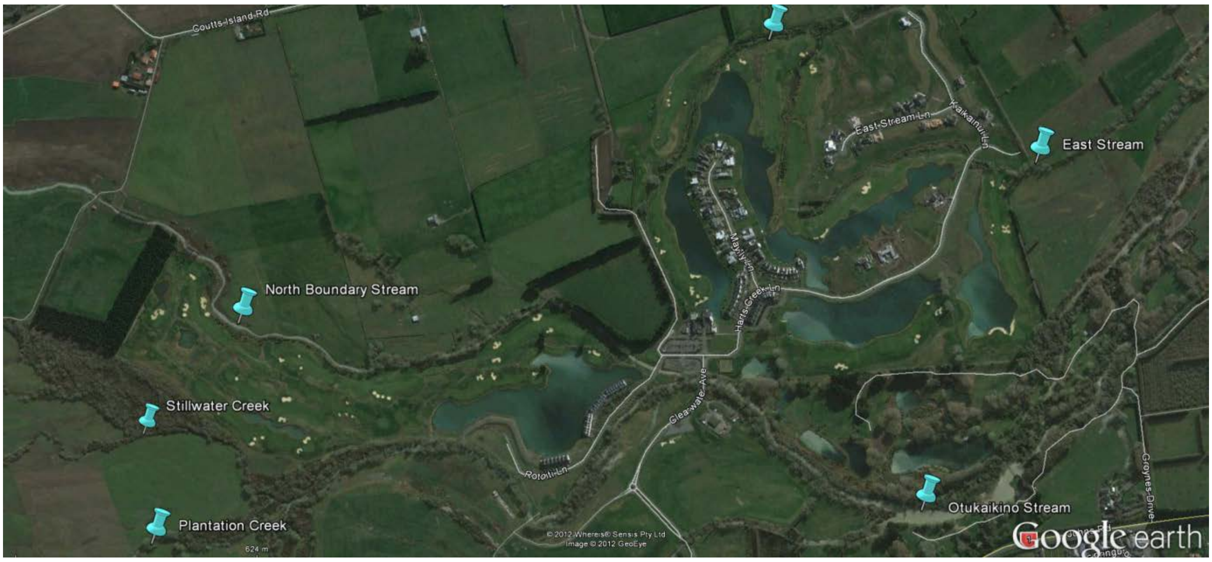


Figure 26a. The turbid nature of the waterways and Clearwater lakes on the day of the 7.3 M earthquake (4th September, local time). Note Google Maps are dated in UTC time (formerly Greenwich Mean Time).

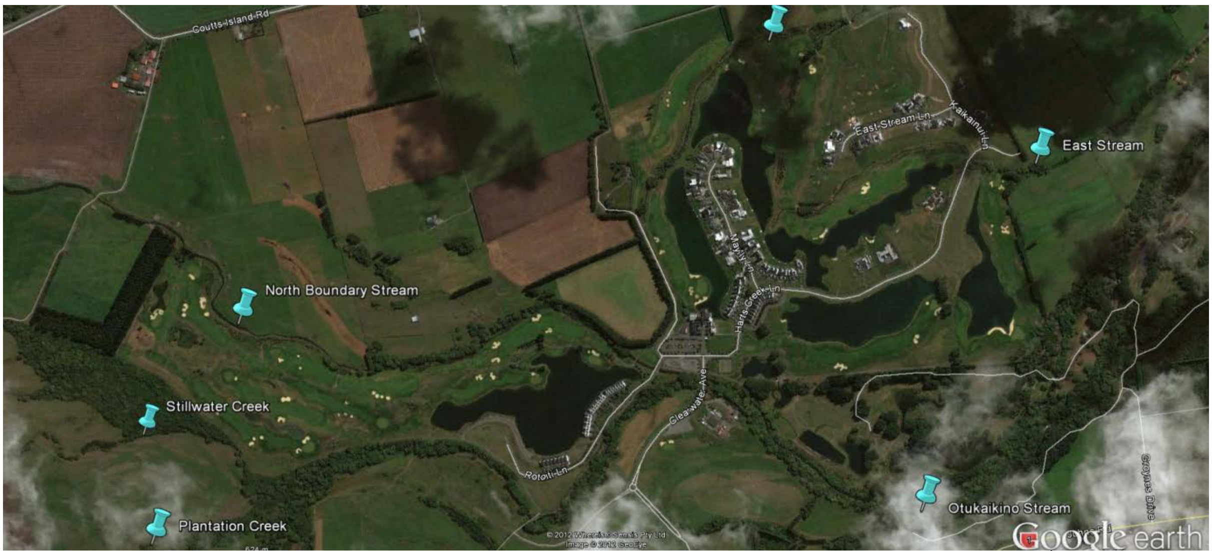


Figure 26b. The relatively clear nature of the waterways 2 days after the February 22nd earthquake. The Christchurch rivers, closer to the fault, were still turbid and elevated at this time.

7.1.4 Plantation Creek, Stillwater Creek

The lower reaches of Plantation Creek had changed substantially, with increased channel width and large tracts of emergent weeds. This reduction in suitable trout spawning habitat, and secondly the operation of the fish trap downstream could explain much of the reduction of trout spawning activity in this channel. The utilisation of the relatively new diversion channel in the headwaters of Plantation Creek demonstrates the extent to which willow in-growth may be compromising trout spawning habitat. Willow ingrowth, and the consequent impoundment and bed siltation could also jeopardise the spawning habitat of native bullies and refuge and habitat for other small native fish (e.g. eel elvers etc.). Luxuriant willow foliage can also transpire significant volumes of water away from spring channels will little flow. Stillwater Creek is of similar nature, increasingly bound by willow-tree ingrowth.

Both of these waterways could benefit from willow-clearing as a matter of priority for reasons outlined above. The difficulty with willow is that some willow is of benefit as it consolidates the banks and sporadic plantings along the stream course can induce channel meander and hydraulic variation suitable for fish habitat, including trout. However, willow ingrowth into the channel can lead to flood conveyance problems and increases siltation. One solution may be the removal of willow from the channel, and the poisoning of the stumps. At the same time the banks are replanted in a variety of non-invasive native trees and shrubs. This is what is taking place on Island Farm, as depicted in Fig. 2, and a process of willow tree removal, and the reintroduction of native riparian plants is taking place along banks of the lower Styx River.

In a discussion on riparian zone replanting, Collier *et al.* (1995) states that, in badly eroding or eroded streams through pasture, the vigorous growth of willows and poplars provide the best and quickest developing bank stability. However, the stony soil, and lack of stream power in these groundwater-fed systems should mean banks are inherently stable, and native plantings, albeit of less vigour than willow are quite suitable. We would recommend that some of the productive willow clearing operations on the Otukaikino River mainstem be extended to Plantation Creek in particular.

7.1.5 North Boundary Stream

Our data showed clear channel erosion in the Kaikanui Stream within Clearwater over 8 years, but the upper reaches of North Boundary Stream also exhibited erosion with sharply increasing wetted widths during summer baseflows (see Fig. 9). For the two unfenced upstream sites (Sites 4 and 6), this is probably due to continued stock-accelerated bank erosion, as these waterway were never fenced. The upper reaches of North Boundary Stream, including Stopbank Creek tributary, are subject to irrigation by pivot sprayer, and although landuse has not changed, the pasture looked much more closely grazed than previously. Further, in 2003, at least some gorse thickets provided some protection to aquatic habitats, but all riparian vegetation has since been removed. The landowner has been made aware of the importance of the upper North Boundary Stream, and Stopbank Creek for trout spawning, native fish, and there are still plans to fence the stream from stock and develop a protective riparian strip (Environment Canterbury, Les Keeper pers. comm.).

Site 8, is downstream of Les Keepers land, and borders the Clearwater development. Site 8 has also become much wider, despite a decrease in free-water depth, and maximum habitat depths. The removal of trees, and consequent bank support, may have led to the increased width in this reach. The reduction in fish cover, especially coarse-substrate cover for small fish, may be responsible for the reduction in the numbers of upland bullies at this site. While stock-accelerated erosion is likely to be a contributing cause of the increase in fines within North Boundary Stream, seismic effects cannot be discounted. The Google aerial photo (Fig. 26a), clearly illustrates very high turbidity in North Boundary Stream after the September 2009 earthquake as if flowed through all three monitored sites.

Across the three sites, there was a marked decrease in fish abundance with substantial reductions in upland bullies and shortfin eels. Upland bullies, as discussed above, are sensitive to sedimentation. A sharp reduction in captured eel numbers was also observed in the eroded Kaikanui sites, and it is possible that increased marginal sediment and macrophyte beds (e.g. watercress, monkey musk) increases escapement of shortfin eels. Further, where the average width has increased substantially, the numbers of fish per area may decrease, even though the numbers caught per length of channel remains unchanged. A check on just numbers of fish caught at each site also depicted sharp reductions in eels and upland bullies for Sites 4 and 8, but an increase in upland bully numbers at Site 6. However, a proportion of the upland bullies were gravid, and no fry were caught in November 2012. Had the 2012 sampling taken place in January/February, similar to the 2003 survey, it is expected that upland bully numbers would have been higher due to the numbers of fry.

North Boundary Stream proved to be a very productive trout spawning stream in 2002, and it was disappointing we were denied land access in the upper reaches to undertake a comparative trout spawning survey. For reaches of the North Boundary Stream downstream of Mr Keeper's land, and bordering Clearwater, the trout redd count was less than about half of that previously, based on a late survey, about 5 weeks after the Fish and Game fish trap was removed from the Groynes reservation area. We have no data to explain the change in redd distribution, the field notes and habitat photographs suggest suitable hydraulics, stable banks, and clean gravels through this reach. It remains a possibility that North Boundary Stream, which lacks holding water for large trout, may have been affected by the trapping and removal of mature hen fish from the installed Fish and Game trap in the Groynes. The uppermost reaches of North Boundary Stream, which is accessible from Island Farm, was characterised by stable banks, and landuse unchanged from many years.

To summarise, the surveyed sections of North Boundary Stream indicate that this waterway remains an important trout spawning area, but the interpretation of our results has been strongly tempered by lack of access to a large proportion of a formerly very productive section of its catchment (App. VI, Fig. ii). An additional complication was the deployment of the fish trap by North Canterbury Fish and Game Council, and clearly there has to be better communication between government agencies, although Fish and Game knew about this trout spawning survey.

8 Recommendations

AEL proposes the following recommendations:

- Better communication between North Canterbury Fish and Game Council and CCC regarding activities which would compromise environmental monitoring activities.
- Continue to monitor the lamprey habitat and population in the Kaikanui Stream.
- That some willow clearing work commence in the Plantation Creek and mainstem of the Otukaikino River.
- CCC and ECan to continue to facilitate the fencing and riparian strip protection of the upper North Boundary Stream. This large sub-catchment possesses value for the brown trout fishery, native fish, and aquatic invertebrates.
- That North Canterbury Fish and Game release trout parr back into the Otukaikino River to compensate for the stripped ova taken from the fishery.
- That the state of trout redd distribution in the North Boundary Stream be monitored when land access is made available.

9 Acknowledgements

We thank management staff at the Clearwater Golf Course, and David Shipley for allowing us access to the Otukaikino catchment waterways to undertake the trout spawning survey. Les Keeper kindly provided us access to his land for the summer phase of the fieldwork.

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11 Appendix I. Clearwater Tributaries 2003-2011

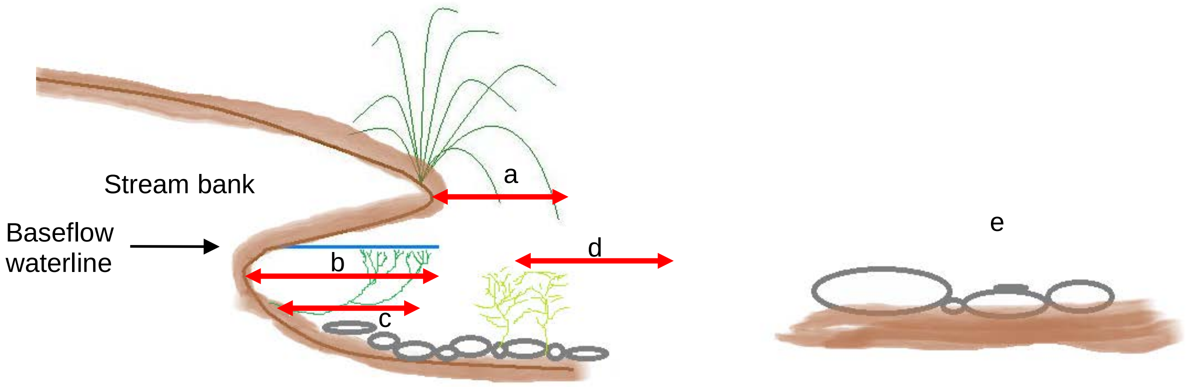

Figure i. Bank profile schematic depicting field measurements of (a) = vegetation overhang distance, (b) = bank overhang distance, (c) = width of bank-rooted marginal emergent vegetation, d = area of bed-rooted aquatic macrophytes (d). Expansion of bed profile depicts the coarse substrate nearly half buried in surrounding fines. This equates to an embeddedness of approximately 30%.

12 Appendix II. Site photographs of Clearwater Development Area

2003	2011

Figure i (a): Kaikanui Stream, northern fork, Site 3

Figure i (b): Kaikanui fork, northern fork, Site 3, 2011, looking upstream.

Figure ii (a): Kaikanui Stream, southern tributary, Site 4, showing narrow channel and *Carex* bank vegetation

Figure ii (b): Kaikanui Stream, southern tributary, Site 4, 2011. Note the significant increase in wetted width.

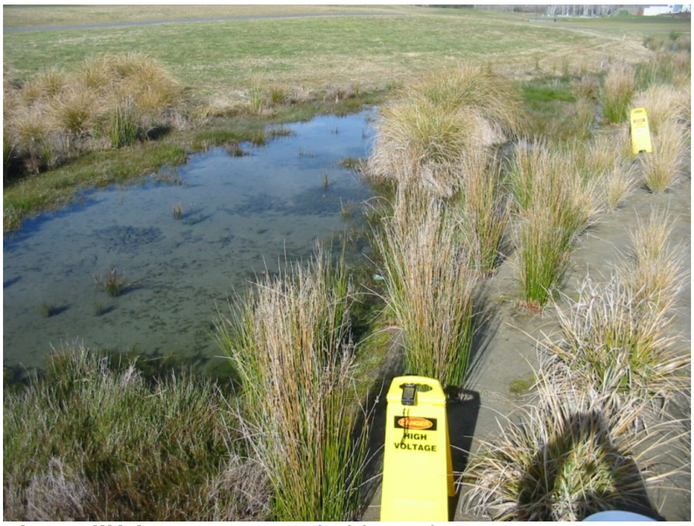

Figure iii(a): East Stream habitat, Site 5

Figure iii(b): new East Stream habitat, Site 5

Figure iv (a): Lower Otukaikino Mainstem, Site 10, 2003


Figure iv (b): Lower Otukaikino Mainstem, Site 10, 2011

13 Appendix III. Monitored sites on North Boundary Stream

2003

Figure i(a). Stopbank Creek, Site 4, Jan 2003.

Figure ii(a). North Boundary Stream, Site 6, Jan 2003

Figure iii(a). North Boundary Stream, Site 8, looking upstream, Aug 2003.

November 2011

Figure i(b). Stopbank Creek, Site 4.

Figure ii(b). North Boundary Stream, Site 6, looking downstream.

Figure iii(b). North Boundary Stream, Site 8, looking upstream.

14 Appendix IV. Upper Otukaikino mainstem, Shingle Pit Creek

2003

Figure i (a): Upper Otukaikino Mainstem, looking upstream, Site 16, September 2003.

2011

Figure i (b): Upper Otukaikino Mainstem, looking downstream, Site 16, November 2011.

Figure ii (a): Otukaikino Mainstem, 2003, Site 15

Figure ii (b): Otukaikino Mainstem 2011, Site 15.

Figure iii (a): Plantation Creek, Site 17, 2003, Site 17

Figure iii (b): Plantation Creek, 2011, showing encroaching vegetation, Site 17.

2003

Figure iv(a): Shingle-Pit Creek, January 2003.

2011

Figure iv (b): Shingle-Pit Creek, 2011.

15 Appendix V. Fish monitoring site locations and basic site attributes

Locality	NZTM East	NZTM North	length (m)	Wetted width (m)	Mean free-water depth (cm)	Mean macro-phyte depth (cm)	Mean sediment depth (cm)	Site maximum depth (cm)	Short-fin eel	Longfin eel	Juvenile lamprey	Common Bully	Upland Bully	Brown trout
Kaikanui (Site 3, northern fork)	1567427.9	5190068.6	10.0	3.77	51.67	51.67	66	72	11	1	20	0	0	0
Kaikanui (Site 4, southern fork)	1567570.6	5189913.9	10.0	6.13	31.33	31.67	1	35	3	3	0	0	1	2
East Stream (new Site 5)	1567687.6	5189675.9	6.5	1.15	7.00	7.00	1	10	6	0	0	1	0	0
Lower Otukaikino Mainstem, Site 10	1566789.0	5189003.6	7.0	4.23	41.00	48.67	0	52	8	0	0	0	1	1
Stopbank Creek (Site 4)	1563366.2	5190097.4	22.9	2.64	23.00	23.00	2	29	4	2	0	0	23	6
Upper North Boundary stream (Site 6)	1564458.1	5189858.8	16.5	3.06	30.67	30.67	0	44	1	0	0	0	33	5
Lower North Boundary Stream (Site 8)	1566068.2	5189524.9	8.0	5.80	25.67	31.00	0	42	7	1	0	0	7	1
Upper Otukaikino Mainstem (Site 16, 2011)	1566294.0	5188389.2	6.1	6.00	48.67	48.67	4	51	6	1	0	0	2	1
Otukaikino Mainstem (Site 15, 2011)	1566273.1	5188883.5	8.0	8.08	45.00	0.00	0	53	6	0	0	0	2	0
Plantation Creek (Site 17, 2011)	1566190.0	5188849.5	7.5	11.06	52.67	0.00	0	56	1	0	0	0	1	1
Shingle-pit Creek (Site 14, 2011)	1564628.1	5187843.5	19.7	5.30	46.33	0.00	0	70	12	1	0	1	10	3

16 Appendix VI. Trout redd distributions in August 2003/2002 and 2011.

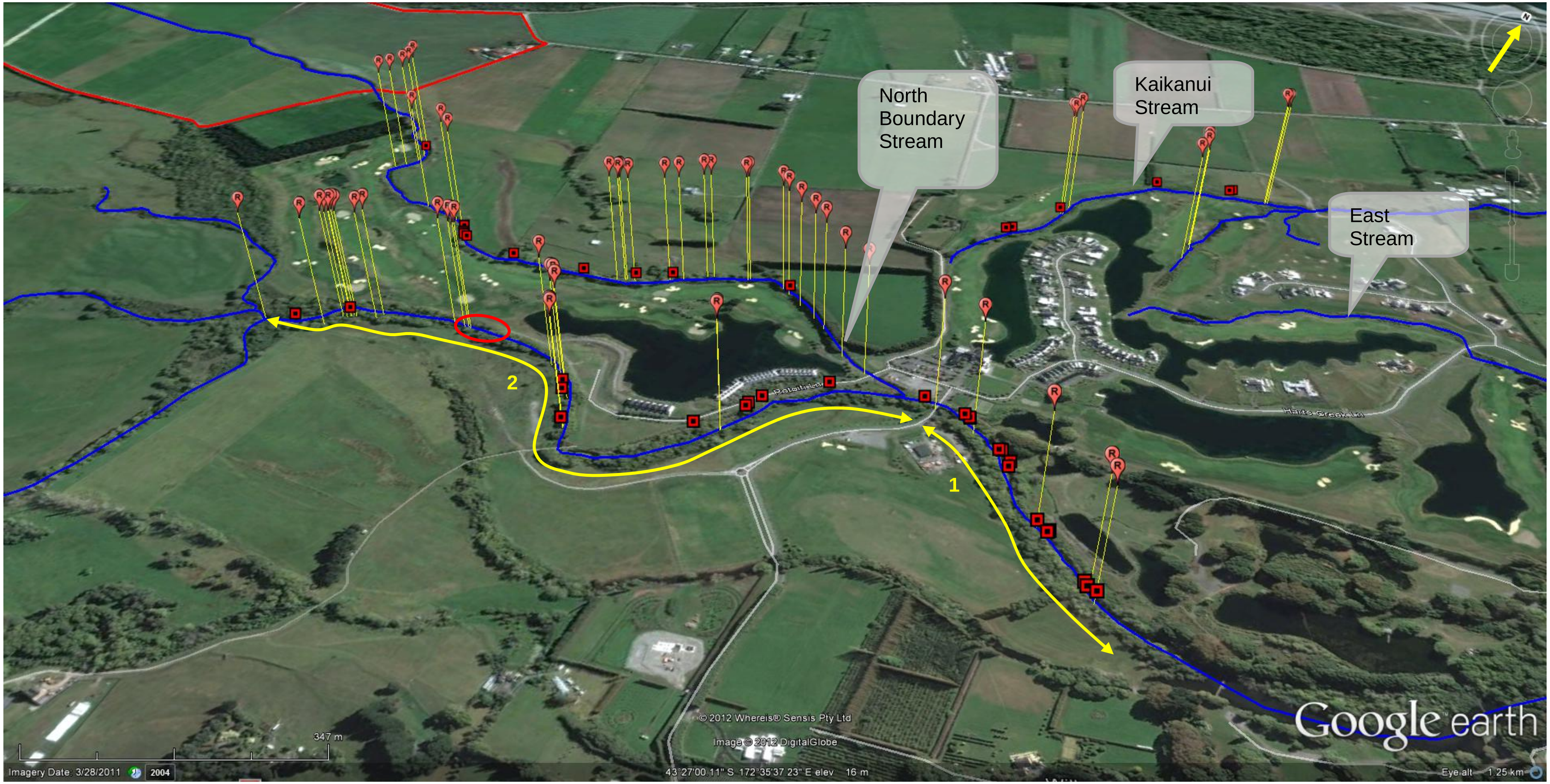

Figure i. Trout redd distribution in the vicinity of Clearwater. Elevated pins = 2003 trout redd distribution, grounded pins = 2012 trout redd distribution. Yellow arrows indicate mainstem reaches mentioned in the text. The red ring marks an area which is choked with willow, and may be compromising the integrity of this spawning reach.

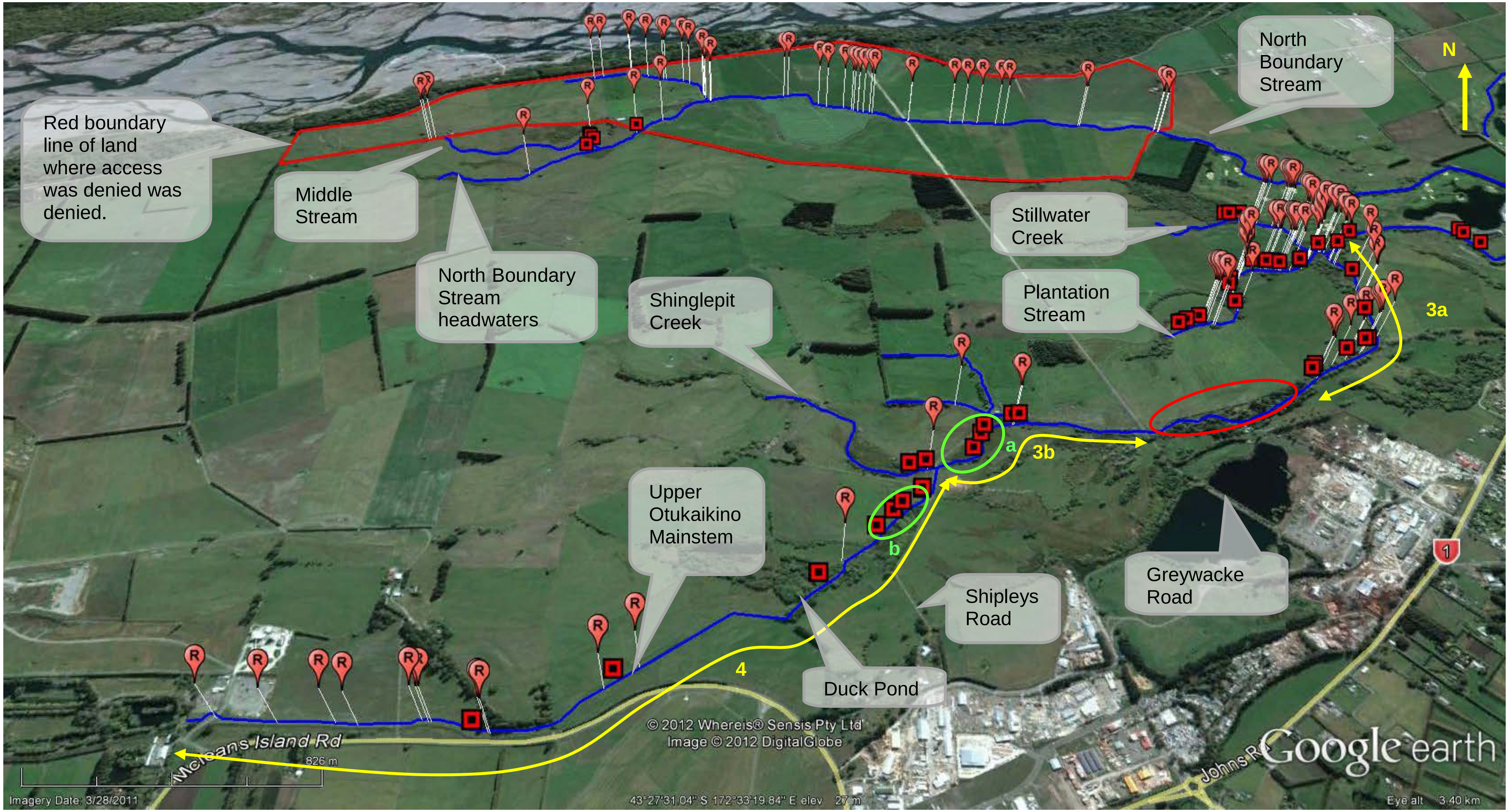

Figure ii. Trout redds in the upper Otukaikino catchment. Elevated pins = 2003 trout redd distribution, grounded pins = 2012 trout redd distribution. Yellow arrows indicate mainstem reaches mentioned in the text. The red-ringed region, a weir-impounded reach was not surveyed in either 2003 or 2011, and the two green-ringed reaches were not surveyed in 2003, but were surveyed in 2012. The red polygon represents private land where survey access was denied by the landowner.

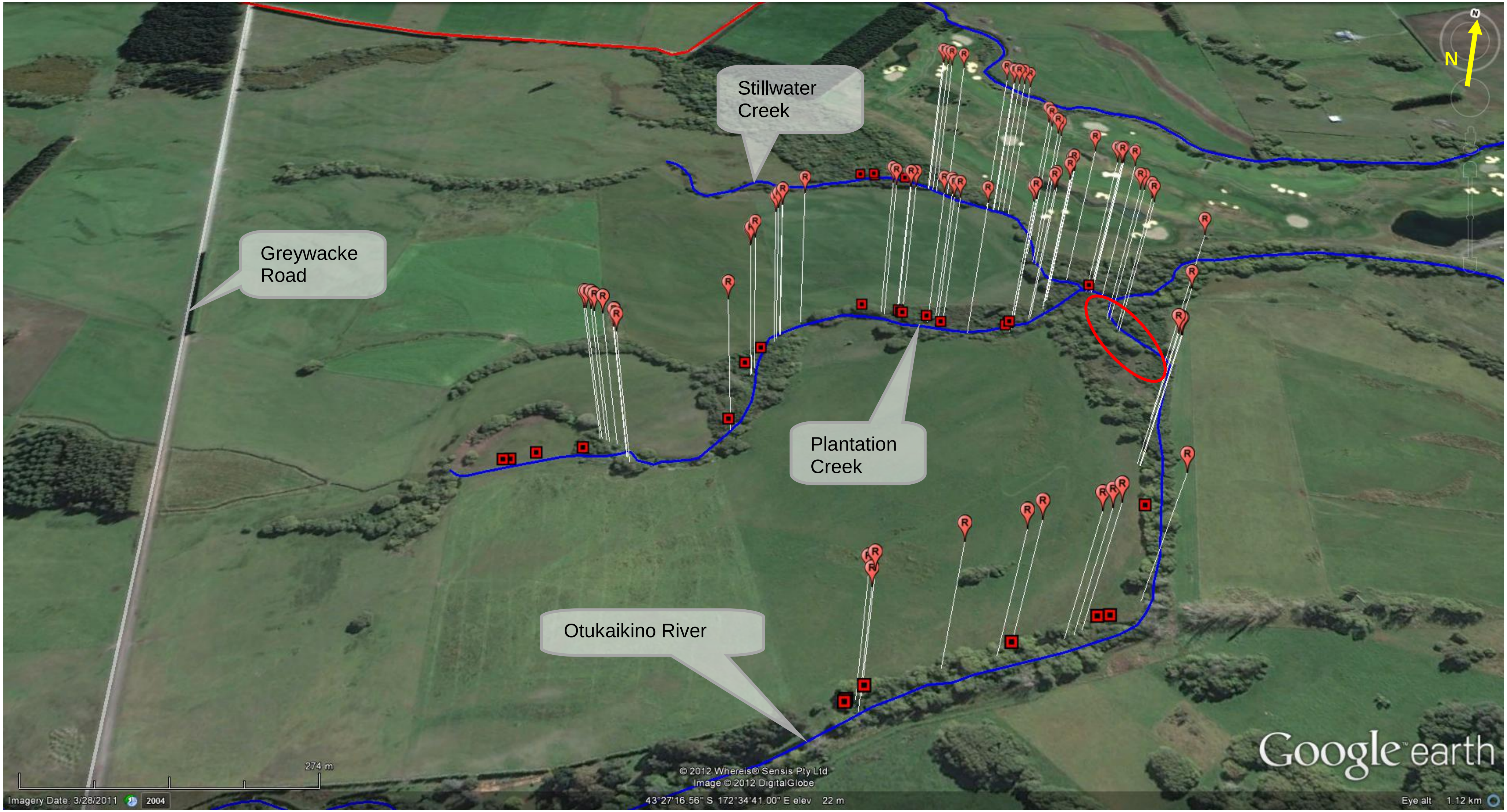

Figure iii. Trout redd distribution in the vicinity of Clearwater (Reach 3). Elevated pins = 2003 trout redd distribution, grounded pins = 2012 trout redd distribution.