June 2009

Minimum Flows and Aquatic Ecological Values of Lower Waimakariri River tributaries

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Environment Canterbury

REPORT

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Golder Associates

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1.0 INTRODUCTION

1.1 Background

Environment Canterbury (ECan) is reviewing the existing environmental flow provisions set out in the Waimakariri River Regional Plan (WRRP) (ECan 2004). One of the aims of the review is to determine if the minimum flows set in the lowland tributaries adequately protect the values identified in the WRRP. The 14 lowland tributary sites considered in this report are shown in Figure 1.

The minimum flow review process involves looking at the flow regime and minimum flow requirements for a wide variety of values, including aquatic ecosystems, landscape/riverscape, aquatic plants, and cultural (Maori) values. Management of the entire water resource also includes balancing instream values (e.g., trout habitat) with out of stream water use requirements (e.g., for irrigation).

1.2 Report Scope

This report focuses on lowland tributaries of the Waimakariri River, north of Christchurch. The purpose of this report is to, for each of the 14 minimum flow sites:

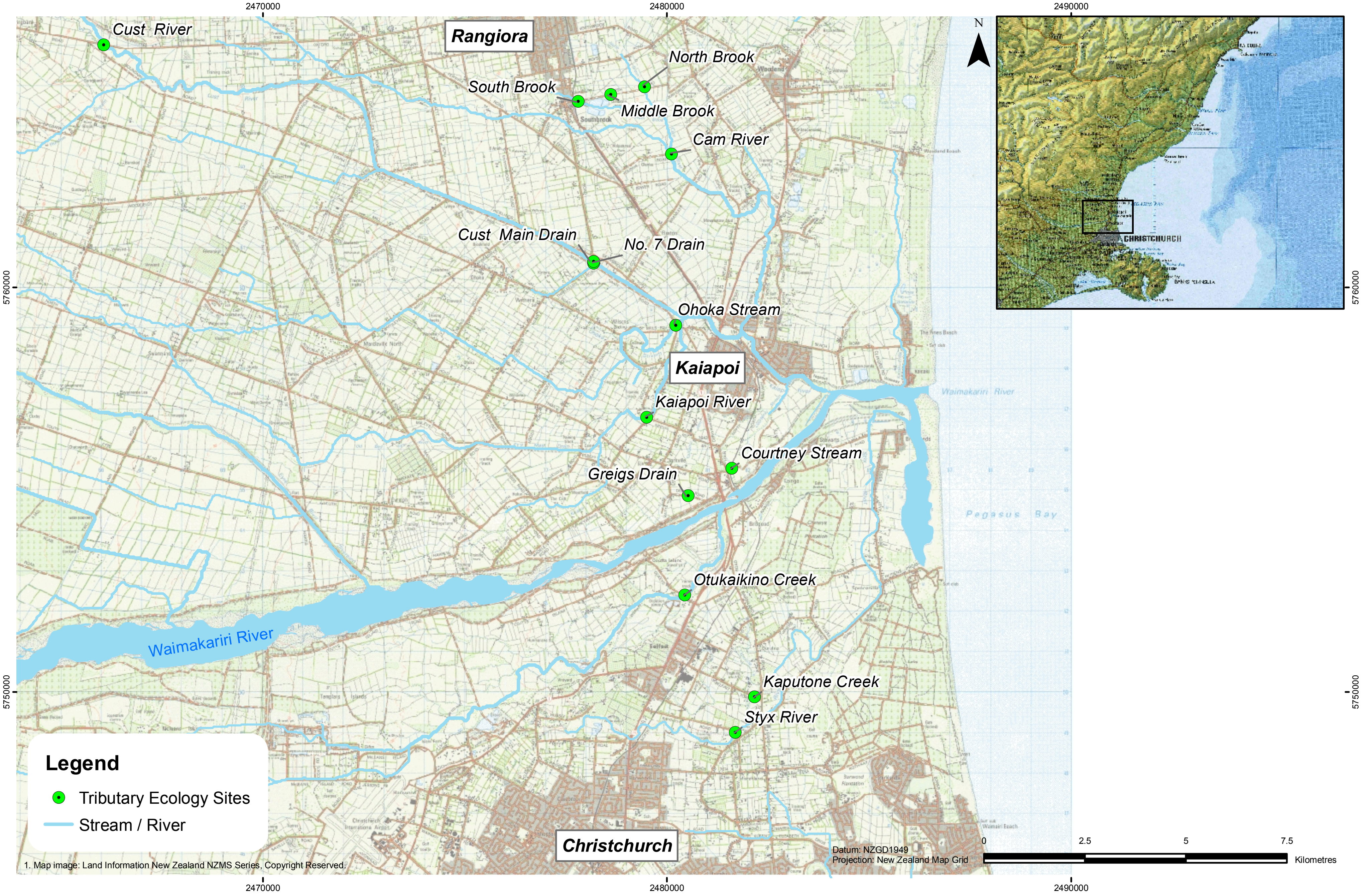
- Describe the aquatic ecological values present (or likely to be present);
- Determine whether the current minimum flow adequately protects the aquatic ecological values identified; and
- Recommend any further work that may be required.

The WRRP includes a list of the aquatic ecological values to be protected by the minimum flow provisions in each waterway. The present report used a combination of existing information and further field sampling to describe the ecological values present in more detail than provided in the plan, as some of the WRRP values are quite general (e.g., “other native fish”).

Without any monitoring data, it is not possible to assess quantitatively whether minimum flows are protecting ecological values. It was outside the scope of this report to assess the ecological health of waterways in relation to minimum flows, as this would require several years, potentially exhaustive sampling, and may in fact be unnecessary for some sites, depending on their ecological values and the degree of pressure for abstractive use of water in the catchment. Therefore, the approach taken was to build on the earlier expert panel assessments and the fish passage modelling (Main 2001) work done as part of the WRRP process. In the absence of ecology monitoring data in relation to low flows, a “balance of probabilities” approach has been used, whereby habitat availability has been modelled and existing and newly collected information has been used to determine whether the minimum flow is likely to be protecting the ecological values present. This involved assessing ecological values (desktop and fieldwork) and modelling habitat availability at different flows.

It is recognised that the minimum flows required to protect other instream values (e.g., landscape values) may differ from those required for aquatic ecosystems. Weighing up the relative importance and flow requirements of different instream and out of stream water use requirements will be undertaken by ECan and is outside the scope of this report. A detailed analysis of water quality and its relationship to flows is also not within the scope of this report, but is discussed briefly as a potential issue in Section 5.0

This report is subject to the limitations outlined in Appendix A.



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2.0 METHODS

2.1 Minimum Flow Sites

Ecology and instream habitat assessment work was undertaken at all of the 14 minimum flow sites shown in Figure 1. Fieldwork was undertaken in February/March 2009 for all sites except for Middle Brook, where fieldwork was undertaken in March 2008.

2.2 Desktop Study

Information on river ecosystems was obtained from existing reports, plans and databases, fieldwork, and discussions with ECan staff and local landowners. The WRRP was the initial source of information on ecological values being protected by minimum flows. Pre-existing information on river flows and invertebrate communities was obtained from ECan. The New Zealand Freshwater Fish Database (NZFFD) was searched for fish records within the Waimakariri River catchment. Information on salmonid habitat quality was obtained from Langlands and Elley (2000) and the associated GIS data layer (obtained from ECan). Results of the most recently published angler survey (2007/2008) were obtained from Unwin (2009). Another important reference document was a previous ECan assessment of minimum flow requirements for fish passage in the lower Waimakariri River tributaries (Main 2001). Seven day mean annual low flow (7dMALF) estimates were calculated for the 14 minimum flow sites by Mandy Chater for ECan and the 7dMALF estimates were provided to Golder for this report. At the time of writing, there was no separate hydrology report for the minimum flow sites available to reference.

2.3 Ecology Sampling

2.3.1 Ecology field methods

Ecological sampling was undertaken over several days in March 2008 and in February/March 2009. Each site comprised a representative 50 to 100 m reach of the river where data on instream habitat and biology and field measured water quality was recorded.

Notes were made at each of the sites on environmental factors that could influence aquatic communities, such as adjacent landuse, riparian vegetation and degree of stream shading. Water temperature, electrical conductivity, pH, and dissolved oxygen concentration were measured at each site during the fieldwork using calibrated field meters.

Habitat assessments were undertaken at each sampling site using the field evaluation forms and standard methods used by ECan as part of its annual biological monitoring programme of rivers throughout Canterbury (Lavender and Meredith 2004). The habitat assessment includes various criteria that are grouped into catchment-scale features, riparian and bank features, reach-scale parameters, and instream and habitat quality parameters. Most habitat variables are scored from 1 - 20, with a score of 20 indicating an optimal state for that variable. Habitat scores were summed to give a total habitat score out of 320, which was then converted to a percentage and was then compared between sites. The ECan habitat scoring method is heavily weighted towards instream habitat quality, and sites with silt-free, stony beds tend to have the highest habitat scores.

Following consultation with ECan staff, the SHMAK (Level 2) method of sampling aquatic invertebrates (Biggs et al. 2002) was chosen in preference to more quantitative kicknet or surber sampling, as it is faster and cheaper than the other methods, but yields sufficient information to characterise the invertebrate community. Briefly, this involved collecting 10 replicate samples (individual stones, or patches of macrophyte or fine sediment) at each site and identifying the invertebrates present in each sample. Habitats (stones, macrophytes, silt/sand) were sampled in proportion to their abundance at the site. The relative abundance of pollution and habitat sensitive mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) (EPT) taxa present per sample was calculated. In general, higher percent EPT abundance is indicative of cleaner water and silt-free stony habitats.

Periphyton was assessed by visually estimating the relative proportion of the riverbed covered by periphyton (algae coating stones and bedrock) at each site using categories outlined in Biggs & Kilroy (2000). Similarly, macrophyte communities at each site were assessed by determining the percent streambed area coverage, and dominant species present.

The fish fauna was surveyed at each site using a single pass technique with a 12V electric fishing machine (EFM). The area fished varied between sites from around 20 m^2 to 50 m^2, in relation to the amount of available fish habitat (i.e., large stony substances, bank or vegetation overhangs, debris jams). A range of representative habitat was surveyed at each site. All fish caught were transferred to a holding bucket, identified, and released back in to the stream. Where depths were too great for efficient fishing (i.e., >0.6 m), NZFFD records were used in combination with habitat quality to assess the fish species likely to be present.

2.4 Instream Habitat Survey

The instream habitat survey methods followed those used previously for similar assessments in North Canterbury by Wilding et al. (2005) and in the Wainono Lagoon catchment in South Canterbury by Kingett Mitchell (2006). Briefly, a section of each river, roughly 100-300 m long, was walked and a representative reach in the vicinity of the minimum flow site was selected to be surveyed. Initially this reach was walked over and habitat mapped, and this is where the type and length of each habitat (i.e., run, riffle and pool) was recorded. Once the reach had been walked, between 6 and 9 cross sections were selected to represent the range of riffle, run, and pool habitat available. The greatest numbers of cross sections were measured at sites with greater habitat variability.

At each cross section depth was measured and substrate composition was visually estimated at numerous points across the cross section. The number of depth and velocity measurements at each cross section varied and was related to the width of the cross section and the bed profile, whereby a greater number of measurements were made at wide cross sections or where the bed profile was not consistent.

A temporary stage was installed at each cross-section and the water level recorded during the first round of fieldwork (March 2008 and April 2009). For the single follow up survey, the water level of each stage was recorded and the stream flow was gauged at one cross section.

2.5 Habitat Modelling

River flow and instream habitat data (depth, width and substrate composition) from each cross-section were entered into the River Hydraulics and Habitat Simulation (RHYHABSIM) software package and then modelled. Habitat preference curves were selected from the library of preference curves available in RHYHABSIM. In addition, two sets of habitat preference curves for large shortfin eels (>300 mm) were provided by Eric Graynoth from NIWA (pers. Comm., 2007); one set of curves is based on daytime eel sampling and the other set is based on sampling at night. The difference between the two large shortfin eel curves reflects the preference for large eels to seek refuge under cover in deeper pools during the day and then enter shallower run and riffle habitat to feed during the night. For sites with very little or no shallow run or riffle habitat (e.g., Kaputone Creek), flow recommendations for adult shortfin eels were based on the daytime habitat preference curves. However, both the daytime and night habitat curves were inspected for sites with shallower run/riffle habitat and at these sites the flow recommendation was based on the shortfin eel habitat (shallow runs versus deeper pools) that was most limiting during low flows. Habitat preference curves were chosen to represent the range of species found at the sites, as determined by the ecology sampling and desktop research described above. Habitat preference curves used in the RHYHABSIM model are attached in Appendix B.

The RHYHABSIM modelling procedure followed that recommended by Jowett (2006). All models were run as reach models with habitat units weighted according to their frequency of occurrence in the study reach. Thus, the modelling followed a habitat mapping approach rather than a representative reach approach (Jowett 2006). Habitat availability was expressed as weighted usable area (WUA; m^2/m) and the habitat suitability index (HSI). The HSI is calculated by dividing WUA by the total wetted area and can be thought of as a measure of habitat quality. Note that m³/s is the default flow unit for RHYHABSIM plots, and this can not be altered. Therefore, although L/s flow units are preferred throughout this report, because most rivers are quite small, units switch between m³/s and L/s in the RHYHABSIM modelling result sections.

Minimum flow recommendations were informed by the relationship between habitat availability and flow for the key aquatic species present. This was done initially by examining the flow versus WUA data and determining the maximum WUA. Then, depending on the significance of the species present (see below), a percentage of the maximum WUA was determined, and the corresponding flow at that level of WUA was calculated. Thus, for the example shown in Figure 2 below, maximum habitat occurs at a flow of 0.9 m³/s and 90% of maximum habitat occurs at a flow of 0.48 m³/s. In this simple example, 0.48 m³/s would be the recommended minimum flow. Where maximum habitat of key species occurred well above 7dMALF, (as is often the case in small streams), minimum flow recommendations were based on retaining a percentage of the amount of habitat at 7dMALF as suggested by Jowett and Hayes (2004) for Southland streams and by Young and Hay (2006) for small streams in Marlborough.

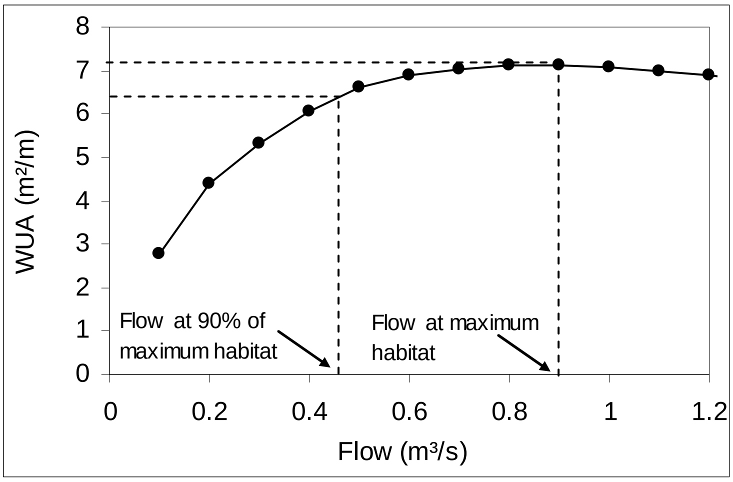

Figure 2: Selecting a minimum flow based on retention of 90% of maximum habitat for the target species.

The first stage of setting a minimum flow based on instream values is to identify what key or "sentinel" species are to be protected at the site. Typically, the sentinel species will be one that has the highest flow requirements. Significance criteria were used to determine what percentage of maximum habitat of the sentinel species should be retained. Significance criteria were developed for a number of North Canterbury streams by ECan (Wilding et al 2005), and were recently used for minimum flow recommendations in tributaries of Wainono Lagoon in South Canterbury (Kingett Mitchell 2006). For consistency and in recognition of the considerable thought that went into creating the criteria, the same criteria were applied to the Waimakariri River tributary sites (Table 1).

Based on the species present in the Waimakariri River tributary sites, the key species to be protected are locally and regionally significant salmonid habitats, with an associated 90% retention of maximum habitat, longfin eel habitat (95% retention), and diverse and abundant native fish communities (85% retention). Protection of large shortfin eel habitat was the key component of the "diverse and abundant native fish" criteria, due to their requirement for deeper water than many other native species. In addition, fish passage is considered an issue for some streams that support significant trout or salmon habitat, so the flow versus riffle depth data provided by Main (2001) is also used for those streams.

Table 1: Fish community significance criteria for determining percentage of maximum habitat retained when setting minimum flows. Criteria adapted from Wilding et al (2005). Acute and chronic threat categories are from Hitchmough et al. 2007).

Significance Criteria		**Habitat Retention (% of max. habitat)**
1	Acutely threatened species e.g. Canterbury mudfish, lowland longjaw galaxias	100%
2	Chronically threatened & regionally threatened species e.g. Longfin eel, banded kokopu	95%
3	Locally or regionally significant brown trout fisheries, plus habitat on which these fisheries depend for spawning and rearing.	90%
4	Diverse and abundant native fish communities. Includes those with high recreational (e.g., whitebaiting) or cultural/mahinga kai values (e.g., eels).	85%
5	Non-diadromous species of native fish.	80%
6	Sparse and unfished trout populations.	60%
7	Streams with few fish or aquatic fauna present.	50%
8	Other fish communities.	70%

3.0 ECOLOGICAL VALUES

3.1 Catchment Overview

The 14 minimum flow sites are located immediately north of Christchurch, as shown in Figure 1 and outlined in Table 2 below. Site photographs are provided in Appendix C. All of the sites are located on relatively flat rural land and most are within 10 km of the coast. Some sites, such as Middle Brook, North Brook and the Styx River, flow through urban areas, but urban development is currently less intense than in other Canterbury catchments, such as the Avon or Heathcote Rivers in Christchurch.

There is considerable growth and interest in residential development in catchments such as the Styx River, Kaputone Creek and South Brook. An increase in the amount of impervious area, such as roads and buildings, has the potential to significantly affect river flows, by reducing base flows (due to reduced groundwater recharge) and by increasing flood flows (due to more rapid runoff from impervious surfaces). Urban development has been implicated as one of the potential causes for the headwaters of Kaputone Creek drying for longer periods in recent years (Nikora 2004).

Table 2: Current minimum flow and seven day mean annual low flow (7dMALF) at the lower Waimakariri River tributary sites.

Site	Location	Easting	Northing	Min Flow (L/s)	7dMALF (L/s)
North Brook	Marsh Rd	2479443	5764957	530	622 ±53
Middle Brook	Marsh Rd	2478609	5764768	60	31 ±11
South Brook	Marsh Rd	2477799	5764602	140	171 ±33
Cam River	Youngs Rd	2480115	5763301	1,000	1,022 ±107
Cust River	Oxford-Rangiora Rd	2466058	5765998	20	140 ±77
Cust Main Drain	Threlkelds Rd	2478181	5760598	230	325
No. 7 Drain	Hicklands Rd	2478185	5760645	60	67 ±21
Ohoka Stream	Kaiapoi R confluence	2480215	5759067	300	526 ±46
Kaiapoi River	Neeves Rd	2479494	5756784	600	1,273 ±236
Courtenay Stream	Doubledays Rd	2481608	5755524	260	393 ±47
Greigs Drain	Greigs Drain Rd	2480522	5754856	150	302 ±47
Otukaikino Creek	Dickeys Rd	2480438	5752390	2,000	3,066 ±88
Styx River	Radcliffe Rd	2481686	5748994	1,200	1,118
Kaputone Creek	Styx R confluence	2482165	5749875	150	214 ±37

Notes: 7dMALF data are courtesy of Mandy Chater (pers. comm., June 2009) on behalf of ECan. “±” indicates error estimate based on regressions with primary recorder sites.

3.2 River Flows

Cust Main Drain and the Styx River are the only two waterways with continuous flow recorders out of the 14 minimum flow sites. Flow data for Cust Main Drain and the Styx River from the last 10 years are shown in Figure 3. The Styx River is representative of most of the tributary sites, being a spring-fed river that shows little flow variation throughout the year. The Cust River and Cust Main Drain (collectively referred to as the Cust) are unique amongst the study sites, being primarily foothill-fed, as indicated by its low baseflow conditions, punctuated by high flood flows (Figure 3). One of the key implications of the Cust being foothill-fed rather than spring-fed is that high flow variability is a natural component of foothill-fed rivers and therefore reduced flow variability, caused by water abstraction, could have an impact on the biological community (e.g., by reducing flood frequency and increasing nuisance algal growths).

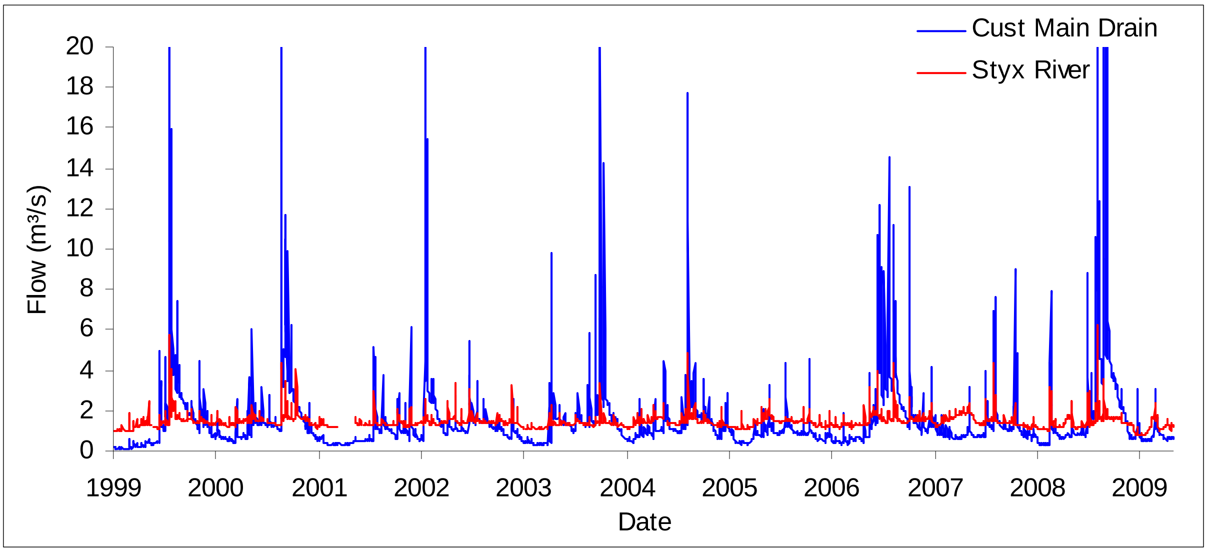

Figure 3: Comparison of daily mean flow over 10 years at Cust Main Drain and the Styx River. Data are from ECan. Note that flows >20 m³/s have been excluded for clarity.

Seven day mean annual low flow estimates range from 31 L/s at Middle Brook to over 3 m³/s at Otukaikino Creek. In general, the existing minimum flows follow a similar pattern to 7dMALF estimates, with the minimum flows comprising on average 78% of 7dMALF (i.e., the average minimum flows relative to 7dMALF across the sites). Notable exceptions are the Cust River, where the minimum flow of 20 L/s is only 14% of 7dMALF (i.e., the minimum flow is much lower than typical low flow conditions), and Middle Brook, where the minimum flow is nearly double 7dMALF (Table 2).

3.3 Water Quality

At all sites visited, water temperatures were cool (<15.5°C), pH was circum-neutral (pH range of 6.4 to 6.9), and dissolved oxygen concentrations were high (>80% saturation). However, river flows were generally higher than 7dMALF levels and it is likely that water quality issues may occur in some of the smaller waterways during low flows and in those with high macrophyte cover. In particular, water temperatures may get high during low flows in small, shallow waterways such as Middle Brook. Rivers with high macrophyte cover, such as Greigs Drain or Courtney Stream may experience low dissolved oxygen concentrations, due to the effects of plant respiration overnight.

Until quite recently, treated municipal wastewater was discharged into Otukaikino Creek from Belfast and into the Cam River and South Brook from Rangiora. However, both wastewater discharges into the Waiamkariri River tributaries have ceased. This is of particular interest for the Cam River minimum flow, which was set relatively high to allow for dilution of municipal wastewater discharged from Rangiora. Thus, Main (2001) noted that the Cam River minimum flow of 800 L/s provided adequate dilution, but that the minimum flow could be lower, 670 L/s, if dilution was not required and the key management issue was provision of adequate depths for salmon passage past shallow riffles.

3.4 Habitat, Periphyton and Macrophytes

The majority of sites are highly modified, with varying degrees of channel alteration including straightening, deepening and periodic removal of macrophytes to mitigate flooding potential. Most of the waterways are deeply incised and narrow (<5 m wide), although Otukaikino Creek and Cust Main Drain are comparatively wide, with average widths of about 10-11 m (Table 3). The shallowest waterways are Middle Brook and Cust Main Drain, with average depths <0.3 m, while a number of sites are comparatively deep, including North Brook, the Kaiapoi River, Courtney Stream, Greigs Drain, Otukaikino Creek, and the Styx River, which all had average depths >0.6m (Table 3). Water depth is an important component of fish habitat, such that depths of >0.6 m typically provide better quality habitat for large eels and adult trout, whilst shallower depths will suffice for smaller native fish such as bullies.

Most sites are dominated by gentle “run” habitat (i.e., water flowing but not broken), with little diversity of run/riffle/pool habitat (Table 3). Riffle habitat is favoured by many native fish species and spawning salmonids, and was only present at the minimum flows sites in the Cam River, the Cust, Ohoka Stream, and Kaputone Creek. However, riffle habitat is known to occur in at least some reaches elsewhere within Otukaikino Creek, South Brook, Kaiapoi River, and the Styx River (G. Burrell, pers. obs.).

Many sites had a reasonable mix of stony bed sediments, although half of the sites had >30% bed coverage with fine sediments <2 mm (Table 3). This is typical of spring-fed streams that have insufficient gradient and flood frequency to scour out fine sediments. The two Cust sites were gravel-dominated and had the lowest fine sediment cover of all sites.

Riparian shading is minimal at most sites, and only Middle Brook and Ohoka Stream had >50% shade (Table 3). Despite a low degree of shading, periphyton cover during the site visits was low to moderate at all sites. Nuisance algal growths, as defined by Biggs (2000), were absent from all sites, with thick mats (>3 mm) covering <60% of the bed and long strands of algae (>2 cm long) covering <30% of the bed at all sites. However, macrophyte cover was high and met or exceeded the proposed NRRP standard of 50% cover at half of the sites (Table 3). High macrophyte cover is typical of lowland, spring-fed streams, due to the stable flow conditions and suitable fine sediments for colonisation. Sites with highest macrophyte cover tend to also have predominantly fine sediments (<2 mm) and are poorly shaded. Thus, all sites with >50% fine sediment had >50% macrophyte cover, and all sites with >30% shade had <30% macrophyte cover (Figure 4).

Table 3: Habitat characteristics at the tributary minimum flow sites.

Site	Depth (m)	Width (m)	Riffle/Run/Pool (%)	Silt/Sand (%)	Shade (%)	Macrophyte cover (%)
North Brook	0.7	4	0 / 100 / 0	65	5	60
Middle Brook	0.1	2	25 / 75 / 0	20	85	10
South Brook	0.3	3	0 / 95 / 5	35	5	5
Cam River	0.4	4	20 / 75 / 5	20	40	10
Cust River	0.25	4	25 / 60 / 15	10	10	<5
Cust Main Drain	0.2	10	25 / 75 / 0	<5	10	<5
No. 7 Drain	0.6	2	0 / 100 / 0	25	0	50
Ohoka Stream	0.4	4.5	10 / 85 / 5	25	55	25
Kaiapoi River	0.7	5	0 / 100 / 0	15	20	50
Courtenay Stream	>1	4	0 / 100 / 0	100	0	75
Greigs Drain	>1	3	0 / 100 / 0	80	10	75
Otukaikino Creek	0.7	11	0 / 100 / 0	60	20	50
Styx River	0.7	7	0 / 100 / 0	90	15	60
Kaputone Creek	0.6	4	40 / 60 / 0	100	20	-

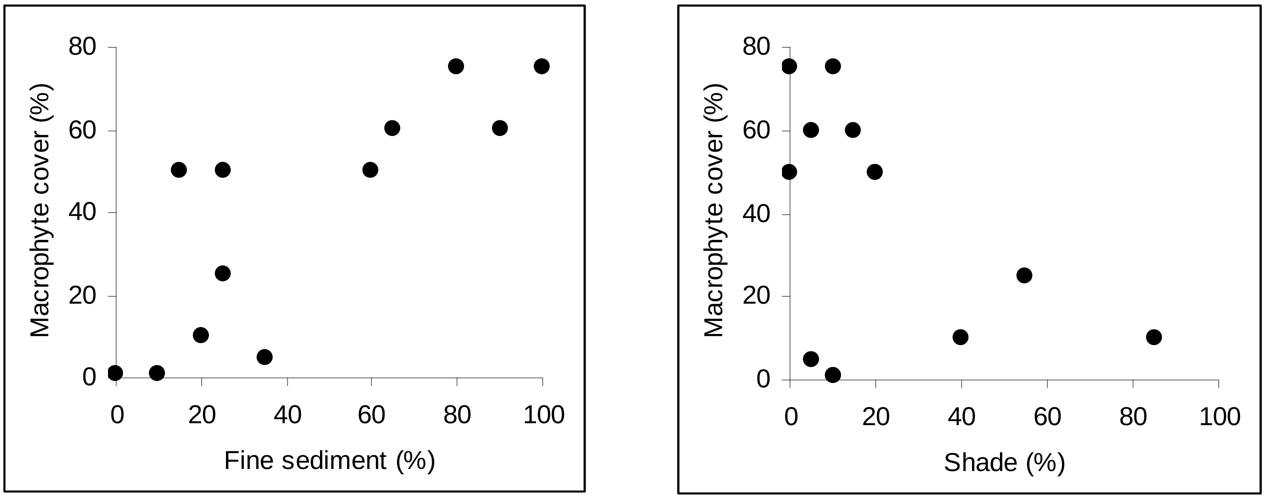

Figure 4: Relationship between macrophyte cover and bed coverage with fine sediment <2 mm (left) and shade (right) at the Waimakariri tributary sites.

The Cust River and Cust Main Drain sites had the highest ECan habitat scores, which was due to their silt-free stony beds. Courtney Stream, Greigs Drain, North Brook and Kaputone Creek had the lowest scores, reflecting their predominantly fine sediment beds and lack of habitat variability. Although already mentioned in Section 2.3 above, it is worth reiterating here that the ECan habitat scoring method is heavily weighted towards instream habitat quality, and sites with silt-free, stony beds tend to have the highest habitat scores. Soft-bottomed streams, that may have low ECan habitat scores, will often support a diverse and ecologically significant fish fauna, provided they have sufficient cover in the form of undercut banks, overhanging vegetation and woody debris.

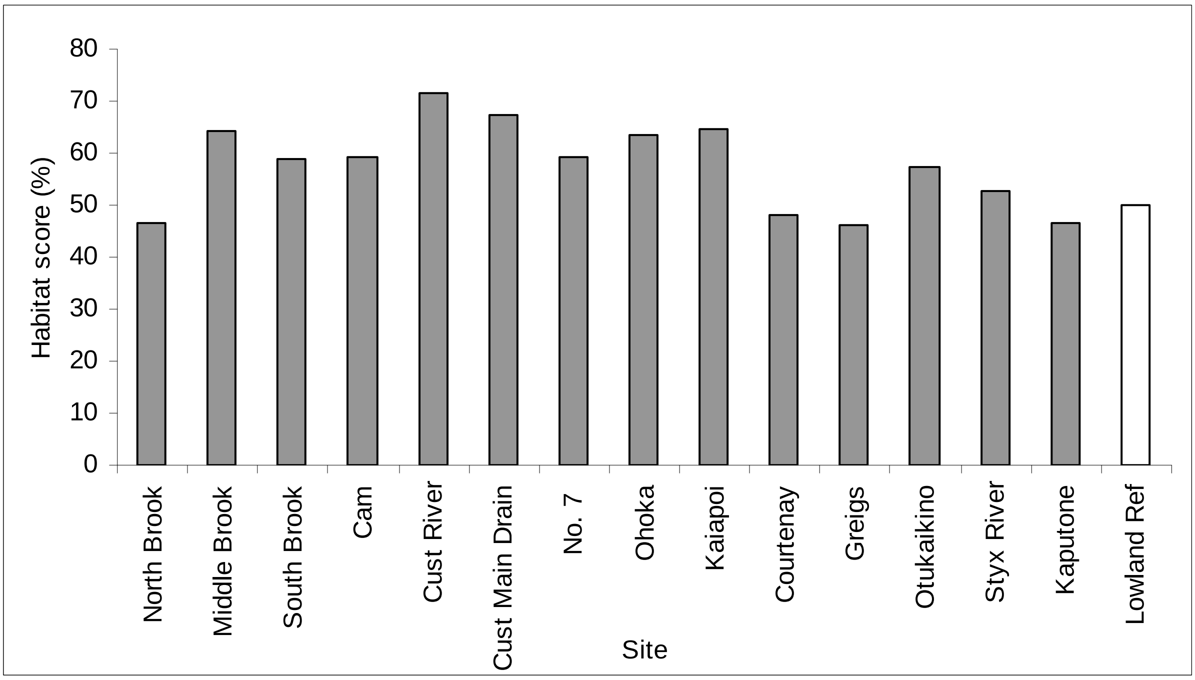

Figure 5: Habitat scores for Waimakariri River tributary sites. The lowland reference data is from Meredith et al. (2003).

3.5 Invertebrates

At most sites sampled for this study, the invertebrate fauna was dominated by amphipod crustaceans, reflecting the stable, spring-fed source of flow and ample macrophyte cover. Other common invertebrate groups included snails (Mollusca), oligochaete worms and dipterans (Figure 6). The Cust had a distinctive invertebrate fauna, being dominated by cased caddisflies (Trichoptera) and mayflies (Ephemeroptera). The dominance of pollution-sensitive mayfly and caddisfly species at the Cust is because the river has a predominantly stony bed, has low macrophyte cover and is more flood-disturbed than the other tributary sites.

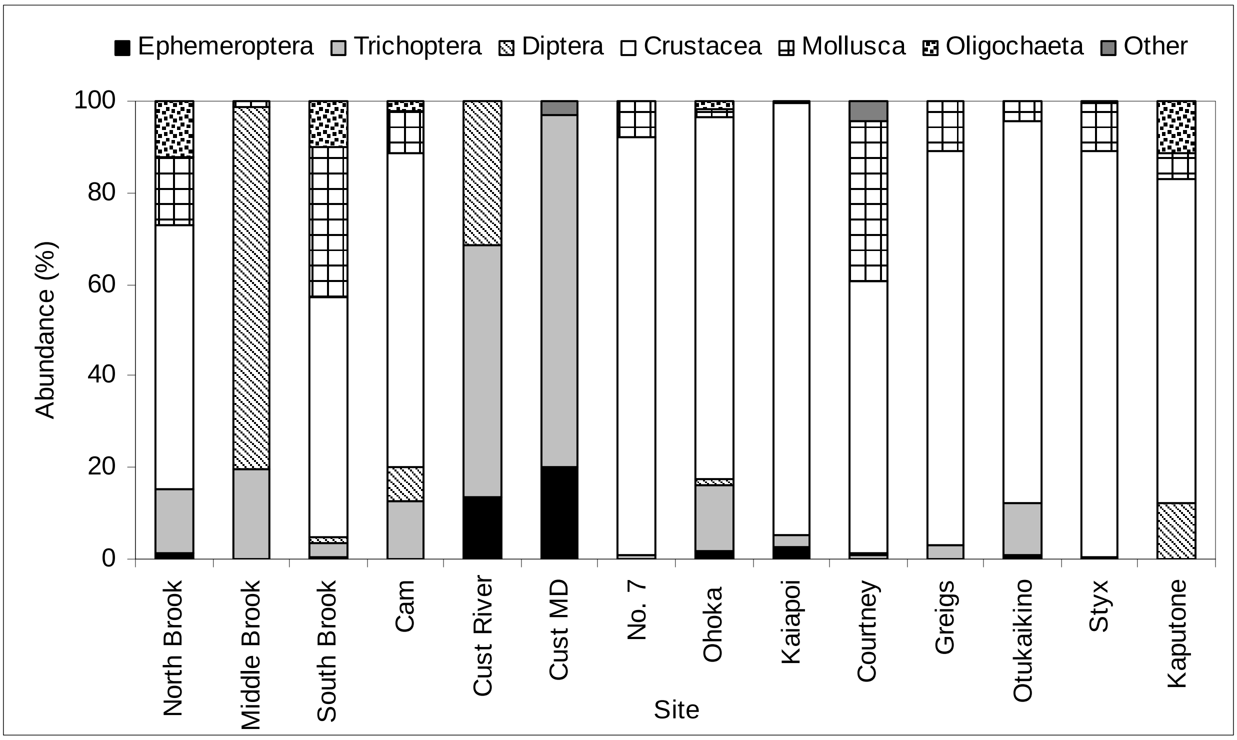

Figure 6: Abundance of different invertebrate groups collected from the Waimakariri River tributary sites.

In addition to species collected during invertebrate sampling, the freshwater shrimp *Paratya* was collected during electric fishing and was abundant amongst macrophytes at Ohoka Stream, No. 7 Drain, Courtney Drain, and the Cam River. There are also records of koura (freshwater crayfish) in the NZFFD for the Styx River, Otukaikino Creek and the Cam River, and koura were also recorded from North Brook and South Brook by Golder Associates (2008).

The invertebrate fauna of most of the Waimakariri River tributaries is typical for lowland, spring-fed Canterbury rivers and most species encountered are common and widespread. The mayfly and caddisfly-dominated invertebrate fauna of the foothill-fed Cust River and Cust Main Drain is indicative of good habitat and water quality and would be more sensitive to reduced water quality and low flows than the other tributary sites. Both koura and *Paratya* are preyed on by native and introduced fish species and koura is also a threatened species in gradual decline nationally (Hitchmough et al. 2007).

In a review of ECan's invertebrate monitoring network, Lavender and Meredith (2004) concluded that in the majority of lowland streams it is difficult to determine whether the minimum flows that have been set are in any way adequately protecting the instream values. This was because most of the lowland monitoring sites are affected by either habitat degradation or water quality degradation, such that low flow effects either cannot be identified or separated from existing degradation (Lavender and Meredith 2004). In practice, the semi-quantitative invertebrate monitoring approach adopted by ECan and most other Regional Councils is best suited to assessing habitat and water quality effects on the biota; more quantitative sampling is probably required to assess low flow effects.

3.6 Fish

Appendix 3 of the WRRP provides an overview of the main aquatic values present throughout the Waimakariri River catchment, including all of the tributary minimum flow sites except for the Ohoka River. The WRRP lists all of the sites as providing significant habitat for eel, “other native fish” and trout. In addition, all sites except for the Styx River and Kaputone Creek are considered to provide significant whitebait habitat. Significant Chinook salmon gravel bed spawning habitat is considered to occur in the Kaiapoi River, Greigs Drain, Courtney Stream, the Cam River and its tributaries and Otukaikino Creek. Although the values of Ohoka Stream are not listed, it is likely to be significant for eels, whitebait, trout and salmon. Further details of the fish species found in the Waimakariri River tributary sites are provided in the following paragraphs.

A total of 20 fish species have been recorded from the lower Waimakariri River tributary sites. Overall, fish taxa richness is high and is a reflection of the sites’ close proximity to the coast, the generally stable spring-fed habitat, and moderate to good depths present. Sites with particularly high taxa richness (i.e., >10 taxa recorded) include the Cust River and Cust Main Drain, Otukaikino Creek, the Styx River and the Cam River (Table 4).

Although there is a good diversity of fish taxa found amongst the sites, there is a core group of five species common to most waterways: common bully, upland bully, shortfin eel, longfin eel, and brown trout. In addition to the core group of freshwater species, a number of primarily marine or estuarine species have been recorded from the tributaries, including black flounder, yelloweye mullet, and common smelt (Table 4). Important mahinga kai species include eel, lamprey, inanga (whitebait), mullet, and flounder.

Species of potential conservation interest include longfin eel (gradual decline), giant kokopu (gradual decline), lamprey (sparse), redfin bully (regionally rare) and Canterbury mudfish (nationally endangered). The NZFFD record associated with Canterbury mudfish within the catchment is from an unknown source dated 1946 (NZFFD Card No. 50371), and the lack of any recent records from the area, despite recent sampling efforts, suggests that mudfish are unlikely to still be present. Similarly the two redfin bully records from Otukaikino Creek and Cust Main Drain are from 1962 and 1955, respectively, and it is unlikely that redfin bully are still present within the catchment. The single giant kokopu record was collected from the Cam River at Marsh Road in 1994. This is a surprising find, given that giant kokopu today are uncommon in Canterbury lowland streams. Again, it is likely that few giant kokopu are present in the lower Waimakariri River tributaries, given that they were not collected during the recent sampling of Golder and EOS Ecology (2005). However, given that several rare fish species are known from the catchment, a regular monitoring programme would provide information on the status of these rare fish populations.

Table 4: Records from the New Zealand Freshwater Fish Database and Golder Associates for Waimakariri River tributary sites.

Species	Threat status	North Brook	Middle Brook	South Brook	Cam River	Cust River[1]	No.7 Drain	Ohoka Stream	Kaiapoi River	Courtney Stream	Greigs Drain	Otukaikino Creek	Styx River	Kaputone Creek
Common bully	Common native	✓	1	✓	5	24	✓	7	3			9	9	4
Shortfin eel	Common native	✓	✓	✓	5	16	✓	6	1	✓	✓	8	14	6
Brown trout	Introduced	3	2	✓	3	20	✓	2	1	1[2]		12	13	
Longfin eel	Gradual decline	✓	1	1	4	16		✓	1			7	15	3
Upland bully	Common native	✓	✓	✓		23	✓	6				8	3	6
Inanga	Common native				1	13						2	7	3
Black flounder	Common native				3	11	✓		2			4	4	
Giant bully	Common native				2	3			2			1	4	
Bluegill bully	Common native					10								
Yelloweye mullet	Common native				2	1							3	
Lamprey	Sparse			✓		1							5	
Rainbow trout	Introduced					2			1			2		
Common smelt	Common native					1			1			1	2	
Chinook salmon	Introduced					2			✓			2		
Redfin bully	Regionally rare					1						1		
Grey mullet	Common native				1								1	
Koura	Gradual decline				1								1	
Torrentfish	Common native					1								
Giant kokopu	Gradual decline				1									
Canterbury galaxias	Common native											1		
Canterbury mudfish	Nationally endangered				1									

Notes: [1]Cust River includes the lower reaches, unofficially known as Cust Main Drain. [2]Record is for unidentified salmonid; but is most likely brown trout, based on habitat and nearby fish records. Numbers are number of freshwater fish database records, not fish abundance. Freshwater fish database data are courtesy of NIWA. North, Middle and South Brook data are from Golder Associates (2008).

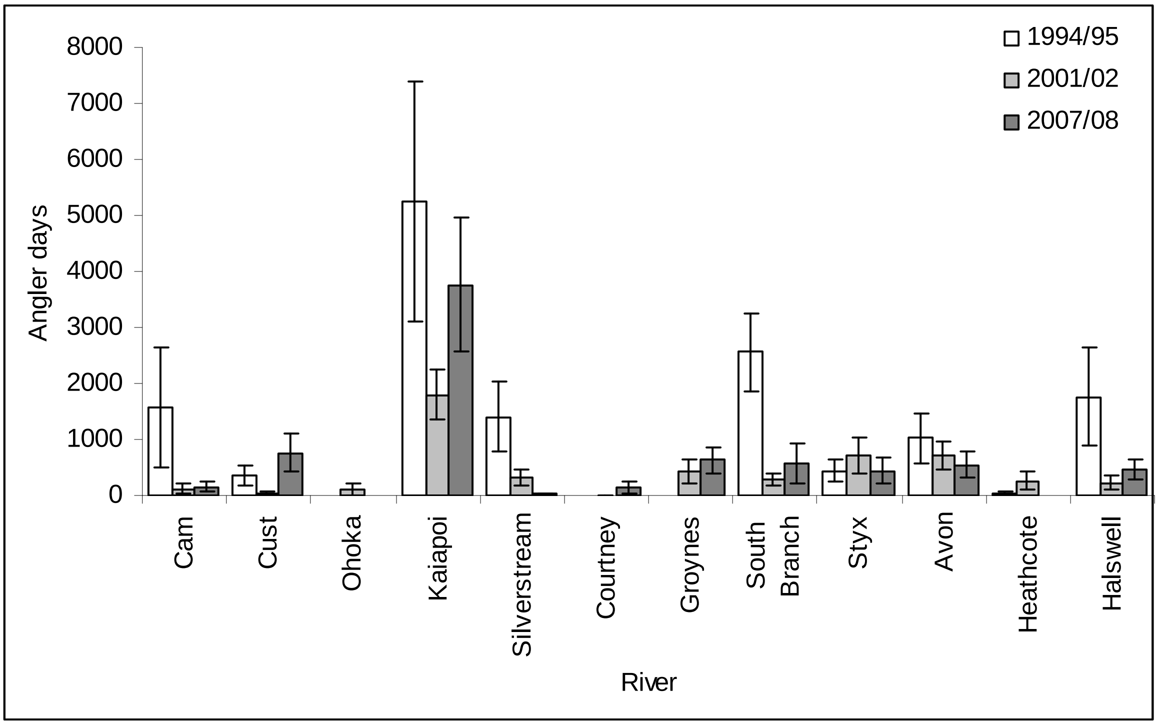

Figure 7: Estimated angler usage (±1SE) for lower Waimakariri River tributaries compared with the nearby Avon, Heathcote and Halswell Rivers. Data are from Unwin (2009).

Brown trout and Chinook salmon are important sports fish and trout are widespread throughout the Waimakariri River tributaries. Recent national angler survey results of Unwin (2009) indicate that the Kaiapoi River is the most heavily fished lowland river in Canterbury (Figure 7), with the lower reaches of the Kaiapoi River being particularly popular for salmon fishing. One of the reasons for the abundance of salmon in the Kaiapoi River is that there is a salmon hatchery in its upper reaches (known as Silverstream). All of the other rivers have comparatively lower angler usage, although some, such as Otukaikino Creek (split into the upper Groynes area and South Branch by Unwin, 2009), are popular local fisheries.

In a study of angler perceptions of the quality of lowland trout fisheries throughout New Zealand, Jellyman et al. (2003) found, *"…a strong consensus that angling quality had declined over up to 70 years of record, with two-thirds of the assessments indicating that angling had become generally or markedly worse. Changes in angling quality appeared to reflect changes in fish abundance rather than fish size, suggesting that for lowland river fisheries availability of fish rather than fish size was the main determinant of angling quality."* The study also found that in North Canterbury lowland rivers such as the Waimakariri River tributaries, declining water quality, rather than flow was considered by anglers as the cause of reduced angling quality and catch rates (Jellyman et al. 2003). Although the angler survey was based solely on angler's perception, it provides the only published long term perspective on trout numbers in the Waimakariri River tributaries, and the results suggest a long term decline in trout abundance in the Cam, Cust, Kaiapoi and Styx Rivers, and in Otukaikino Creek.

4.0 MINIMUM FLOW REVIEW

4.1 Introduction

As discussed in Section 1, the key question being asked as part of the lower Waimakariri River tributaries flow review process is whether the existing minimum flows adequately protect the values identified in Objective 5.1 of the WRRP. The key values relating to aquatic ecology listed in Objective 5.1 of the WRRP are:

> *(b) safeguarding the life-supporting capacity of the water, including its associated: aquatic ecosystems, significant habitats of indigenous fauna, and areas of significant indigenous vegetation;*
>
> *(c) safeguarding their existing value for providing mahinga kai for Tangata Whenua;*
>
> *(h) protecting the significant habitat of trout and salmon.*

In particular, the WRRP states that all of the lower Waimakariri River tributaries provide significant habitat for eels, “other native fish” and trout, whilst some sites also provide significant habitat for whitebait and salmon spawning (see Section 3.6 above).

It is understood that the minimum flows in the WRRP were arrived at using an expert panel approach and community consultation. Prior to the WRRP becoming finalised, Main (2001) made recommendations specifically for protection of instream values, based on minimum depths for upstream passage of salmonids, plus dilution of wastewater. Although the WRRP has been operative for 5 years, there has been no monitoring dedicated to assessing the effects of low flows on instream values. Although a lack of ecological monitoring of environmental flows is typical within Canterbury and throughout New Zealand, this lack of information does hamper the ability to assess the effectiveness of existing minimum flows in protecting instream values.

In the absence of any relevant ecological monitoring data relating to low flows, instream habitat modelling has been used in combination with existing information from Main (2001) to assess whether the existing minimum flows are *likely* to adequately protect the ecological values present in the lower Waimakariri River tributaries.

4.2 Minimum Flows for Fish Passage

Existing minimum flows, the recommendations of Main (2001) and estimated 7dMALF for the lower Waimakariri River tributary sites are summarised in Table 5. As noted in Section 3.2 above, the existing minimum flows are on average 78% of 7dMALF (Table 5). The minimum flows recommended by Main (2001) for protection of fish passage are generally higher and are on average 90% of 7dMALF. It is noted that the 800 L/s flow recommended by Main (2001) for the Cam River was to allow for dilution of effluent from the Rangiora wastewater treatment plant (WWTP). The Rangiora WWTP no longer discharges into the Cam River, so Main’s (2001) lower minimum flow of 670 L/s for protection of fish passage would apply.

The fish passage criteria used by Main (2001) were based on a minimum depth of passage past shallow riffles of 0.25 m for salmon and 0.15 m for brown trout, with a lower minimum of 0.1 m in the Cust River, due to only smaller trout being found there.

Table 5: Seven day mean annual low flows (7dMALF), existing minimum flows and flows recommended by Main (2001) for protection of upstream fish passage.

Site	7dMALF (L/s)	Minimum Flow (L/s)	Fish Passage (L/s)
North Brook	622	530	480 (salmon)
Middle Brook	31	60	–
South Brook	171	140	210 (salmon)
Cam River	1022	1000	800 (dilution) 670 (salmon)
Cust River	140	20	40 (juvenile trout)
Cust Main Drain	325	230	280 (trout)
No. 7 Drain	67	60	110 (trout)
Ohoka Stream	526	300	415 (salmon)
Kaiapoi River	1273	600	930 (salmon)
Courtenay Stream	393	260	–
Greigs Drain	302	150	195 (trout)
Otukaikino Creek	3066	2000	3100 (salmon)
Styx River	1118	1200	610 (salmon)
Kaputone Creek	214	150	–

4.3 Instream Habitat Modelling Results

4.3.1 Introduction

Nine of the 14 minimum flow sites had sufficiently robust stage versus flow relationships for predictive instream habitat modelling to be undertaken. WUA and HSI plots for the nine sites are shown in Appendix D. For the remaining five sites (Middle Brook, South Brook, Kaiapoi River, Styx River and Otukaikino Creek), changes in river flow resulted in inconsistent changes in water levels. It is likely that a combination of macrophyte growth and clearance upstream and in the vicinity of the minimum flow sites resulted in unreliable stage versus flow relationships at these sites.

Data from all sites (including the five with poor stage versus flow relationships) were entered into RHYHABSIM and instream habitat was modelled. Modelled instream habitat data (widths, depths, velocities, WUA and HSI) from the survey flow at each site was then tabulated and plotted to derive general relationships between flow and habitat availability. These general relationships were then used for sites where modelling habitat availability above or below the survey flow in RHYHABSIM was hampered by good stage/flow relationships.

4.3.2 Relationships between flow and habitat

The increase in depth and width with flow evident across the sites is shown in Figure 8. Sites that depart appreciably from the general depth-flow relationship include Cust Main Drain, which is very wide and shallow, and Greigs Drain and Courtney Stream, which are narrow and deep (Figure 8). Because of its particularly wide and shallow channel form compared with other sites, Cust Main Drain was excluded from correlations used to calculate general relationships between flow, depth and habitat availability. Velocity did not follow any general trend with flow between the sites, reflecting the influence of local conditions (e.g., macrophyte cover) on velocities.

Species habitat preferences are summarised in Appendix B and show that in general, large eels prefer depths >0.6-0.8 m, while depths >0.6 m are ideal for adult brown trout. Depths of around 0.3-0.6 m are preferred by juvenile trout, while many native fish, including juvenile eels, prefer depths <0.25 m. Based on the general relationship between depth and flow for the lower Waimakariri River tributary sites (Figure 8), rivers with flows >1.3 m^3/s will provide good depths for adult trout and large eels, while flows in the range of 0.3-1.3 m^3/s will include depths suitable for juvenile trout, provided the channel shape is not particularly broad and shallow or narrow and deep. Figure 8 suggests that flows <0.3 m^3/s are necessary to obtain suitably shallow depths for many native fish species, although higher flows will still provide suitable edge habitat for most native species that prefer shallower depths (Jowett and Richardson 1995).

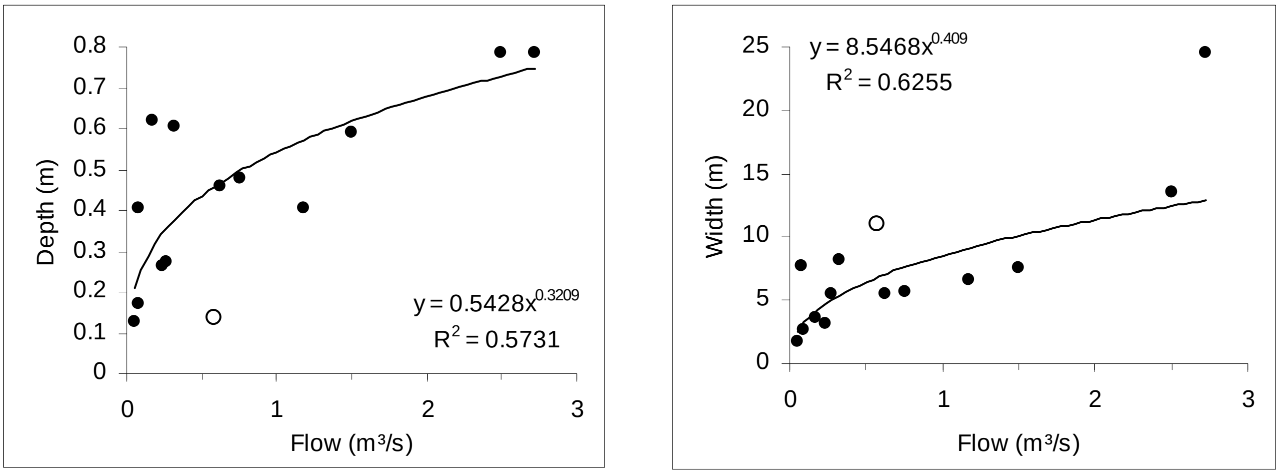

Figure 8: Relationship between survey flow and mean depth (left), and width (right) at the minimum flow sites. The power curve regression line is shown. Regression equations exclude data from Cust Main Drain (open circles).

When comparing habitat changes with flow amongst sites, HSI is preferred over WUA, as it expresses habitat changes independently of river size or width. Habitat quantity (as WUA) and habitat quality (as HSI) follow very similar patterns for each of the rivers modelled (see plots in Appendix D), which gives confidence that general relationships between flow and HSI can be used to infer changes in WUA with flow at individual sites.

At the sites studied, habitat quality (HSI) declines more rapidly as flows drop below around 0.4 m^3/s for juvenile trout and below around 0.6 m for adult trout, as depths become too shallow for these different trout life stages (Figure 9). Cust Main Drain has lower habitat quality for juvenile and adult brown trout for a given flow than the other sites, due to it being so shallow. Other species and life stages had weaker flow versus HSI relationships than for adult and juvenile brown trout, perhaps reflecting greater influence of other habitat preferences on habitat quality, such as substrate composition.

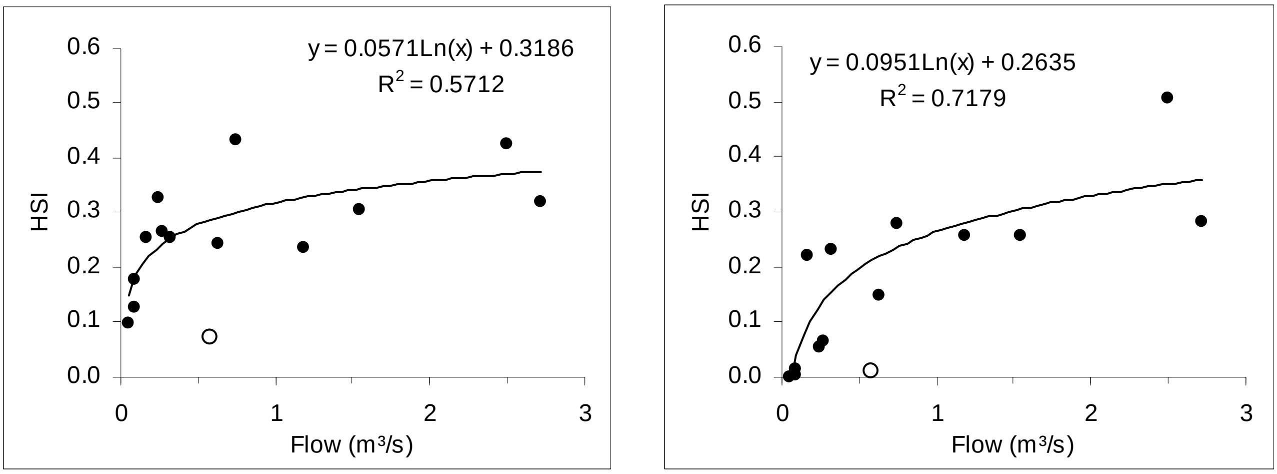

Figure 9: Relationship between survey flow and the habitat suitability index (HSI) for brown trout juveniles (left) and adults (right) at the minimum flow sites. The log-linear regression line is shown. Regression equations exclude data from Cust Main Drain (open circles).

4.3.3 North Brook

In North Brook, the existing minimum flow is 530 L/s and the estimated 7dMALF is 622 L/s. Maximum WUA occurred above 7dMALF for brown trout fry and adults and for both eel species (Figures 1 and 2, Appendix C). There was minimal habitat available for salmonid spawning, due to the lack of suitable gravels at the site. Ninety percent of habitat available at 7dMALF occurred at a flow of 480 L/s for brown try juveniles and 550 L/s for brown trout adults. Ninety-five percent of habitat available at 7dMALF occurred at 570 L/s for large longfin eels, while 85% retention of large shortfin eel habitat (day curve) occurred at 390 L/s. The existing minimum flow of 530 L/s equates to approximately 90% of large longfin eel habitat at 7dMALF.

Based on the relationship between instream habitat and flow for the key species summarised above, the existing minimum flow of 530 L/s provides a reasonably high level of protection of the key ecological values present. The flow of 480 L/s recommended by Main (2001) for maintenance of upstream passage of spawning salmon would result in reduced habitat availability for other key species.

4.3.4 Middle Brook

RHYHABSIM modelling results are not available for Middle Brook, due to a poor flow versus stage relationship. However, based on the stream's shallow nature and the general relationship between flow and habitat amongst sites, habitat is likely to be limiting at 7dMALF (31 L/s) for trout and larger eels. Therefore, a minimum flow set at 7dMALF, or a large proportion of it, would be required for adequate protection of the fish species present.

Mean depth at the Middle Brook minimum flow site was only 0.13 m during the survey flow of 51 L/s. Therefore, Middle Brook is generally too shallow to provide significant habitat for adult trout or large eels, but does provide some juvenile trout habitat and provides some trout spawning habitat. Based on the general relationship between flow and HSI (Figure 9), 90% of juvenile habitat at 7dMALF occurs at a flow of 21 L/s. However, the generalised habitat relationship for juvenile brown trout overestimates habitat availability for small streams such as Middle Brook, and a conservative approach to minimum flow setting is therefore recommended.

The existing minimum flow in Middle Brook is 60 L/s, which is nearly double the estimated 7dMALF of 31 L/s. In general, it is considered impractical to have a minimum flow higher than 7dMALF, which is the naturally occurring low flow limit to aquatic habitat. Therefore, it is recommended to lower the minimum flow from 60 L/s to 30 L/s, which approximates 7dMALF. Further lowering of the minimum flow below 7dMALF is not recommended, given the shallow depths present.

4.3.5 South Brook

RHYHABSIM modelling results are not available for South Brook, due to a poor flow versus stage relationship. Mean depth at the minimum flow site was 0.26 m during the survey flow of 240 L/s. Based on the generalised relationship between flow and depth shown in Figure 8, dropping the flow from 7dMALF of 171 L/s to the minimum flow of 140 L/s results in a drop in mean depth of only 2 cm, and habitat availability for juvenile brown trout drops by only 6% (Figure 9). Ninety percent retention of juvenile trout habitat present at 7dMALF occurs at a flow of around 120 L/s.

Main (2001) estimated that a higher flow of 210 L/s would be required to allow upstream passage for spawning salmon. South Brook is not mentioned in a summary of salmonid habitat throughout Canterbury (Langlands 2000) and it is unclear how extensively South Brook is actually used for salmon spawning. However, South Brook is used by brown trout for spawning (Golder Associates 2008). Based on the relationship between flow and riffle depths for South Brook provided by Main (2001), and the general relationship between flow and mean depth shown in Figure 8, a flow in the order of 60–100 L/s would be required to provide a minimum depth of 0.15 m past shallow riffles and provide habitat for spawning brown trout in autumn/winter.

In summary, the existing minimum flow of 140 L/s in South Brook is considered to provide adequate habitat for the aquatic species present, and could be lowered to 120 L/s and still provide adequate protection. Based on the recommendations of Main (2001), a higher minimum flow of 210 L/s may be required if, following stakeholder consultation, salmon spawning is considered a critical value. However, a lower minimum flow of around 60–100 L/s in autumn/winter would be sufficient to provide for upstream passage of adult trout and trout spawning habitat.

4.3.6 Cam River

The current minimum flow for the Cam River is 1,000 L/s and 7dMALF is estimated at 1,022 L/s. Maximum WUA for adult brown trout occurs above 7dMALF at 1,420 L/s, and 90% retention of habitat available at 7dMALF occurs at a flow of 890 L/s (see Figure 3, Appendix D). All of the other salmonid life stages show declining WUA and HSI with increasing flow, reflecting their preference for shallower depths. Similarly, habitat availability either changes little or declines with increasing flow for most of the native fish and invertebrate species modelled (Figure 4, Appendix D). Ninety-five percent of maximum large longfin eel habitat occurs at around 640 L/s, while 85% of large shortfin eel habitat (day curve) at 7dMALF occurs at around 470 L/s. Main (2001) recommended that a minimum flow of 670 L/s would provide adequate upstream passage of spawning salmon in the Cam River.

In summary, the current minimum flow of 1,000 L/s could be lowered to 890 L/s and still provide a high level of protection for adult brown trout habitat. A lower minimum flow of around 670 L/s would provide habitat for salmonid spawning, juveniles and native fish.

4.3.7 Cust River

At the Cust River, maximum WUA for the various salmonid species and life stages examined occurs well above the 7dMALF of 140 L/s. Based on the river’s size and channel shape, the Cust River provides limited habitat for large adult salmonids, but does provide reasonable habitat for juvenile trout, or stunted adults. Ninety percent of juvenile trout habitat available at 7dMALF occurs at a flow of 120 L/s, while 90% retention of trout spawning habitat occurs at 135 L/s (see Figure 5, Appendix D). The existing minimum flow of 20 L/s provides only 22% and 2% of the habitat available at 7dMALF for brown trout juveniles and spawning, respectively. Main (2001) recommended a minimum flow of 40 L/s to allow for upstream passage of juvenile trout, assuming a minimum depth requirement of 0.1 m. However, a flow of 40 L/s would provides only 40% of the juvenile trout habitat present at 7dMALF, and therefore such a flow is considered too low for protection of juvenile trout habitat.

Main (2001) noted that the lower reaches of the Cust River regularly go dry over summer, and therefore provision for upstream passage of adult salmon (which migrate upstream in summer and autumn) was considered unnecessary.

Overall, the Cust River's only moderate depths provide poor quality habitat for longfin eels and adult shortfin eels (day curve), and there is little change in habitat availability with flow. However, the WUA curve for large shortfin eels based on night sampling reveals greater habitat availability and greater change with flow; maximum WUA occurs above 7dMALF and 85% of WUA at 7dMALF occurs at 50L/s. Ninety five percent of habitat available at 7dMALF for large longfin eels occurs at 105 L/s. WUA generally declines with increasing flow for inanga, reflecting this species' preference for sluggish, deeper water. Most of the other native fish species show little change in WUA with flow.

Based on the relationship between flow and instream habitat availability for the different species examined in the Cust River, the existing minimum flow of 20 L/s appears to be too low. The modelling results presented above suggest that a minimum flow of 120 L/s would provide adequate protection of the depths required for juvenile trout habitat, while a minimum flow in the order of 60–100 L/s would adequately protect habitat for eels and other native fish.

4.3.8 Cust Main Drain

The very broad and shallow nature of Cust Main Drain greatly limits habitat available for adult salmonids and large eels, but provides good quality habitat for smaller native fish and for salmonid spawning. Ninety percent of juvenile brown trout habitat at 7dMALF occurs at 220 L/s, while 90% of 7dMALF habitat occurs at 290 L/s for salmon and brown trout spawning.

As indicated above, depths are generally too shallow for large eels and therefore WUA is low and varies little with flow for large longfin and large shortfin (day curve) eels. However, night foraging habitat for large shortfin eels is reasonably abundant, due to the prevalence of shallow run habitat. Eighty five percent of the habitat available at 7dMALF for large shortfin eels (night curve) occurs at a flow of around 235 L/s. The existing minimum flow of 230 L/s provides at least 85% of habitat available at 7dMALF for all of the other native fish examined.

Overall, the instream habitat modelling results presented above indicate that the existing minimum flow of 230 L/s provides a good level of protection of the habitat available for juvenile brown trout and native fish in Cust Main Drain. Main (2001) recommended a minimum flow 280 L/s for upstream passage of adult brown trout, which could be used as part of an autumn/winter minimum flow, if necessary.

4.3.9 No. 7 Drain

Number Seven Drain is very shallow and narrow, with reasonably high macrophyte cover. As such, No. 7 Drain provides poor quality habitat for adult salmonids, but provides some habitat for smaller native fish and juvenile salmonids. Ninety percent of WUA habitat available at 7dMALF occurs at a flow of around 60 L/s, which is the existing minimum flow (see Figure 9 in Appendix D).

Eighty five percent of WUA available at 7dMALF for large shortfin eels (night curve) occurs at a flow of around 45 L/s. The existing minimum flow of 60 L/s provides over at least 90% of habitat available at 7dMALF for all other native species and life stages modelled.

Overall, the existing minimum flow of 60 L/s is considered to provide sufficient depths and adequate protection of aquatic habitat for the native and salmonid fish species present.

4.3.10 Ohoka Stream

The combination of moderate depths and stony bed sediments would provide reasonably good instream habitat for juvenile and spawning salmonids, plus eels and other native fish species at Ohoka Stream. Maximum WUA for juvenile brown trout occurs slightly above 7dMALF, and 90% of juvenile trout available at 7dMALF occurs at a flow of around 365 L/s (see Figure 11 in Appendix D). The existing minimum flow of 300 L/s equates to retention of 82% of juvenile brown trout WUA present at 7dMALF. Maximum WUA for both brown trout and salmon spawning habitat occurs at or below 7dMALF and 90% retention of spawning habitat for both species occurs at 335 L/s. Main (2001) suggested that a minimum flow of 415 L/s was required to allow upstream passage of spawning salmon past shallow riffles.

All of the native fish WUA curves either show relatively little change or a decline with increasing flow. Ninety five percent of large longfin eel habitat at 7dMALF is retained by a flow of around 400 L/s, and the existing minimum flow of 300 L/s retains 90% of WUA present at 7dMALF. Eighty five percent retention of large shortfin eel habitat (day curve) at 7dMALF occurs at around 150 L/s. The night curve for adult shortfin eels was not used for flow setting, as it shows declining WUA with increasing flow, so is less sensitive to low flows than the day curve.

In summary, the instream habitat modelling results summarised above suggest that the existing minimum flow of 300 L/s for Ohoka Stream is a little low and that flows in the order of 365 L/s would be necessary to protect the salmonid and native fish habitat.

4.3.11 Kaiapoi River

The Kaiapoi River at the Neeves Road minimum flow site is dominated by moderately deep and uniform run habitat. The combination of good depths, gravel substrate and macrophyte cover provide good habitat and cover for native fish and salmonids, including large eels and adult brown trout. RHYHABSIM modelling results are not available for the Kaiapoi River, due to a poor flow versus stage relationship. However, based on the general relationship between flow and depth shown in Figure 8, 7dMALF flows of 1,273 L/s would provide average depths of around 0.6 m, while the existing minimum flow of 600 L/s would provide average depths of 0.46 m. Based on the general relationship between flow and HSI for brown trout juveniles and adults (Figure 9), 90% retention of HSI at 7dMALF occurs at 1,000 L/s for adult brown trout and at 800 L/s for juvenile brown trout. The existing minimum flow of 600 L/s provides around 75% of HSI available at 7dMALF for adult brown trout.

Given the greater depth requirements of large eels, habitat is likely to follow a pattern of declining habitat availability with declining flow, similar to that of adult brown trout. Therefore, protection of adult brown trout habitat would likely also protect large eel habitat.

Main (2001) recommended a minimum flow of 930 L/s to provide for upstream passage of spawning salmon past shallow riffles. Using the relationship between flow and maximum depth at critical riffles given by Main (2001), the existing minimum flow of 600 L/s would provide a depth of 0.19 m over shallow riffles, which is lower than the minimum requirement of 0.25 m given by Main (2001). While some studies have used 0.20 m as the minimum depth for salmon passage, 0.19 m is probably too shallow. Given the significance of the Kaiapoi River for salmon fishing and the presence of the Silverstream salmon hatchery upstream, protection of salmon passage in the Kaiapoi River is considered a high priority.

In summary, Main (2001) indicates that a minimum flow of 900 L/s in the Kaiapoi River is necessary for protection of salmon passage, while the generalised relationship between flow and habitat derived from this study indicates that a minimum flow of 1,000 L/s would adequately protect habitat for adult brown trout, large eels and other native fish. As such, the existing minimum flow of 600 L/s is considered too low for protection of the key species identified in the Kaiapoi River.

4.3.12 Courtney Stream

Courtney Stream is relatively narrow and deep, with high macrophyte cover and a silt-dominated bed. Maximum WUA for juvenile brown trout occurs below 7dMALF and 90% retention of maximum WUA occurs at 210 L/s (see Figure 13 in Appendix D). Ninety percent of habitat available for adult brown trout at 7dMALF occurs at around 350 L/s.

Based on the WUA plots in Figure 14 (Appendix D) and field observations, Courtney Stream provides good instream habitat for large eels. Ninety five percent retention of WUA at 7dMALF occurs at 360 L/s for longfin eels, while 85% retention of large shortfin eel habitat (day curve) at 7dMALF occurs at 290 L/s. Based on the chosen habitat retention levels, the existing minimum flow of 260 L/s is a little low for protection of adult eel habitat and is equivalent to 82% and 79% of habitat at 7dMALF for large shortfin and longfin eels, respectively. Most of the other native fish species/life stages show relatively little change in habitat availability with flow and therefore protection of adult eel habitat will also adequately cater for other native fish.

In summary, the existing minimum flow of 260 L/s is a little lower than what would be recommended based on the species examined and the recommended levels of habitat protection. A higher minimum flow of around 350 L/s would provide adequate habitat for adult brown trout, large longfin eels and other native fish.

4.3.13 Greigs Drain

Greigs Drain is deep and narrow, with high macrophyte cover and predominantly silty bed sediments. There is little habitat diversity, with sluggish run habitat dominating. Overall, the combination of good depths and good instream cover provide reasonably good juvenile and adult brown trout habitat and good habitat for large eels. There is generally very poor habitat for salmonid spawning, due to the lack of suitably shallow, stony and swift habitat. Maximum WUA occurs above 7dMALF for juvenile and adult brown trout, but 90% of WUA available at 7dMALF occurs at 240 L/s for juvenile trout and at 225 L/s for adults (see Figure 15 in Appendix D). The existing minimum flow provides 73% and 79% of WUA available at 7dMALF for brown trout juveniles and adults, respectively.

Main (2001) recommended a minimum flow of 195 L/s in Greigs Drain to allow for upstream passage of adult trout. Based on the instream habitat modelling undertaken in the present study, a flow of 195 L/s would provide 83% of WUA available at 7dMALF. Therefore, while a flow of 195 L/s may provide for passage of adult trout past shallow riffles, it will not provide the required level of habitat protection afforded by a higher minimum flow.

Habitat availability for large eels and most other native fish in Greigs Drain shows very little change with declining flow. Therefore, a flow recommendation based on protection of adult trout habitat will also protect native fish.

In summary, the existing minimum flow of 150 L/s is a little low, as it does not provide sufficient protection of adult brown trout habitat. A minimum flow of 230 L/s is recommended, which provides a good level of protection of habitat for adult and juvenile brown trout.

4.3.14 Otukaikino Creek

With an estimated 7dMALF of 3,066 L/s, Otukaikino Creek is the largest of the lower Waimakariri River tributary sites. Being both very broad and deep, with a mix of fine and stony bed sediments and reasonable macrophyte cover, Otukaikino Creek provides excellent habitat for adult salmonids, large eels and other native fish. Shallower areas upstream of the minimum flow site also provide excellent spawning habitat for trout and salmon.

RHYHABSIM modelling results are not available for Otukaikino Creek, due to a poor flow versus stage relationship. However, based on the general relationship between flow and depth shown in Figure 8, 7dMALF flows of 3,066 L/s would provide average depths of around 0.78 m at the minimum flow site, while the existing minimum flow of 2,000 L/s would provide average depths of around 0.68 m. Based on the general relationship between flow and HSI for brown trout juveniles and adults (Figure 9), 90% retention of HSI at 7dMALF occurs at 2,050 L/s for adult brown trout and at 1,700 L/s for juvenile brown trout. The existing minimum flow of 2,000 L/s provides around 93% of HSI available at 7dMALF for juvenile brown trout and 89% of habitat at 7dMALF for adults. Main (2001) recommended a minimum flow of 3,100 L/s in Otukaikino Creek to provide for upstream passage of spawning salmon.

Given the greater depth requirements of large eels, habitat is likely to follow a pattern of declining habitat availability with declining flow, similar to that of adult brown trout. Therefore, protection of adult brown trout habitat would likely also protect large eel habitat.

In summary, the existing minimum flow of 2,000 L/s is considered to provide a high level of protection of aquatic habitat for trout and salmon, eels and other native fish. Based on the work of Main (2001), a higher minimum flow of 3,100 L/s may be necessary to allow for upstream passage of spawning salmon.

4.3.15 Styx River

The Styx River is the second largest of the lower Waimakariri River tributary sites and has a 7dMALF of 1,118 L/s. Although it is narrower than Otukaikino Creek at the minimum flow site, the Styx River has a similar depth which, combined with good instream cover from macrophytes, provides good habitat for adult trout and large eels. Much of the Styx River is characterised by soft sediments, but there are some stony areas upstream of the minimum flow site that are used for trout spawning.

Recent macrophyte clearance activities resulted in a poor stage versus flow relationship, and RHYHABSIM modelling results could not be used. However, based on the general relationship between flow and depth shown in Figure 8, the 7dMALF flow of 1,118 L/s would provide average depths of around 0.56 m at the minimum flow site, while the existing minimum flow of 1,200 L/s would provide average depths of around 0.58 m. Based on the general relationship between flow and HSI for brown trout juveniles and adults (Figure 9), 90% retention of HSI at 7dMALF occurs at 650 L/s for juvenile brown trout and at 850 L/s for adult brown trout. The existing minimum flow of 1,200 L/s is greater than 7dMALF, so provides >100% protection of brown trout habitat available at 7dMALF. Main (2001) recommended a minimum flow of 610 L/s in the Styx River to provide for upstream passage of spawning salmon, although it is unclear how significant the Styx River is for salmon spawning.

In summary, the instream habitat data collected for this report suggests that a minimum flow of 850 L/s in the Styx River would provide sufficient depths to adequately protect significant adult brown trout habitat. Protection of adult trout habitat would also provide sufficient habitat for juvenile and spawning salmonid habitat, and native fish habitat.

4.3.16 Kaputone Creek

Kaputone Creek is a deeply incised, moderately deep and soft-bottomed tributary of the Styx River. In recent years, the upper reaches of Kaputone Creek have dried, while, paradoxically local residents have voiced concern that the lower reaches of the river (near the minimum flow site) are prone to flooding. Instream habitat fieldwork at a flow of 180 L/s revealed that the creek overtopped its banks, inundating the low-lying, muddy riparian zone. Thus, while increasing flows result in an increase in wetted width, there is very little change in depth. This, in turn, is reflected in little change in habitat availability with flow for most of the species modelled.

Overall, the deeply incised and sluggish flows of Kaputone Creek are suitable for large eels, as confirmed by previous Golder sampling efforts that yielded large numbers of longfin and shortfin eels (Golder, unpublished data). There is generally insufficient depth for adult brown trout and a lack of gravels for spawning salmonids, but Kaputone Creek does provide some potential habitat for juvenile trout.

Maximum WUA occurs above 7dMALF for juvenile trout, but 90% of WUA available at 7dMALF occurs at 170 L/s for juvenile trout and the existing minimum flow provides 85% of WUA available at 7dMALF for juvenile trout (see Figure 17 in Appendix D). Habitat availability either changes very little or declines with increasing flow for eels and other native fish.

In summary, the existing minimum flow of 150 L/s provides good depths and hence a high level of protection of habitat available for large eels. While a higher minimum flow of 170 L/s would provide more potential habitat for juvenile trout, the existing minimum flow still provides 85% of juvenile trout habitat at 7dMALF. Given this high habitat retention level, and the fact that there are no NZFFD records of trout from Kaputone Creek and they were not collected during recent sampling, the existing minimum flow of 150 L/s is considered appropriate.

5.0 SUMMARY AND RECOMMENDATIONS

5.1 Minimum Flows

The instream habitat modelling results for the lower Waimakariri River tributary sites presented in Section 4 above suggest that the existing minimum flows are adequate for six sites, are too high for three sites, and could be increased for five sites (Table 6). Section 4 provides further details for each site, including the ecological values present and alternative minimum flows (e.g., for protection of adult trout versus eel habitat).

Table 6: Seven day mean annual low flow, existing minimum flows and recommended minimum flows for protection of aquatic habitat for native fish and salmonids.

Site	7dMALF (L/s)	Existing Minimum Flow (L/s)	Recommended Minimum Flow (L/s)
North Brook	622	530	No change
Middle Brook	31	60	30
South Brook	171	140	120–140
Cam River	1,022	1,000	890
Cust River	140	20	120
Cust Main Drain	325	230	No change
No. 7 Drain	67	60	No change
Ohoka Stream	526	300	365
Kaiapoi River	1,273	600	1,000
Courtenay Stream	393	260	350
Greigs Drain	302	150	230
Otukaikino Creek	3,066	2,000	No change
Styx River	1,118	1,200	No change
Kaputone Creek	214	150	No change

5.2 Recommendations

5.2.1 Monitoring

Notwithstanding the merits of the predictive modelling approach used in this report, without any monitoring data it is not able to quantitatively assess whether minimum flows are actually protecting ecological values. Given the relatively high ecological values present in many of the lowland tributaries sampled, monitoring of ecological values in relation to low flow conditions is recommended. This will be particularly relevant for sites where there is the potential for increased abstractive demands in the future.

5.2.2 Water quality modelling

Dissolved oxygen (DO) is probably the key water quality parameter of concern in relation to low flows in the lower Waimakariri River tributaries that have high macrophyte cover. Macrophytes consume oxygen from the water column during the night, which can result in low DO concentrations and mortality of sensitive fish and invertebrates (Dean and Richardson 1999). The relationship between flow and DO concentration can be modelled using the RHYHABSIM or WAIORA computer software, but it does require some DO data to be measured during low flow conditions. This is easily done by deploying a DO data sonde in a stream to continuous measure DO over the summer period.

5.2.3 Macrophyte clearance

Many of the lowland tributary sites had high macrophyte cover during the fieldwork, but macrophytes are regularly cleared to reduce flooding risk. Macrophyte clearance results in a drop in water levels and as a consequence affects the relationship between flow and habitat predicted by modelling undertaken when macrophyte cover was high. Although the greatest potential effect of low flows on habitat availability typically occurs over summer, reduced water levels caused by macrophyte clearance may worsen the effects of low flows, depending on stream size and channel shape.

Trout spawn in autumn and winter, so effects on trout spawning habitat are probably the key potential effects to be considered in relation to habitat effects of macrophyte clearance. Potential effects on trout spawning habitat could be assessed by undertaking instream habitat measurements before and after macrophyte clearance, along with assessing streambed coverage of potential spawning gravels.

5.2.4 Flow variability

The effect of water abstraction on flow variability is not of great concern for most of the lowland spring-fed waterways considered in this report, because flow variability is naturally low. However, natural variability is a feature of the Cust River and Cust Main Drain, and floods are responsible for keeping these waterways relatively clear of macrophytes and nuisance algal growths. The hydrograph in Figure 3 suggests that although the Cust experiences low flows, the current level of abstractive use from the catchment does not appear to be affecting flow variability. However, protection of natural flow variability should be a consideration for the Cust River and Cust Main Drain, particularly if demand for water abstraction grows over time.

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APPENDIX A

Report Limitations

APPENDIX A
Report Limitations

REPORT LIMITATIONS

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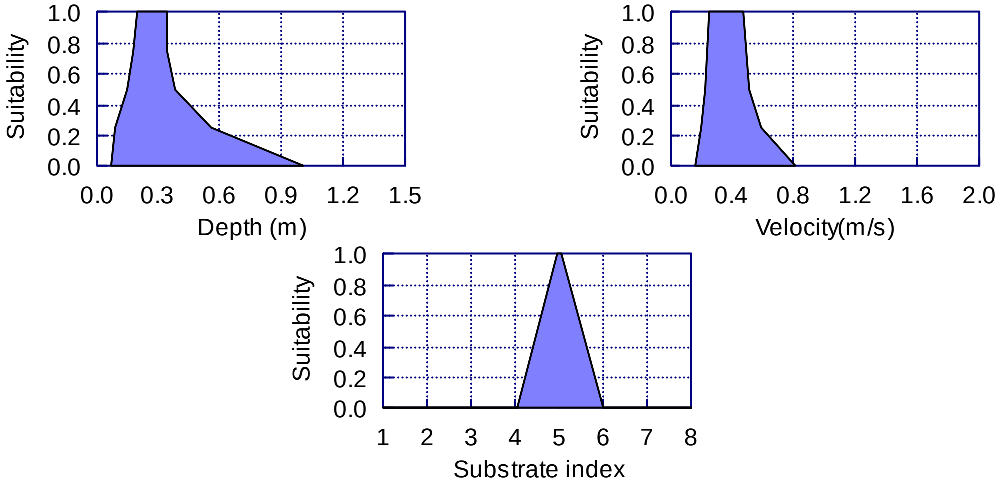
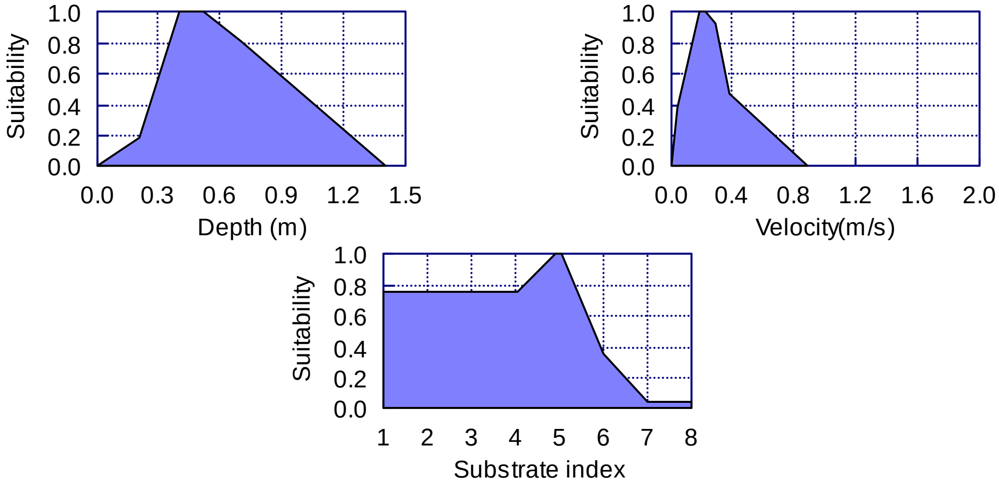
APPENDIX B

Rhyhabsim Habitat Preference Curves

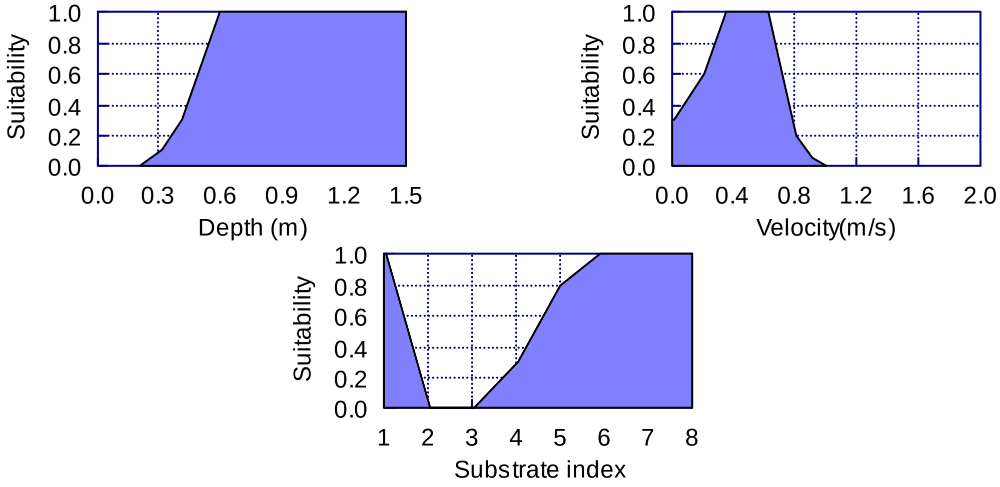
Brown trout spawning (Shirvell and Dungey 1983)



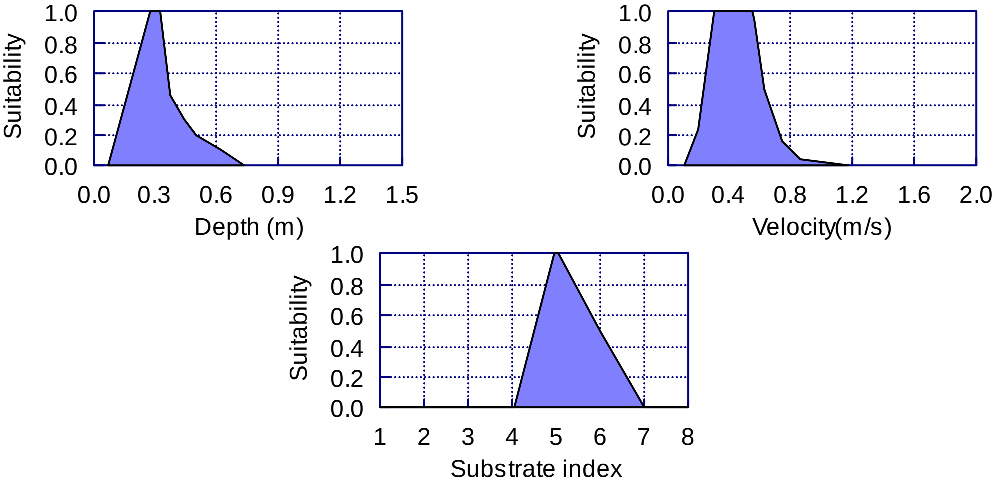
Brown trout fry to 15cm (Raleigh et al 1986)



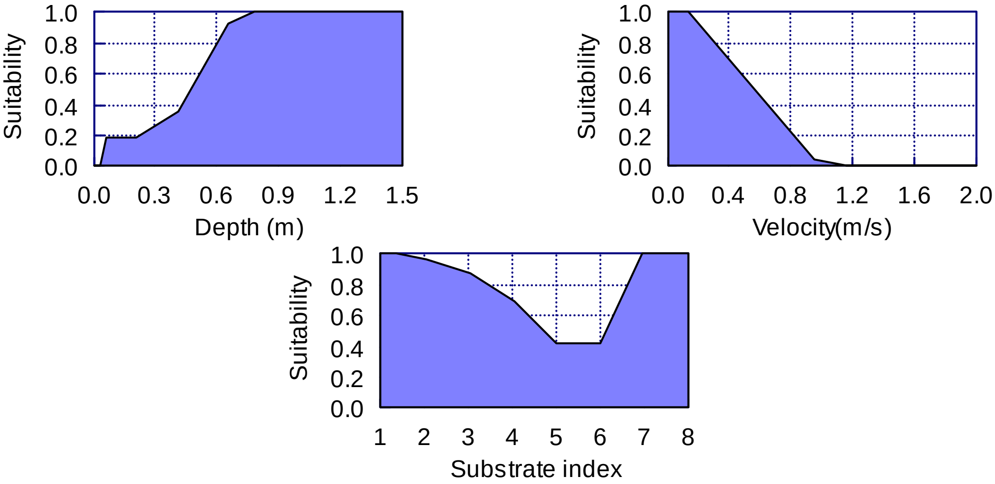
Brown trout adult (Hayes and Jowett 1994)



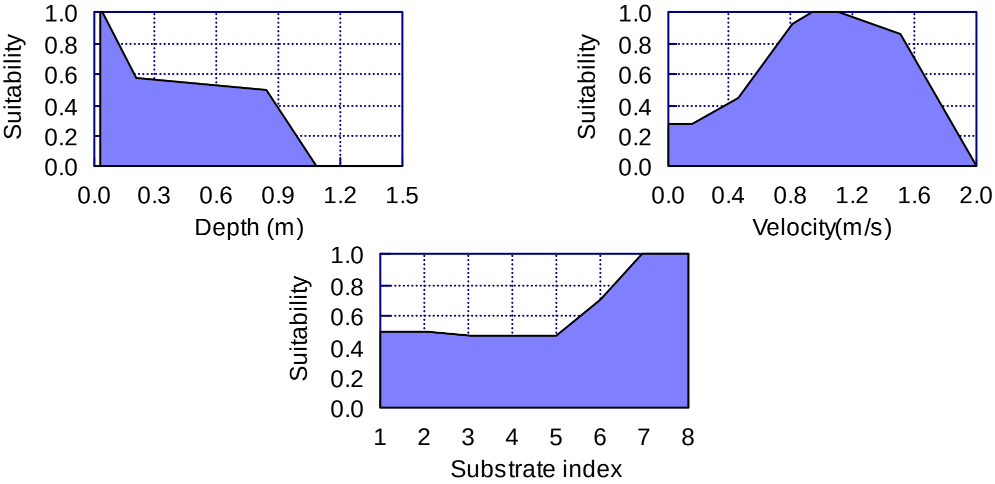
Chinook salmon adult spawning (Bovee 1978)



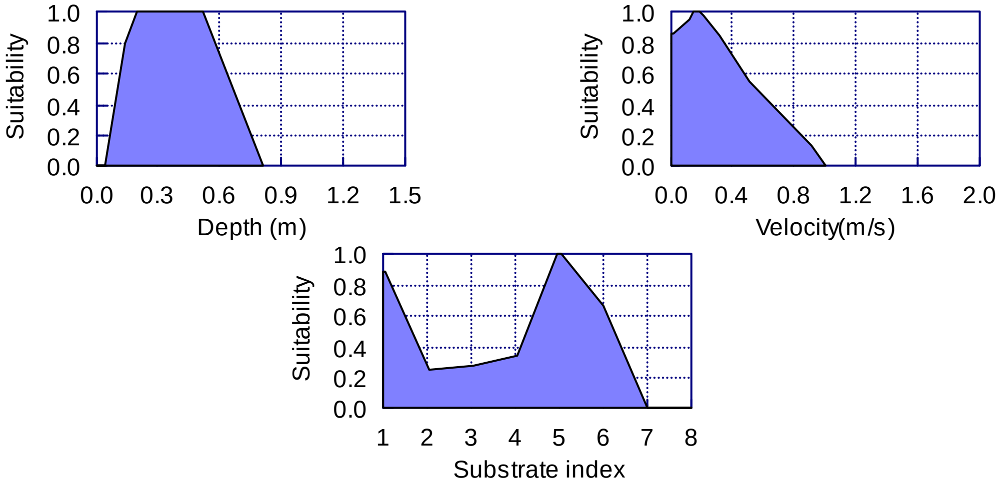
Longfin eel >300 mm (Jellyman et al. 2003)



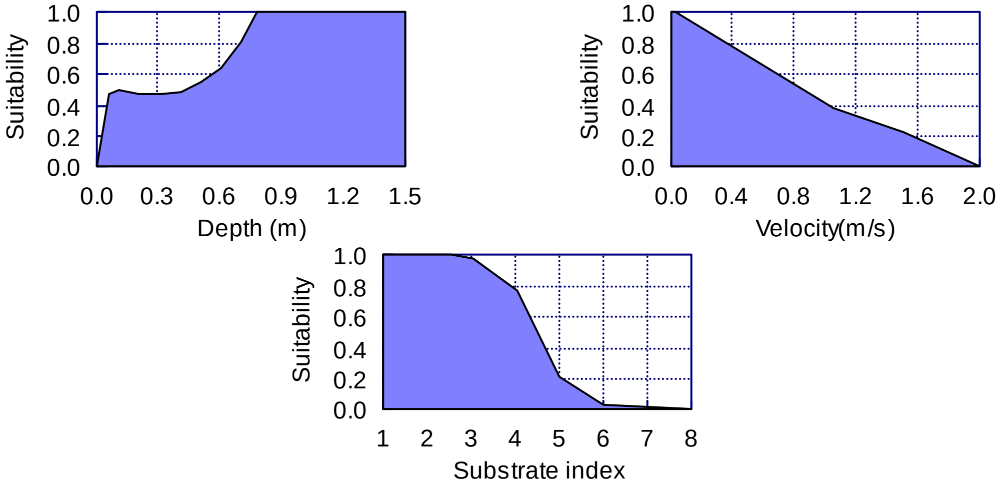
Longfin eel <300 mm (Jellyman et al. 2003)



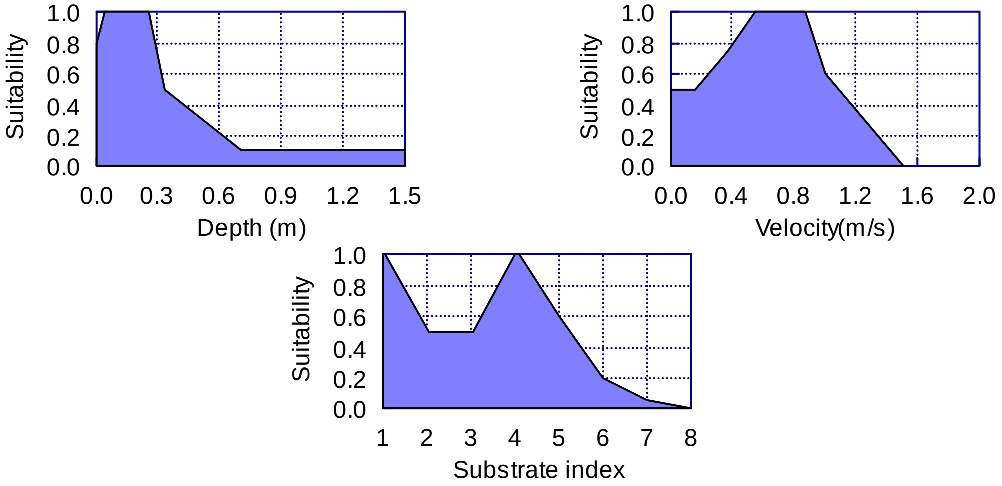
Shortfin eel >300 mm (night) (Graynoth pers comm 2007)



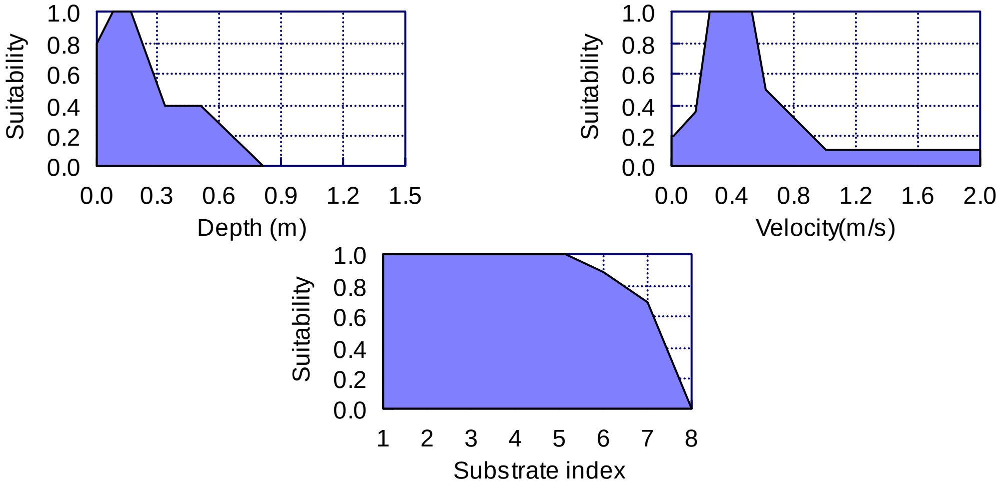
Shortfin eel >300 mm (day) (Graynoth pers comm 2007)



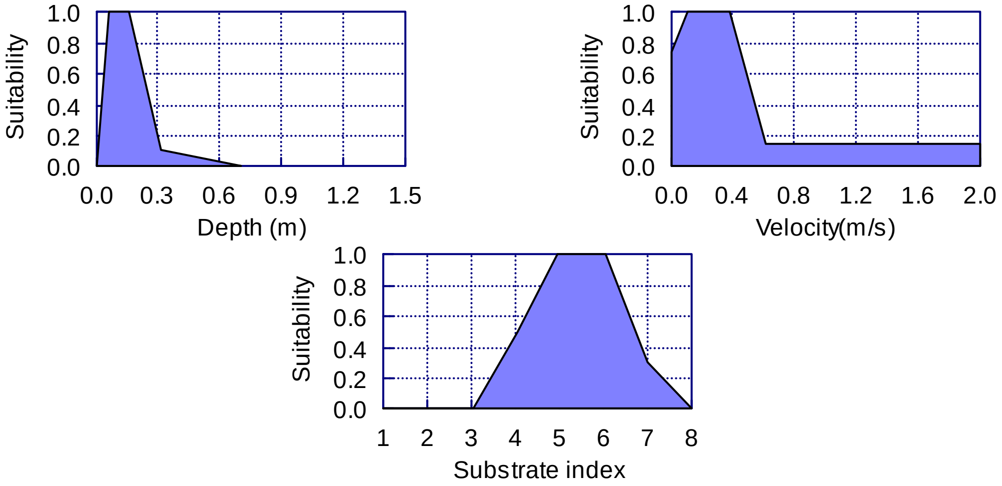
Shortfin eel <300 mm (Jowett and Richardson 1995)



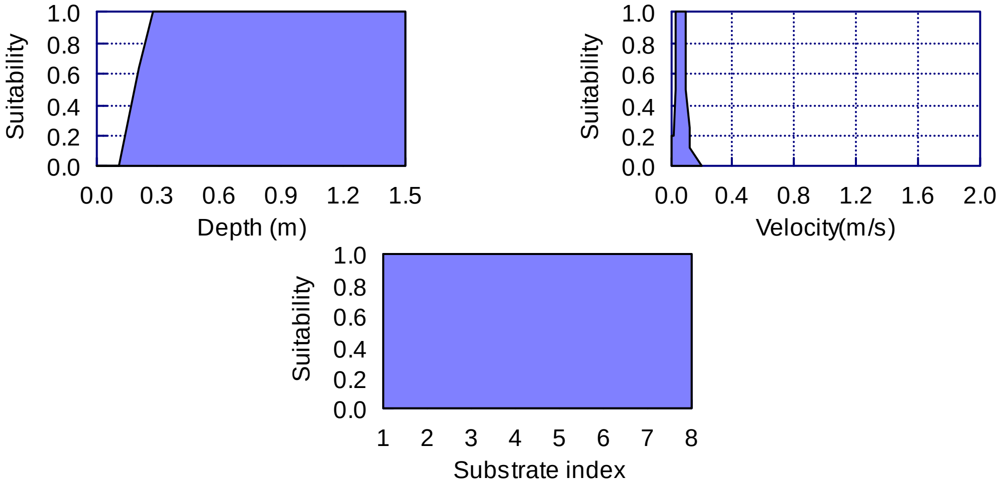
Common bully (Jowett and Richardson 1995)



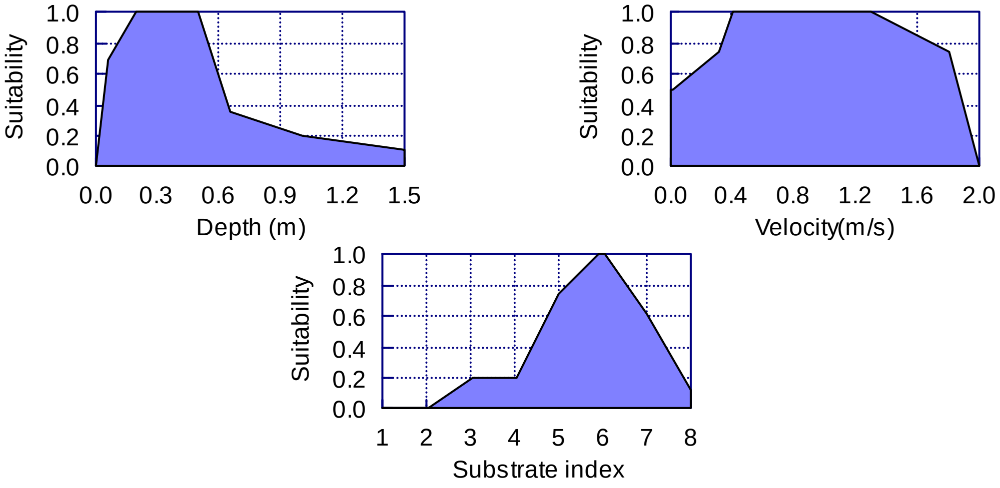
Upland bully (Jowett and Richardson 1995)



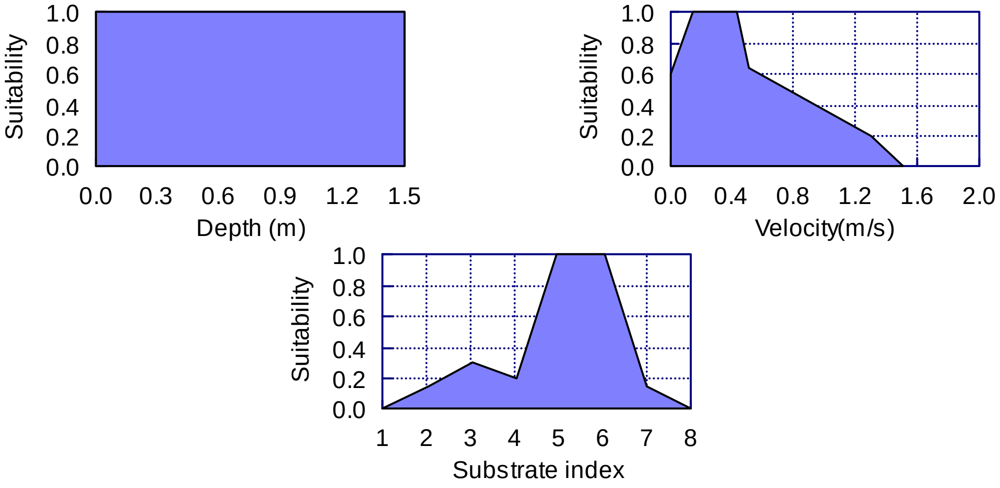
Inanga feeding (Jowett 2002)



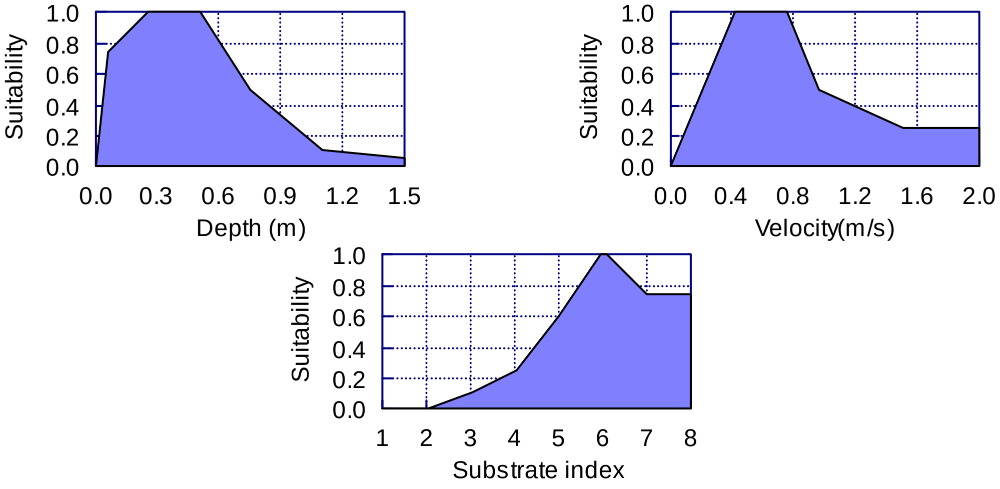
Deleatidium (mayfly) (Jowett et al. 1991)



Potamopyrgus (Waitaki)



Pycnocentrodes (stony-cased caddis) (Jowett et al. 1991)



APPENDIX C

Site Photographs

Photo 11: Greigs Drain at Greigs Drain Road.

Photo 12: Otukaikino Creek at Dickeys Road.

Photo 11: Greigs Drain at Greigs Drain Road.

Photo 12: Otukaikino Creek at Dickeys Road.

Photo 13: Kuputone Creek at Styx River confluence

Photo 14: Styx River at Radcliffe Road recorder site.

Photo 1: North Brook at Marsh Road.

Photo 2: Middle Brook at Marsh Road.

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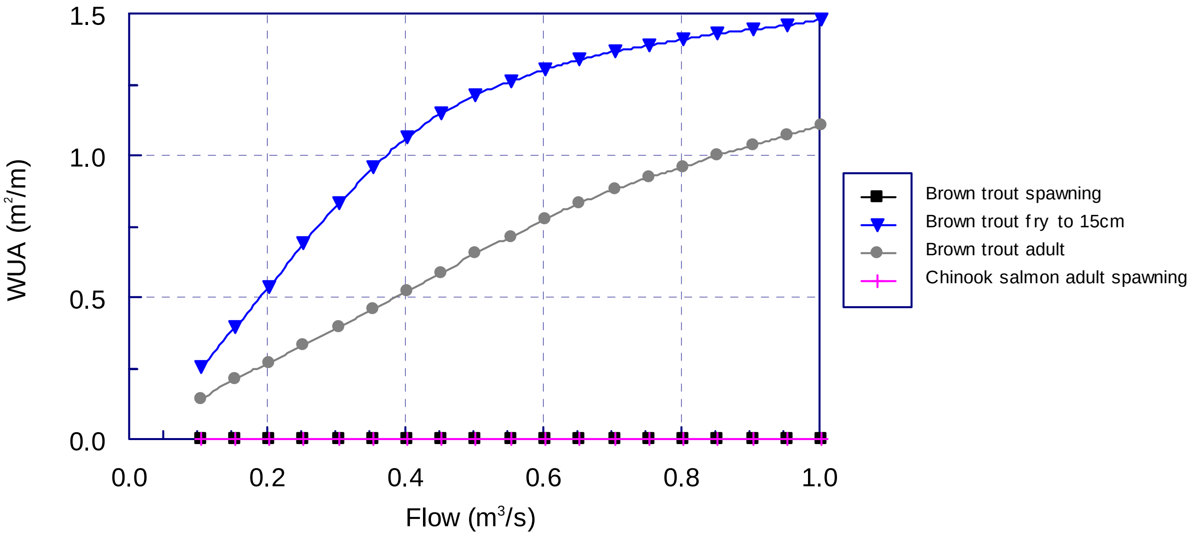
Photo 14: Styx River at Radcliffe Road recorder site.

APPENDIX D

Rhyhabsim Plots



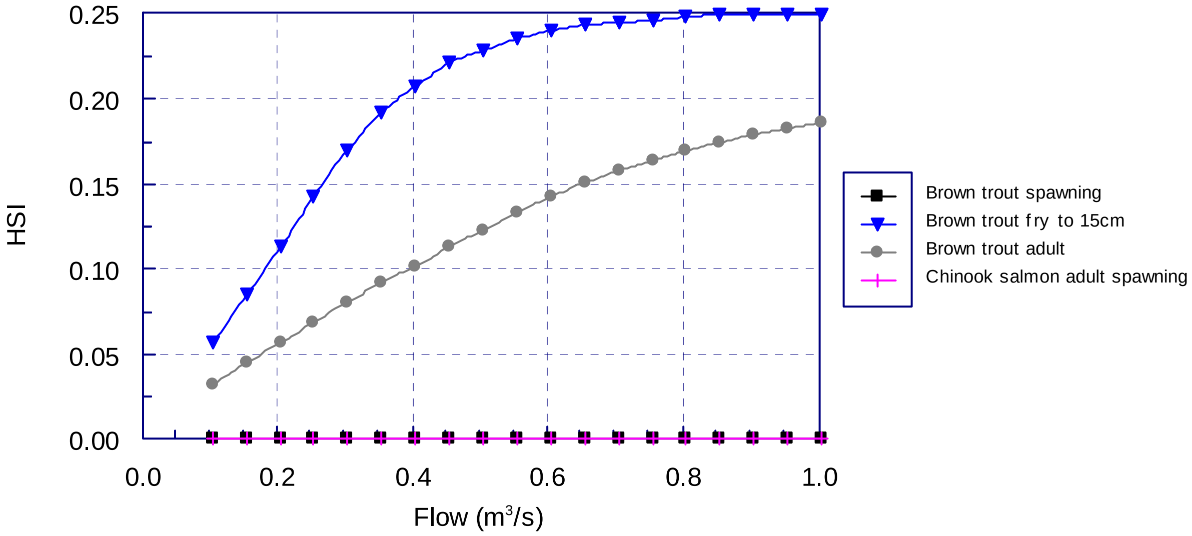
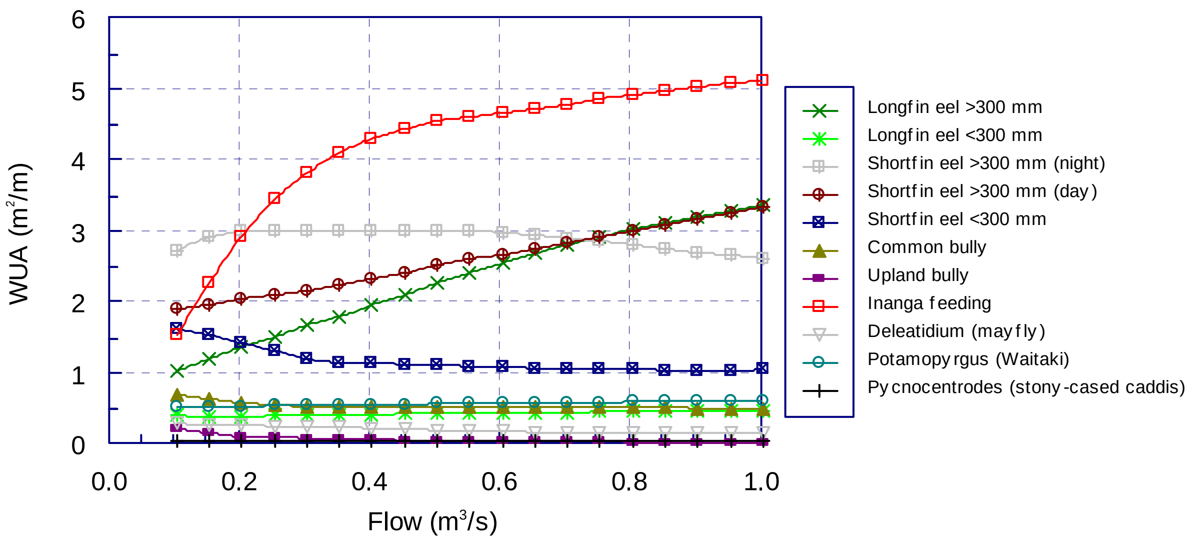


Figure 1: North Brook relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for salmonids.



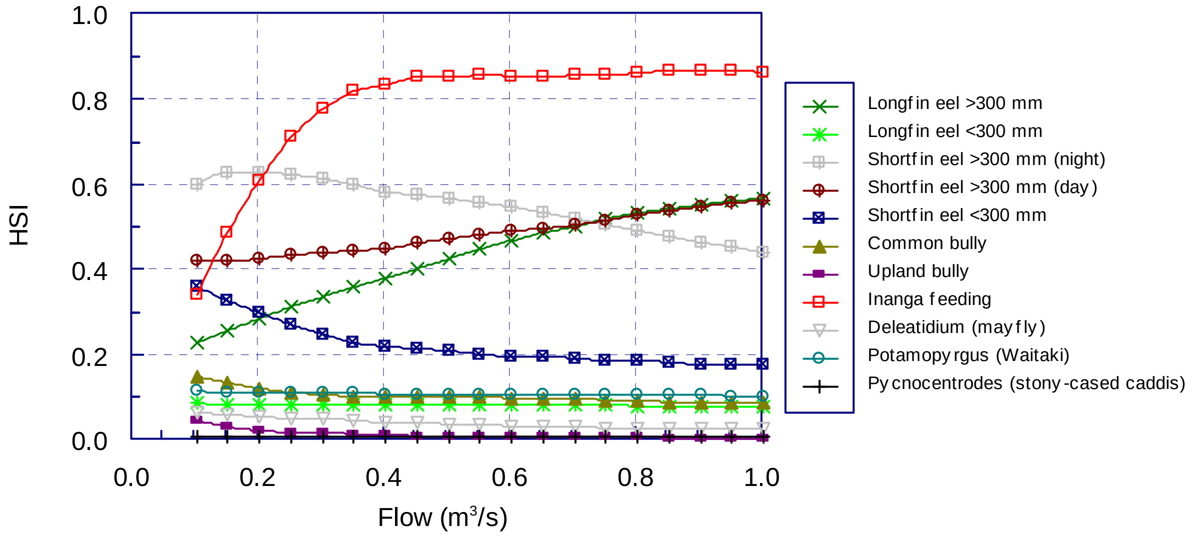
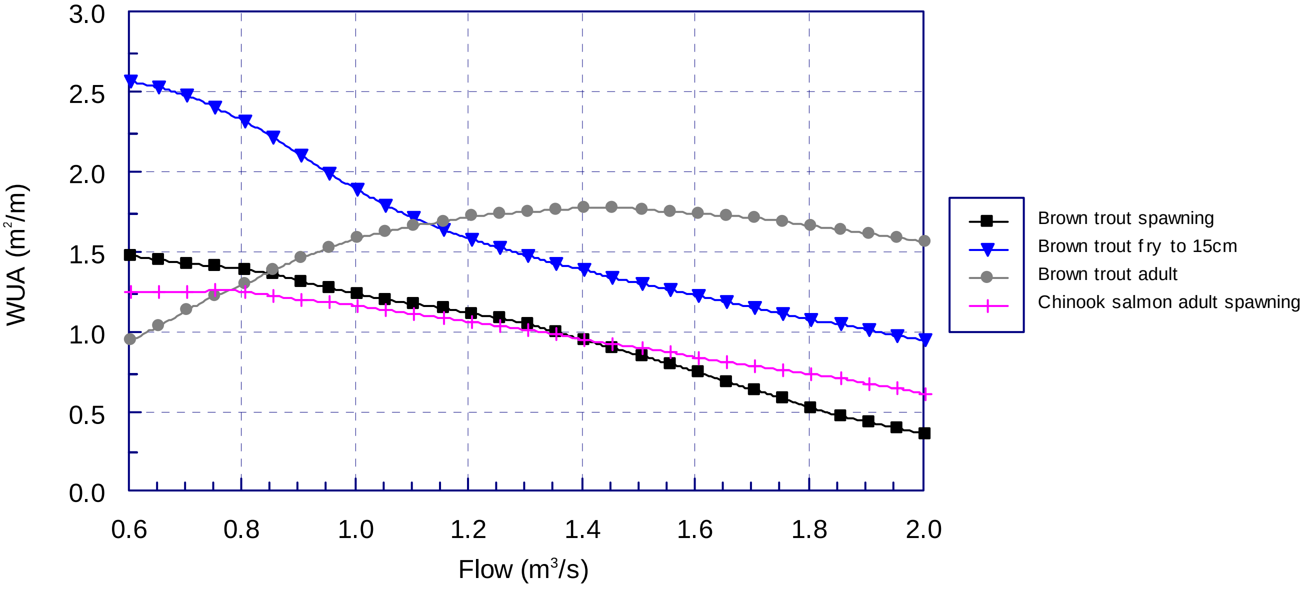


Figure 2: North Brook relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for native fish and invertebrates.



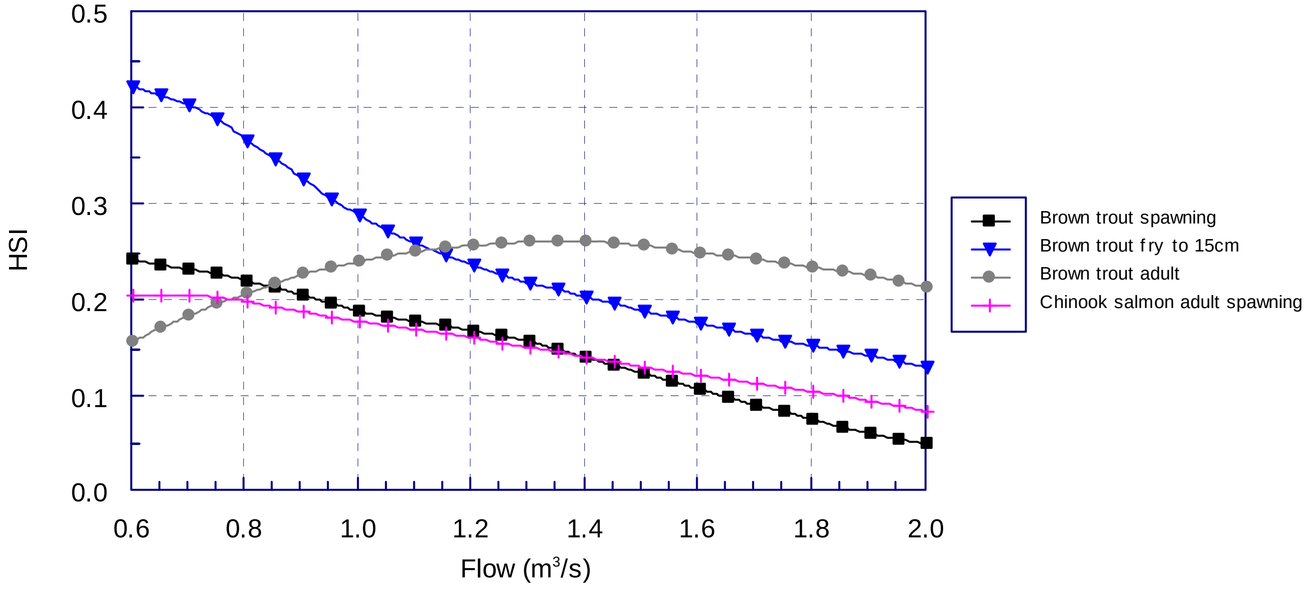
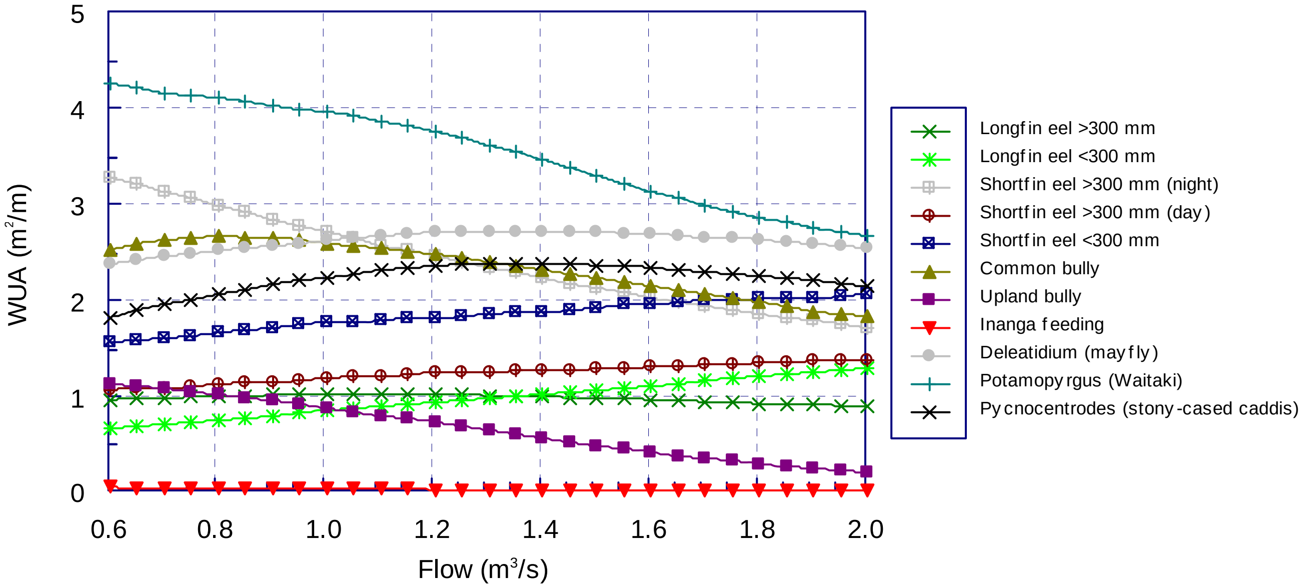


Figure 3: Cam River relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for salmonids.



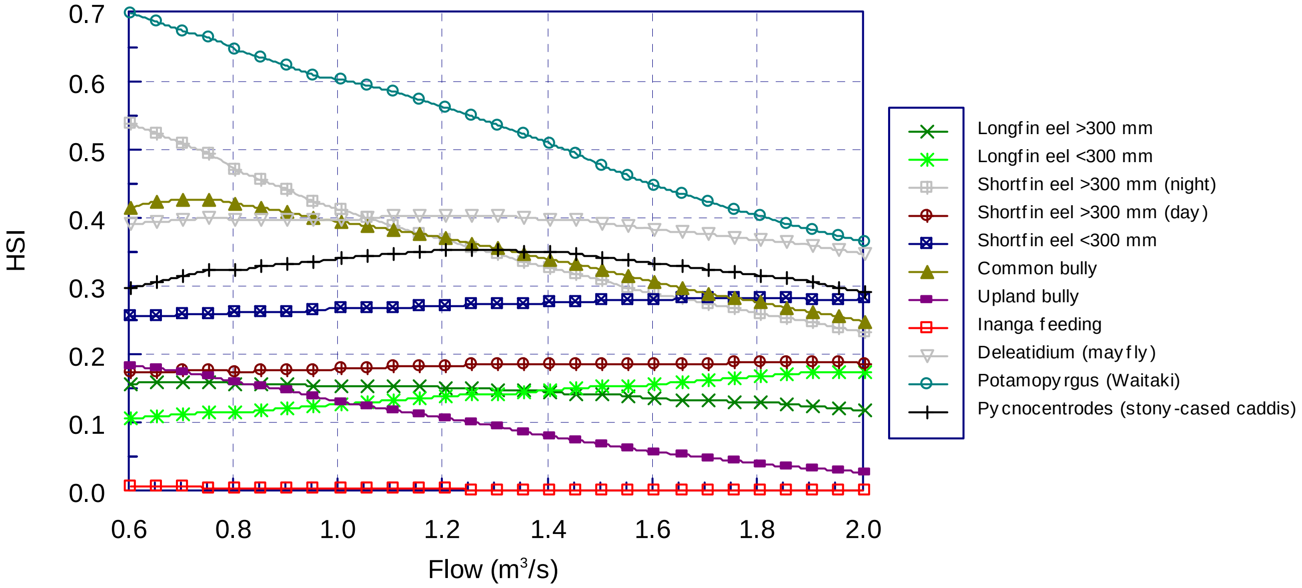


Figure 4: Cam River relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for native fish and invertebrates.

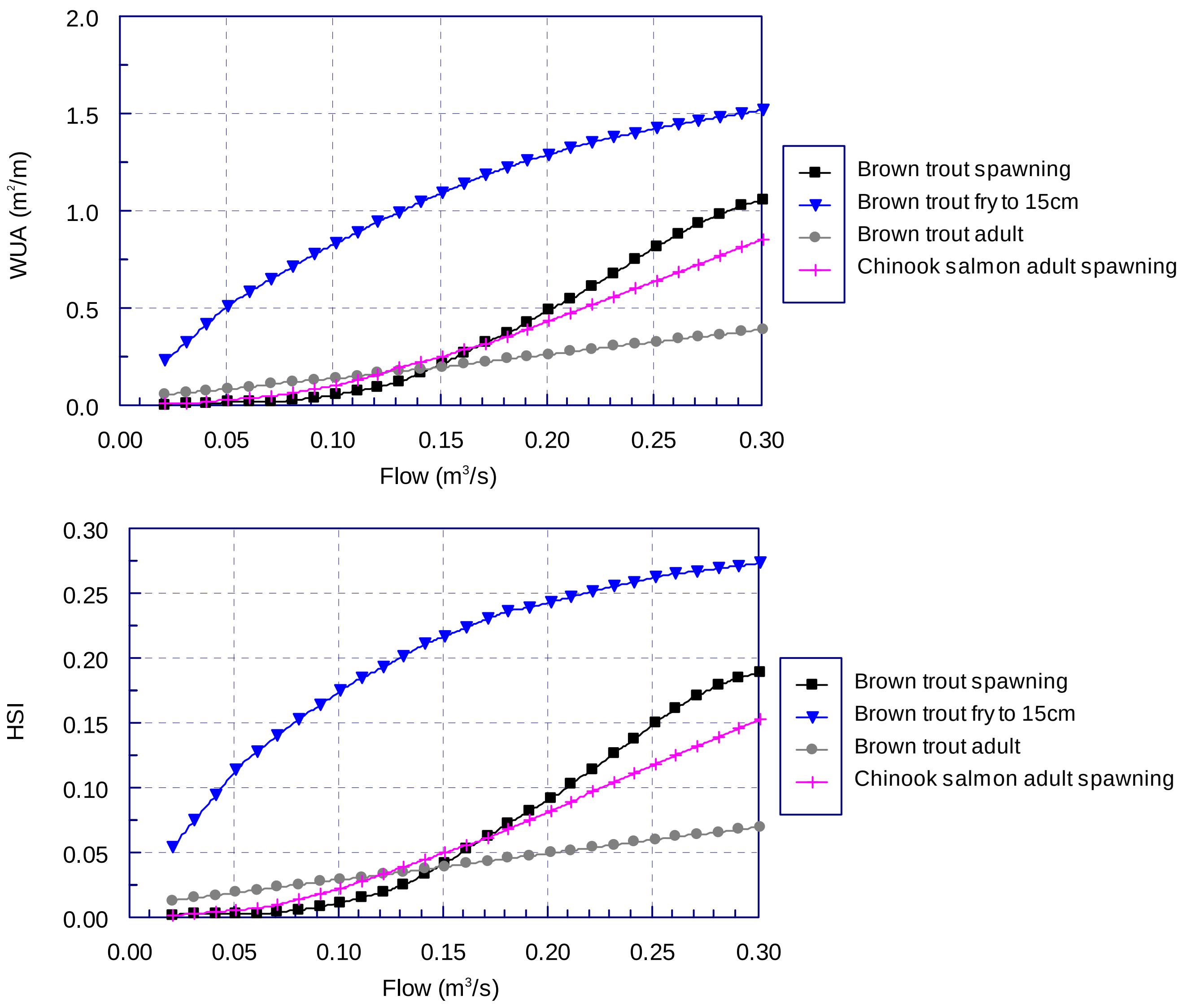
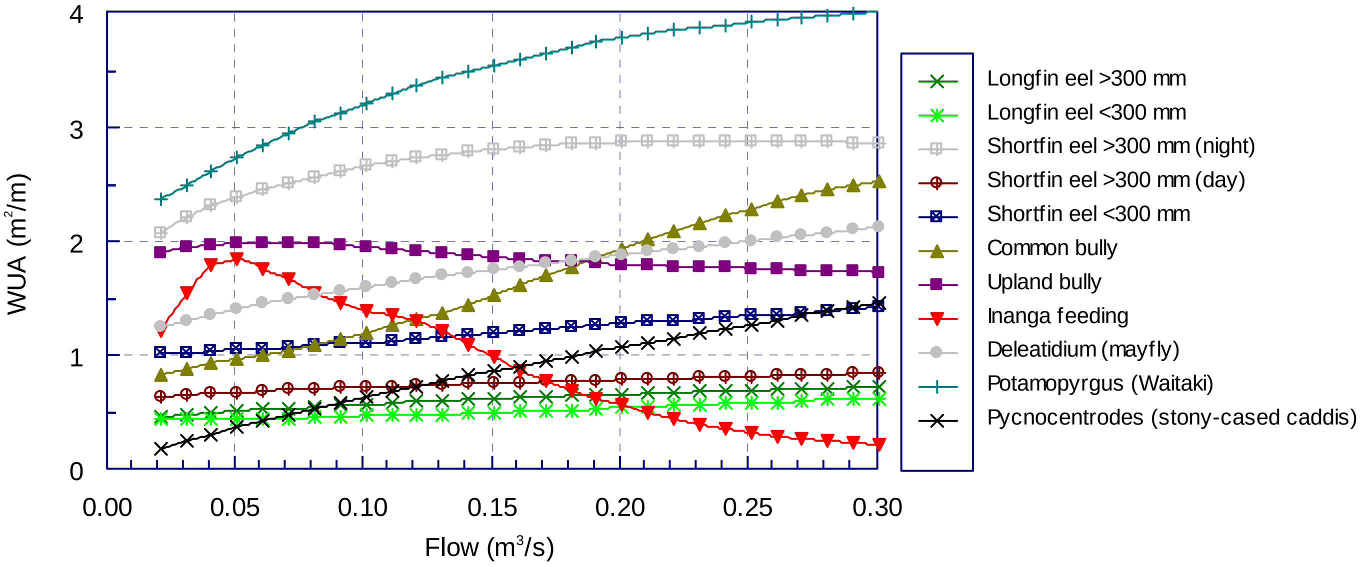


Figure 5: Cust River relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for salmonids.



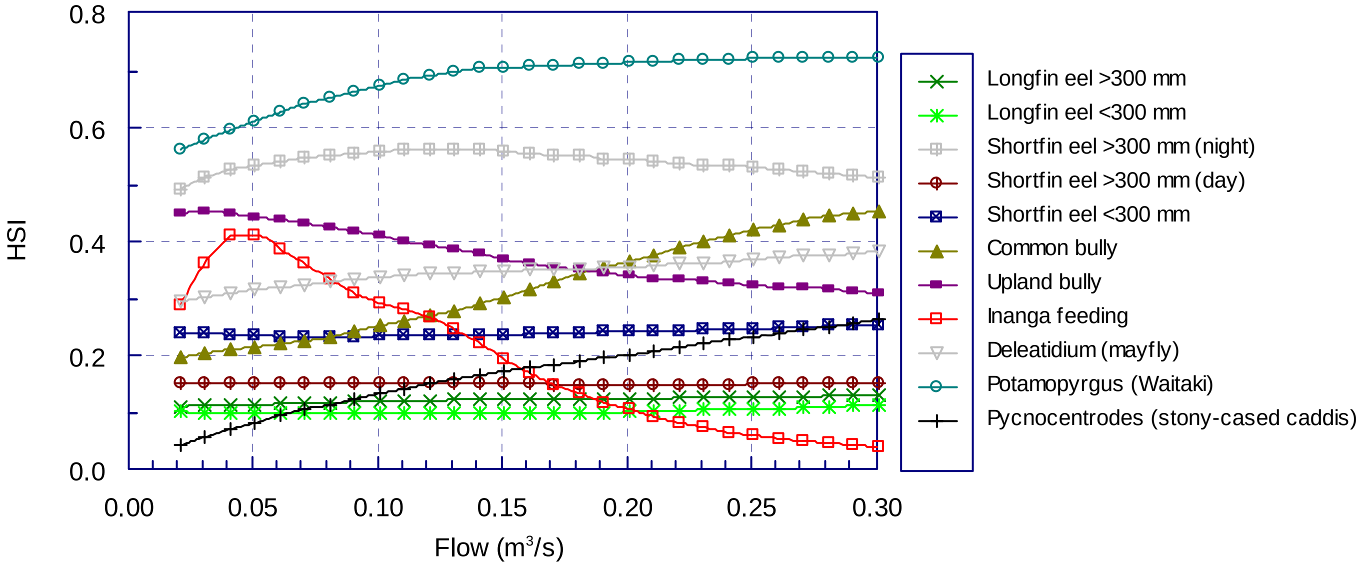
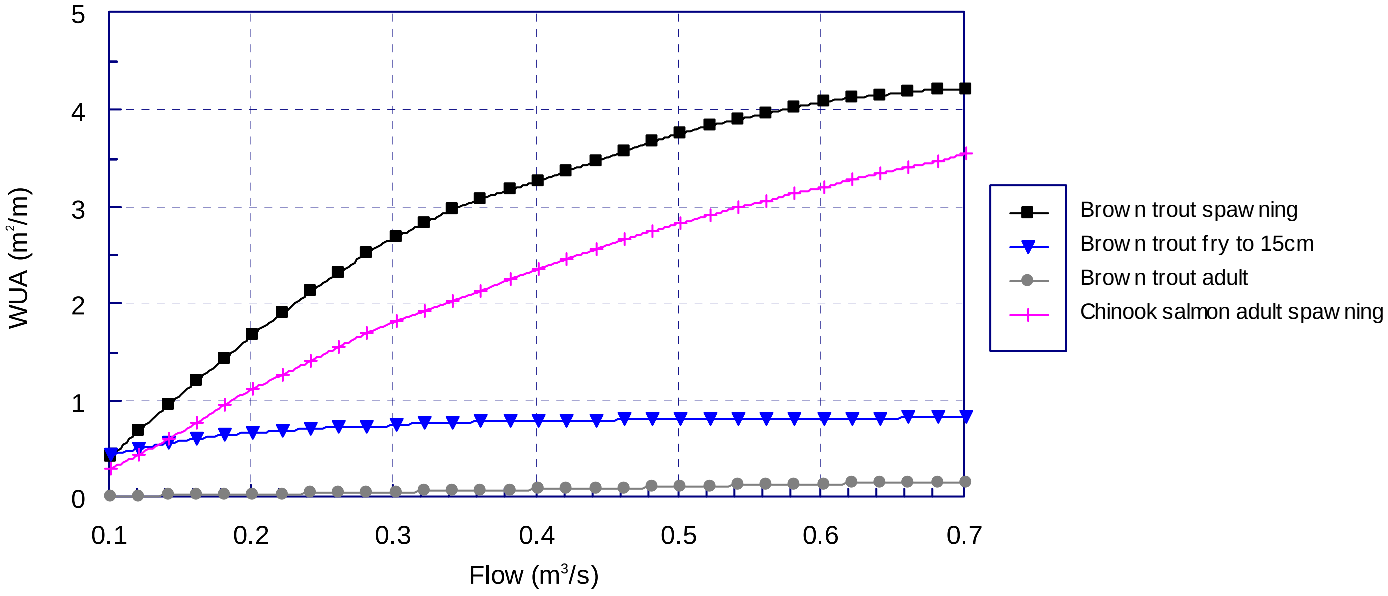


Figure 6: Cust River relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for native fish and invertebrates.



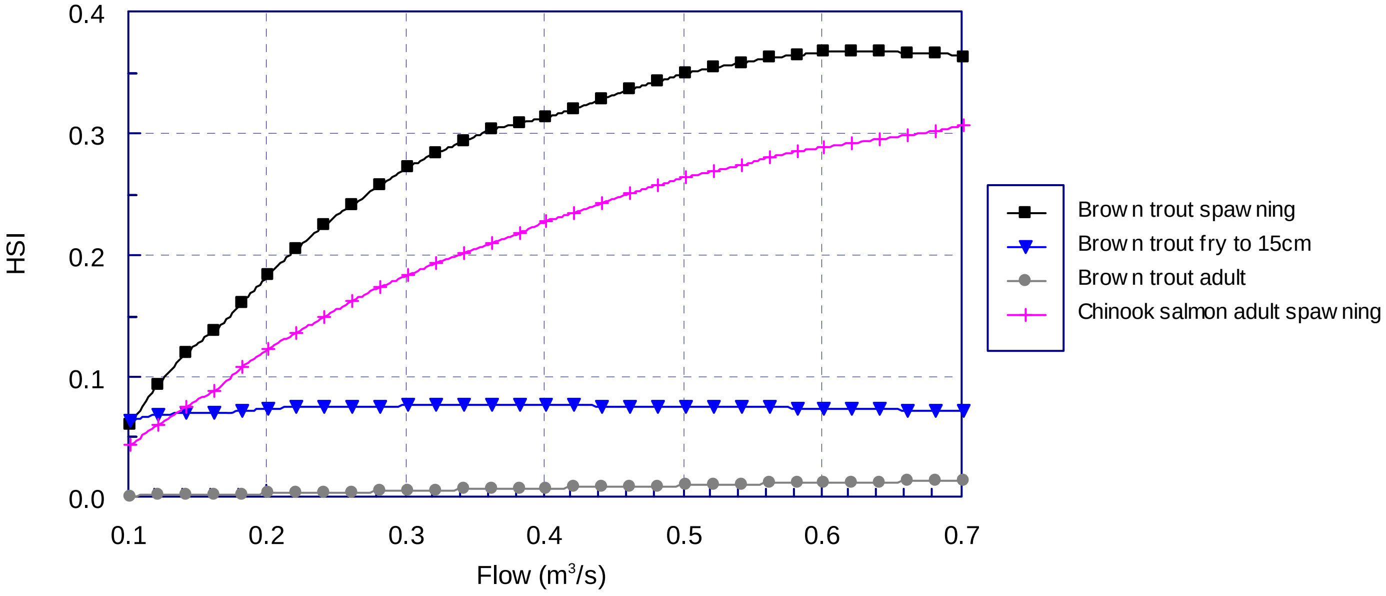
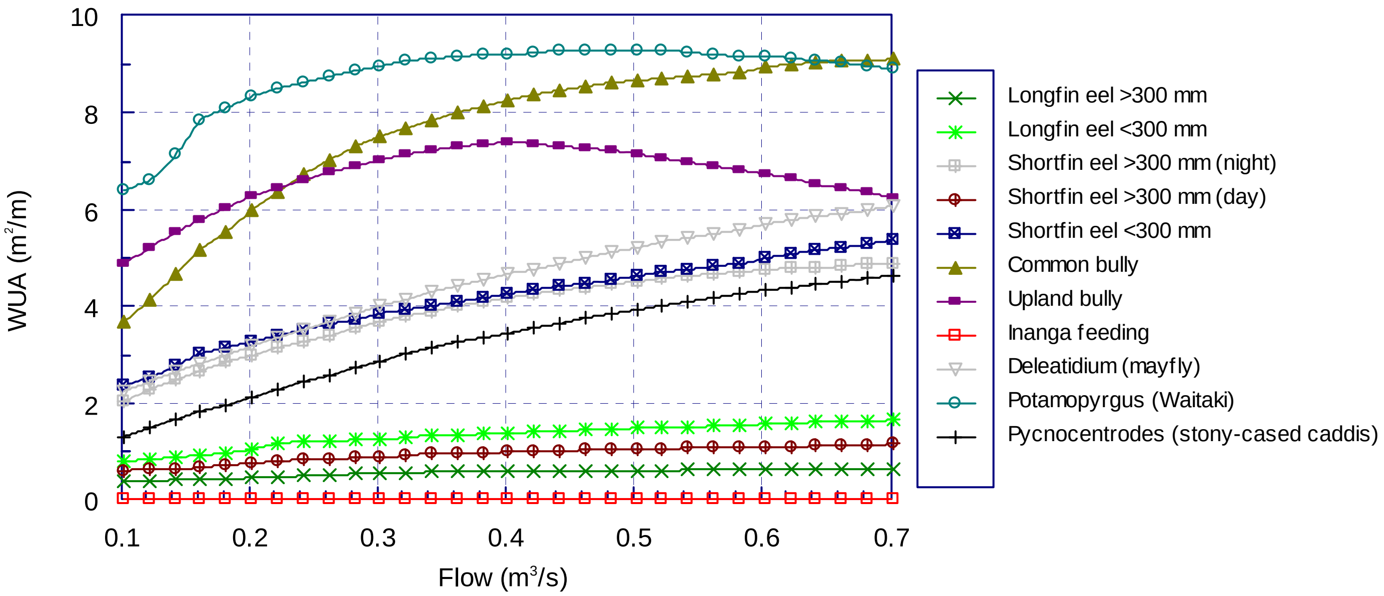


Figure 7: Cust Main Drain relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for salmonids.



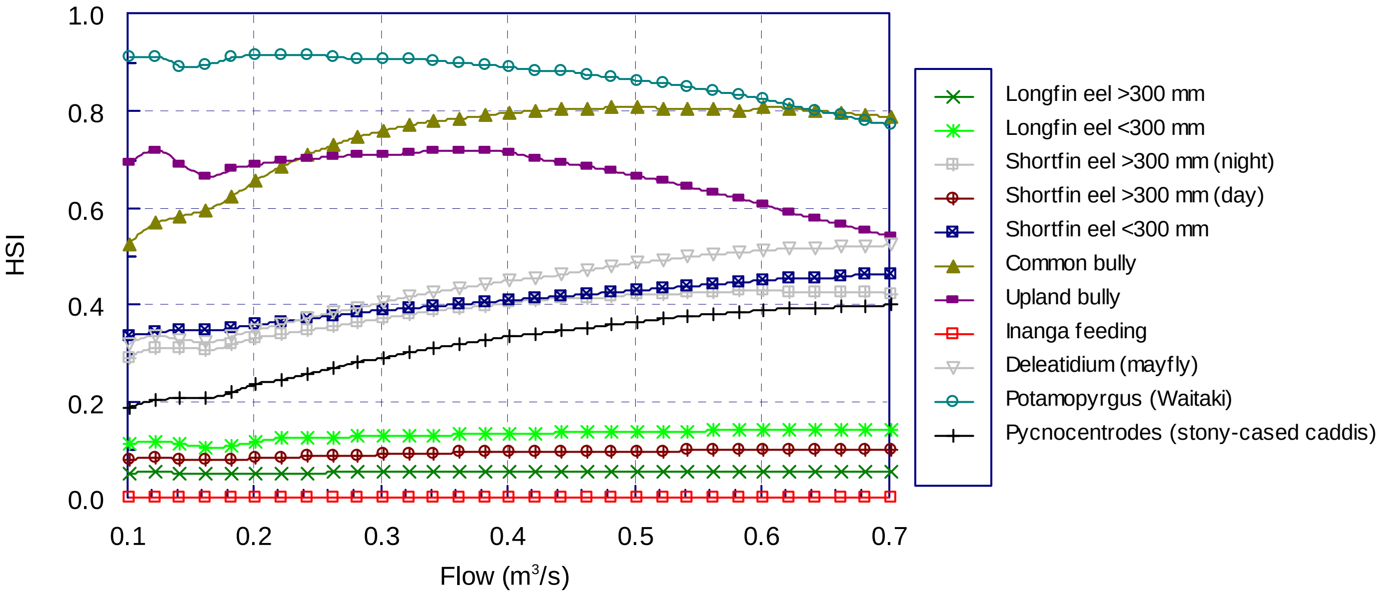
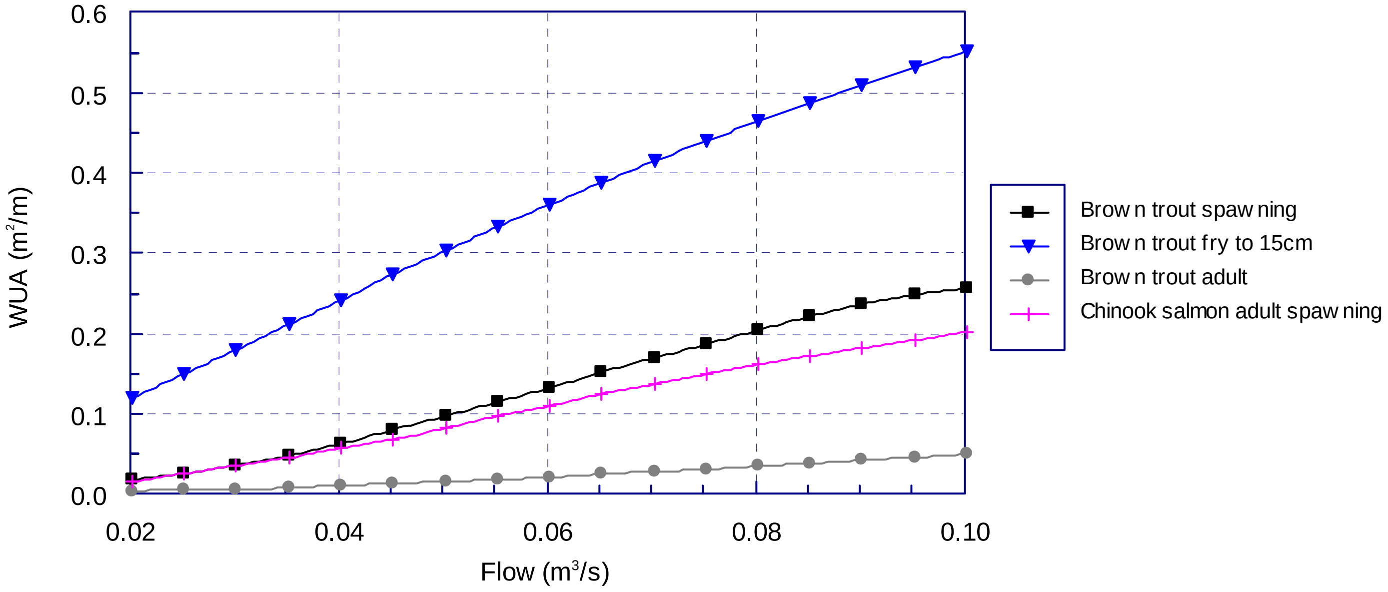


Figure 8: Cust Main Drain relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for native fish and invertebrates.



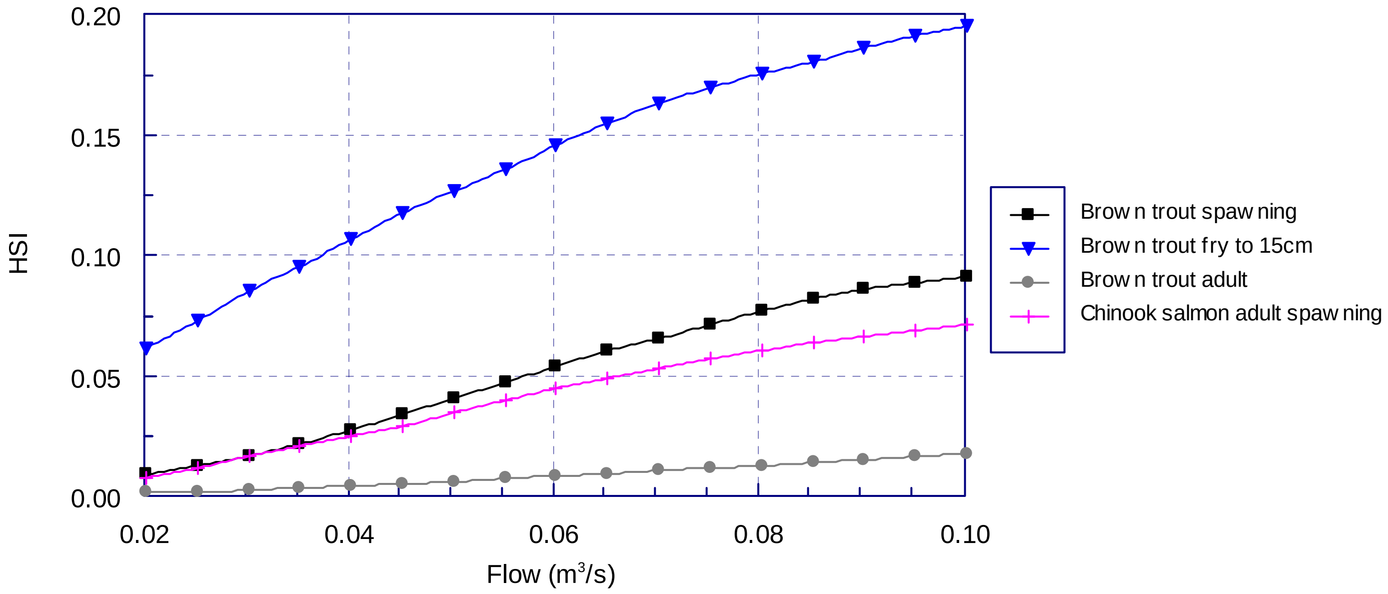
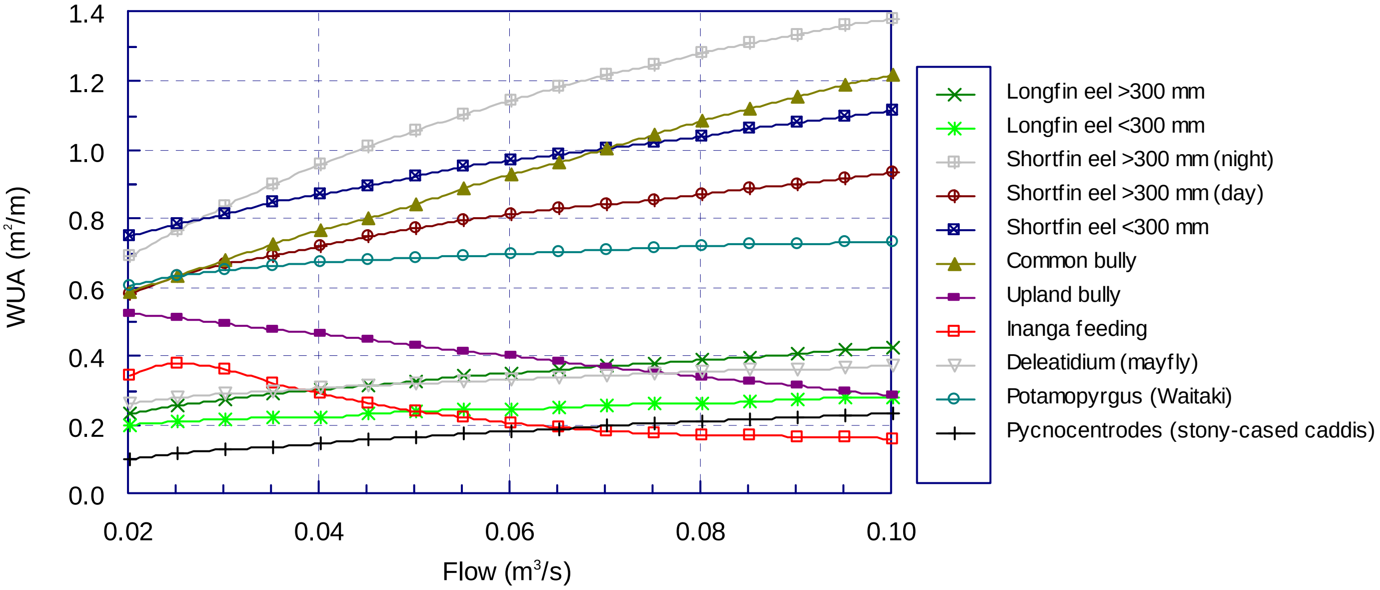


Figure 9: No. 7 Drain relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for salmonids.



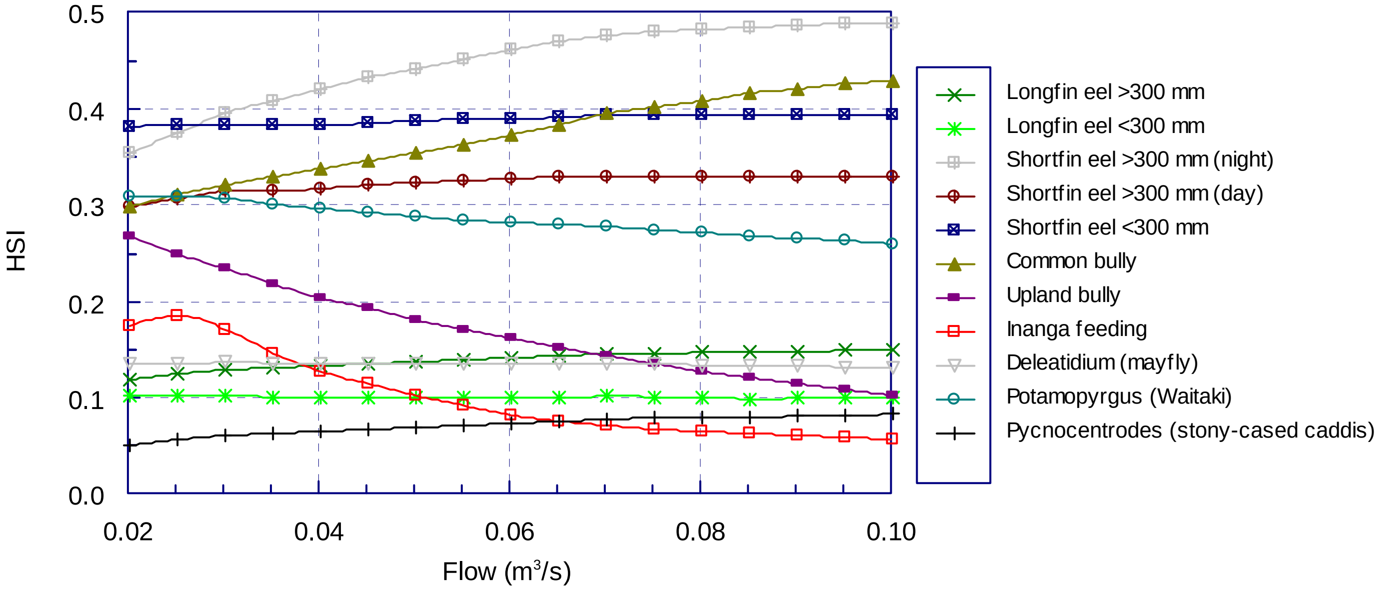
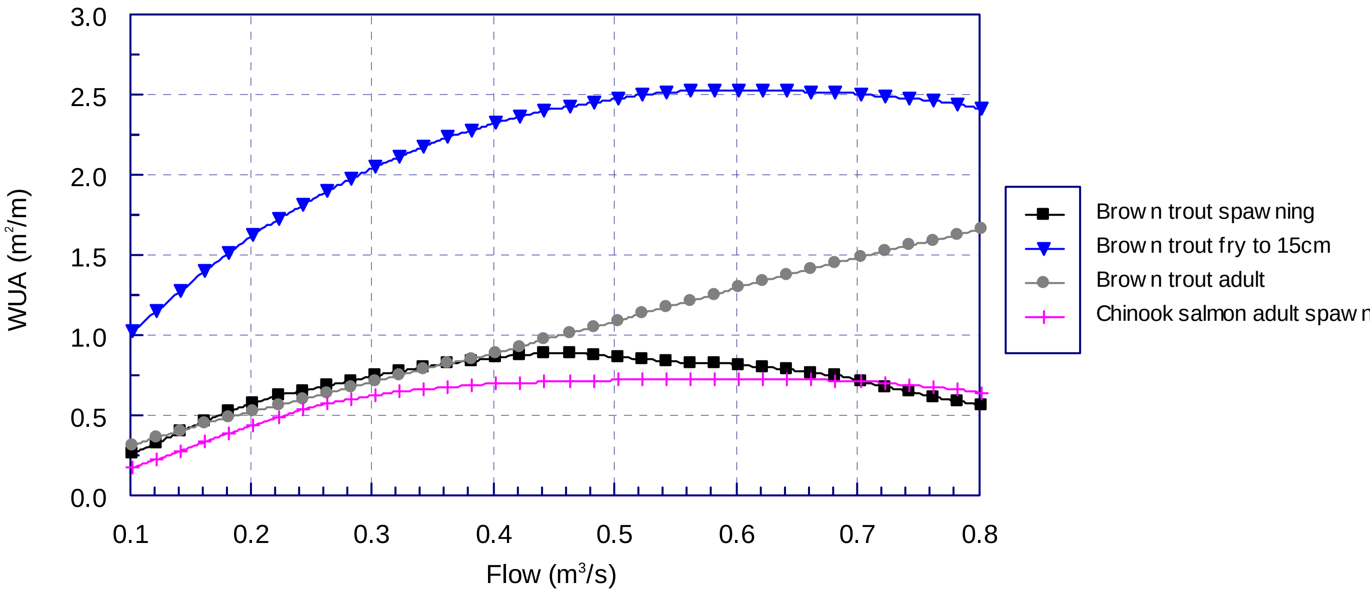


Figure 10: No. 7 Drain relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for native fish and invertebrates.



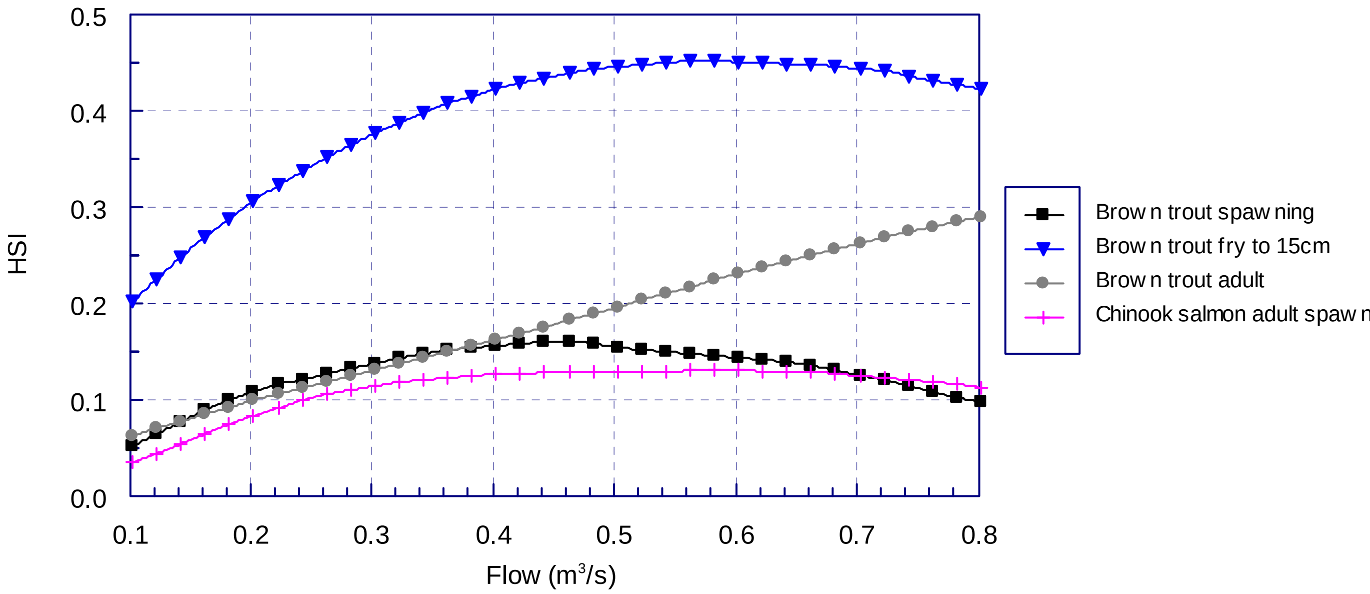
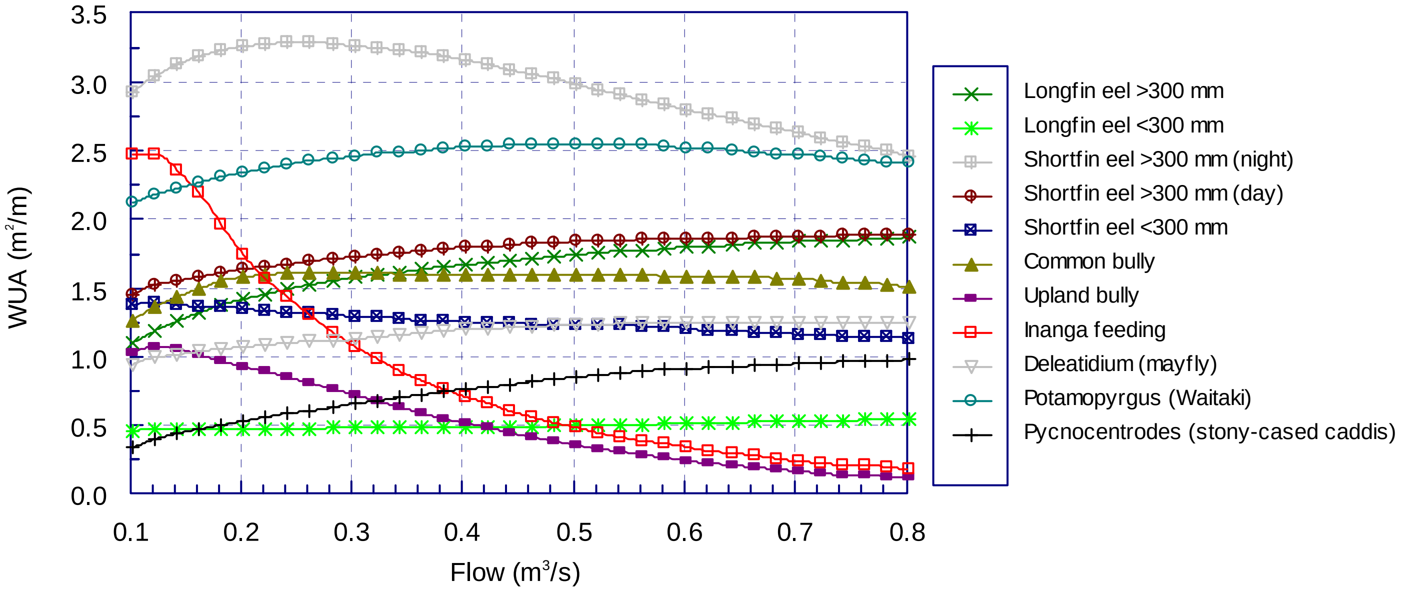


Figure 11: Ohoka Stream relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for salmonids.



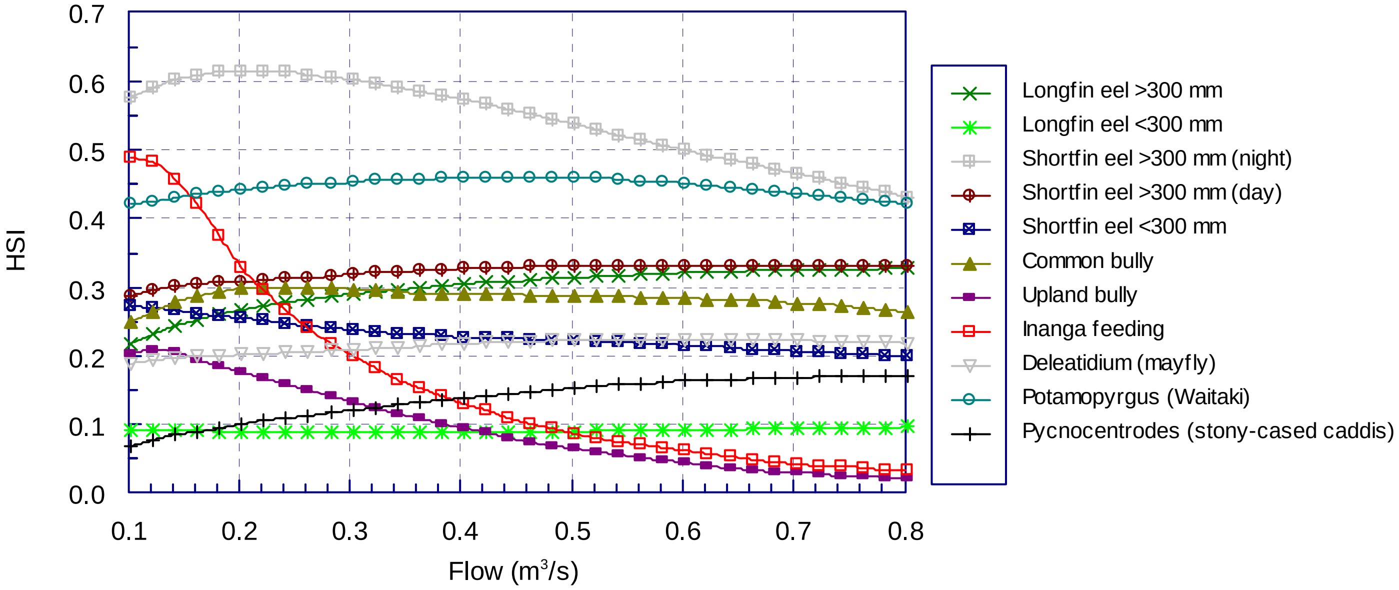
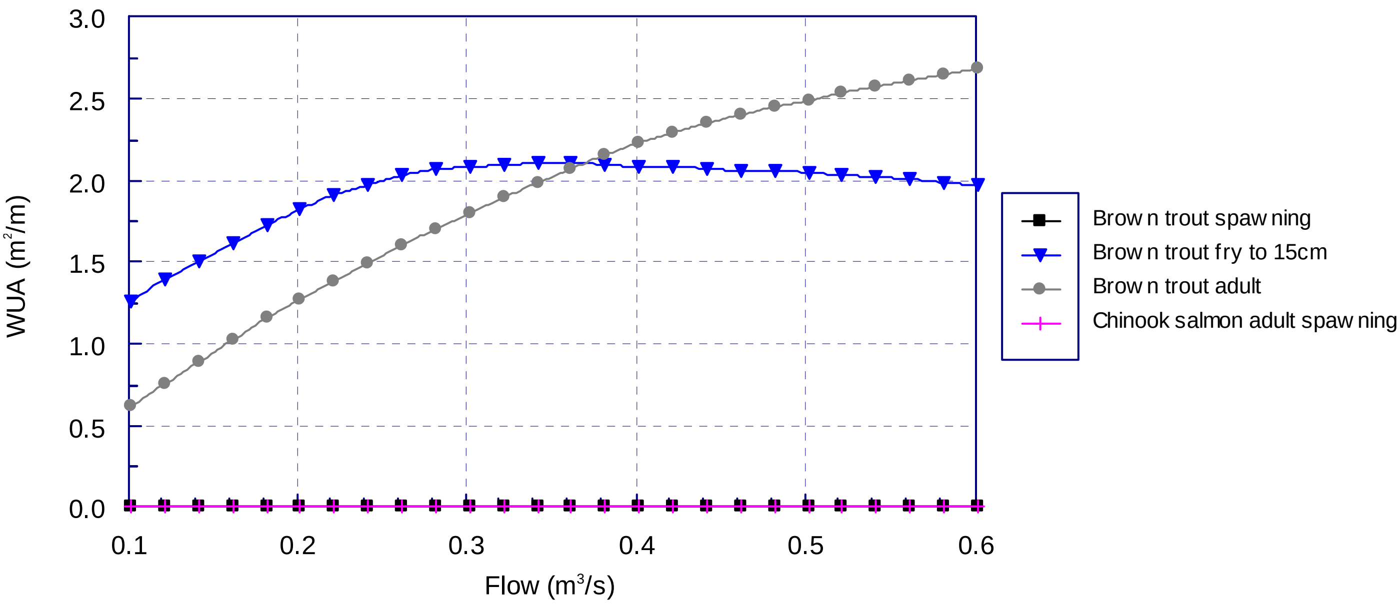


Figure 12: Ohoka Stream relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for native fish and invertebrates.



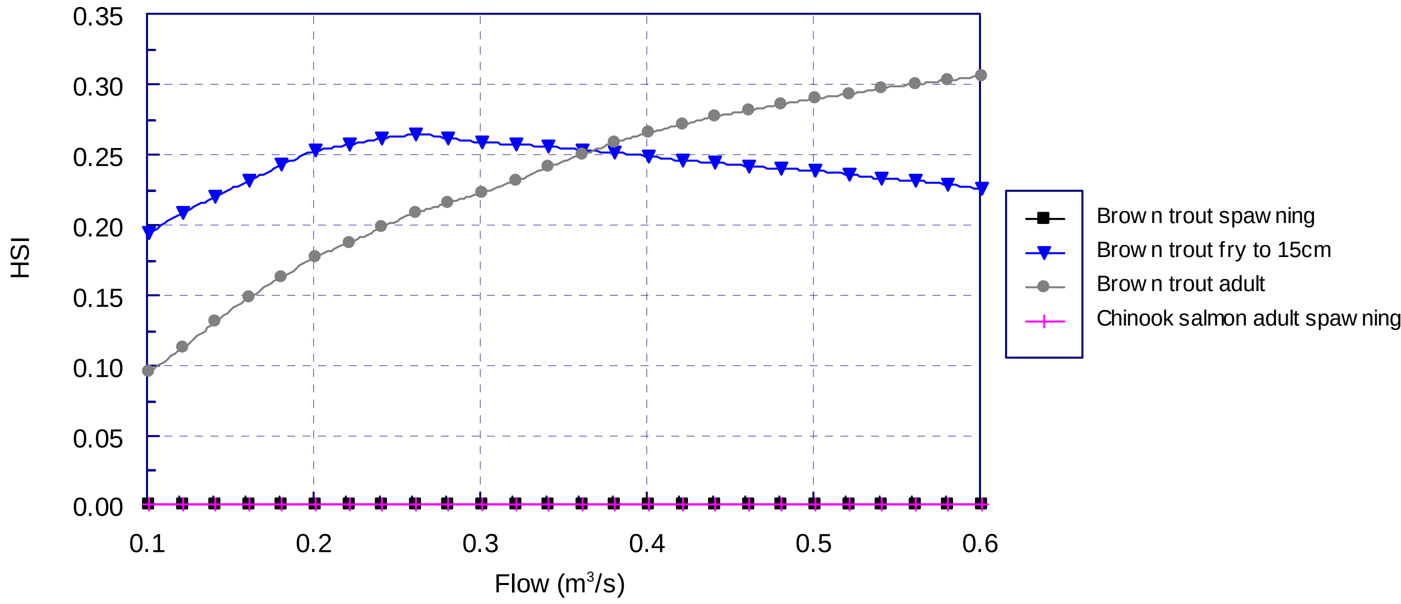
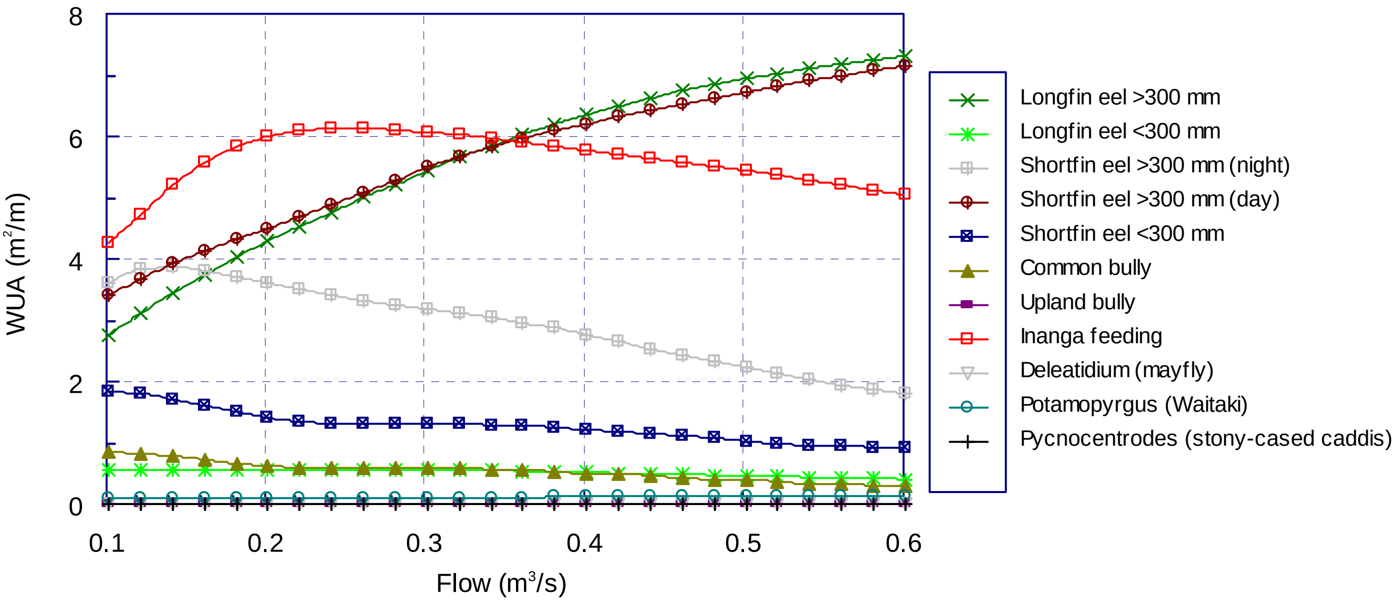


Figure 13: Courtney Stream relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for salmonids.



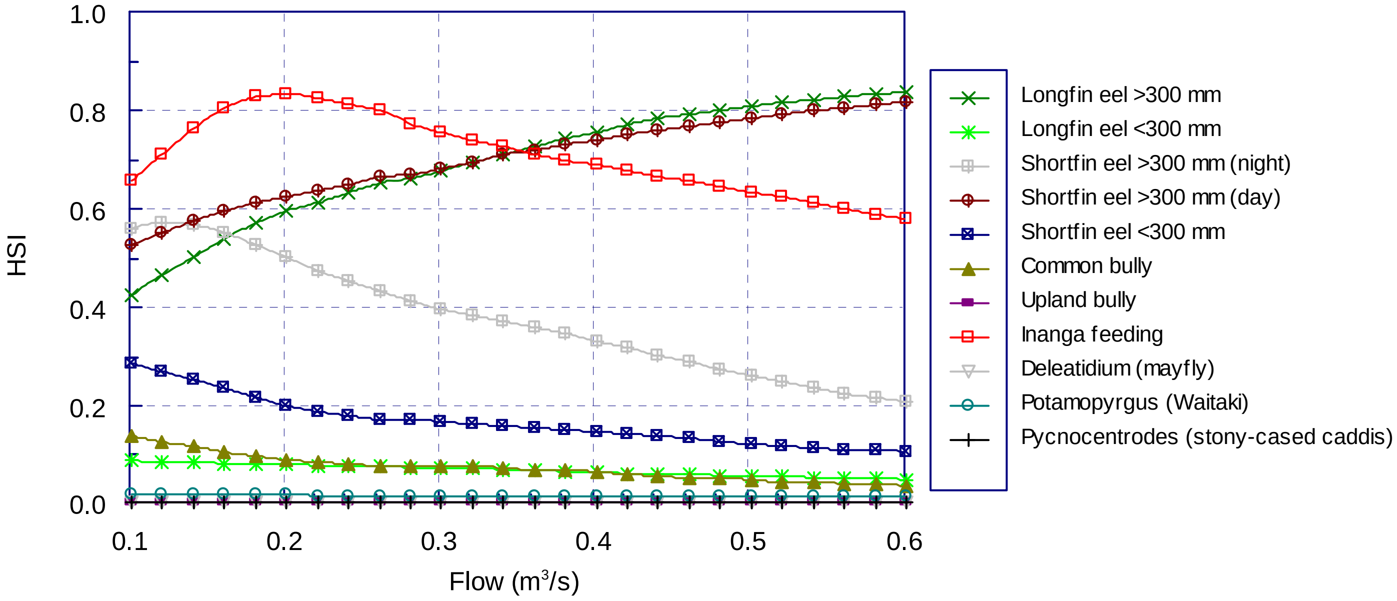
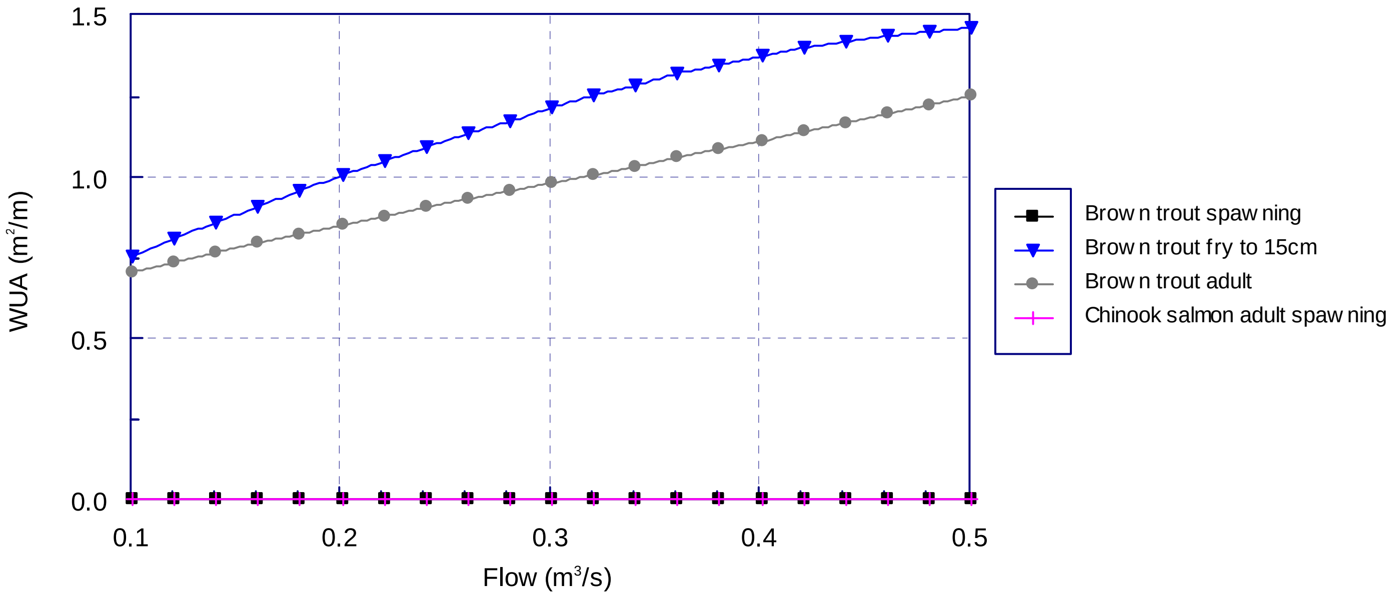


Figure 14: Courtney Stream relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for native fish and invertebrates.



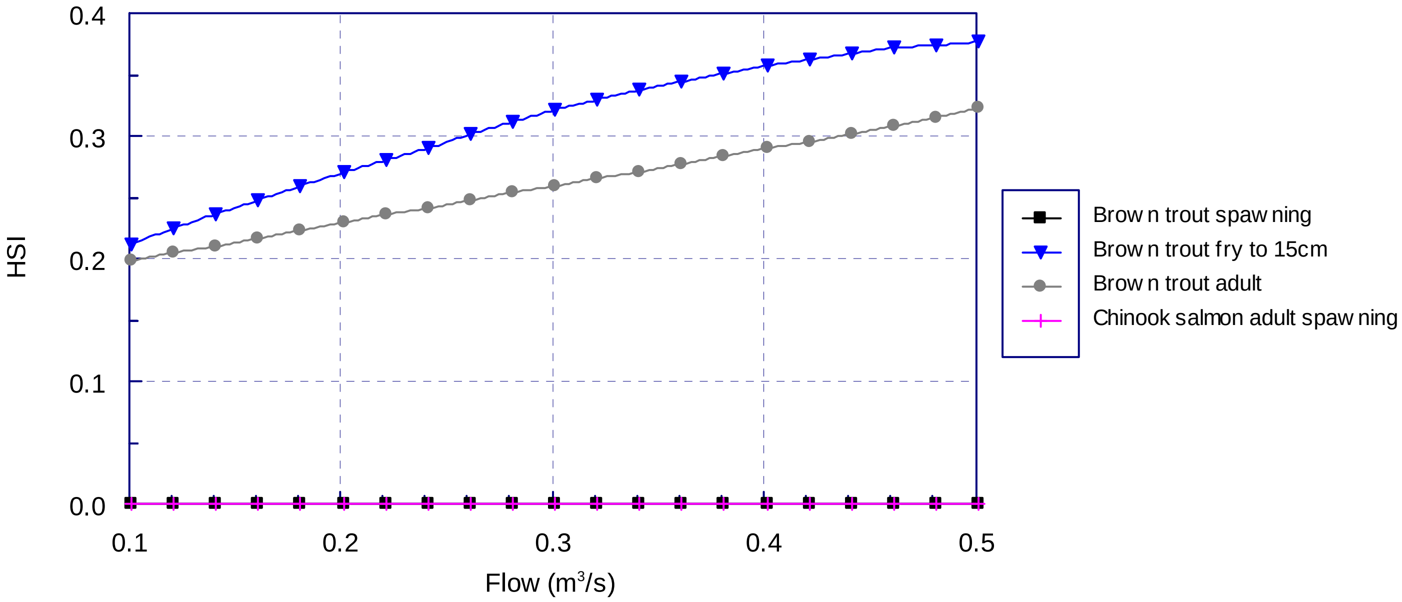
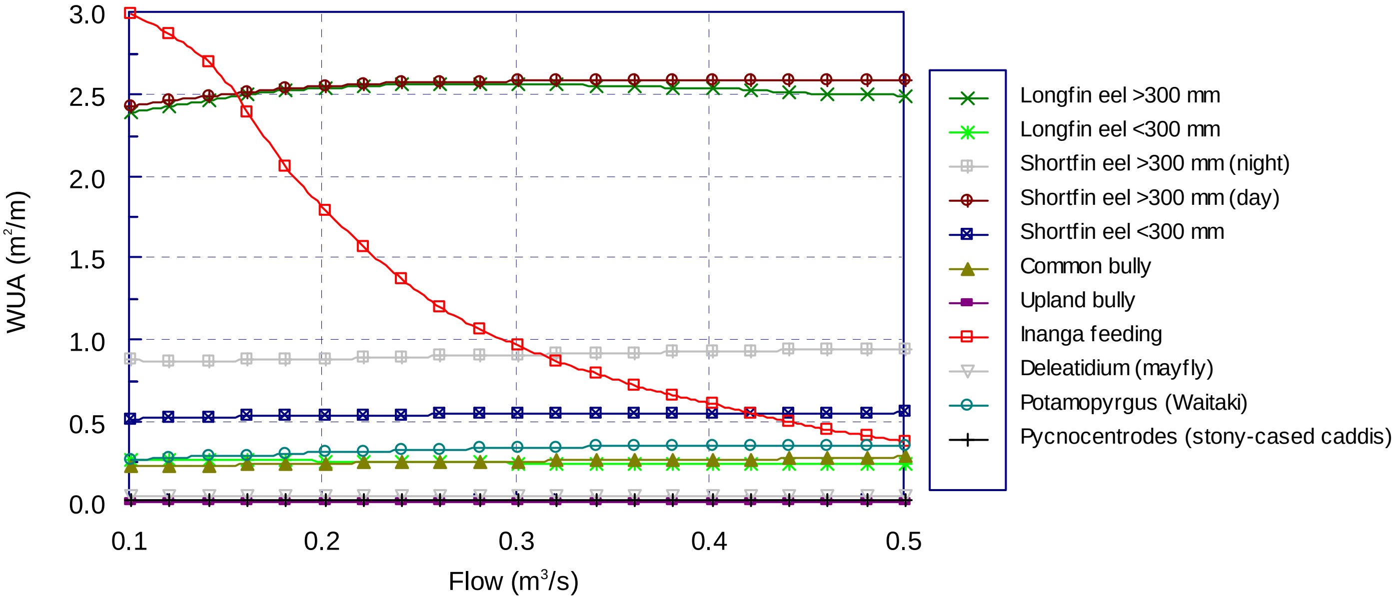


Figure 15: Greigs Drain relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for salmonids.



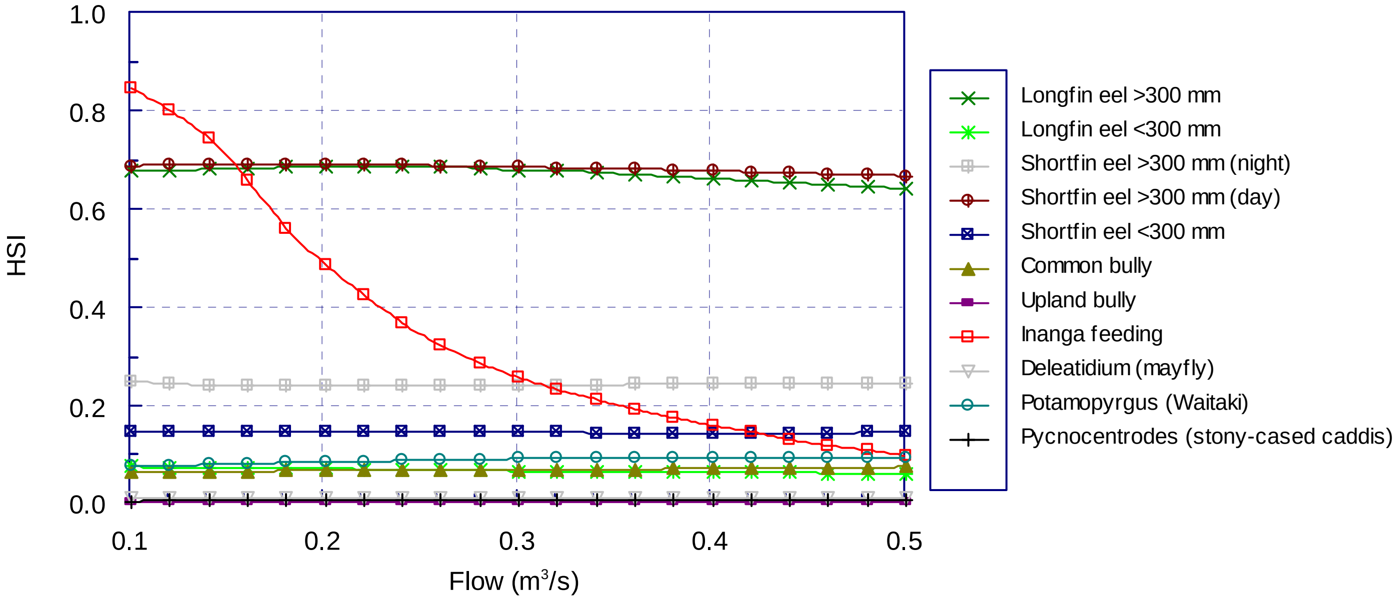
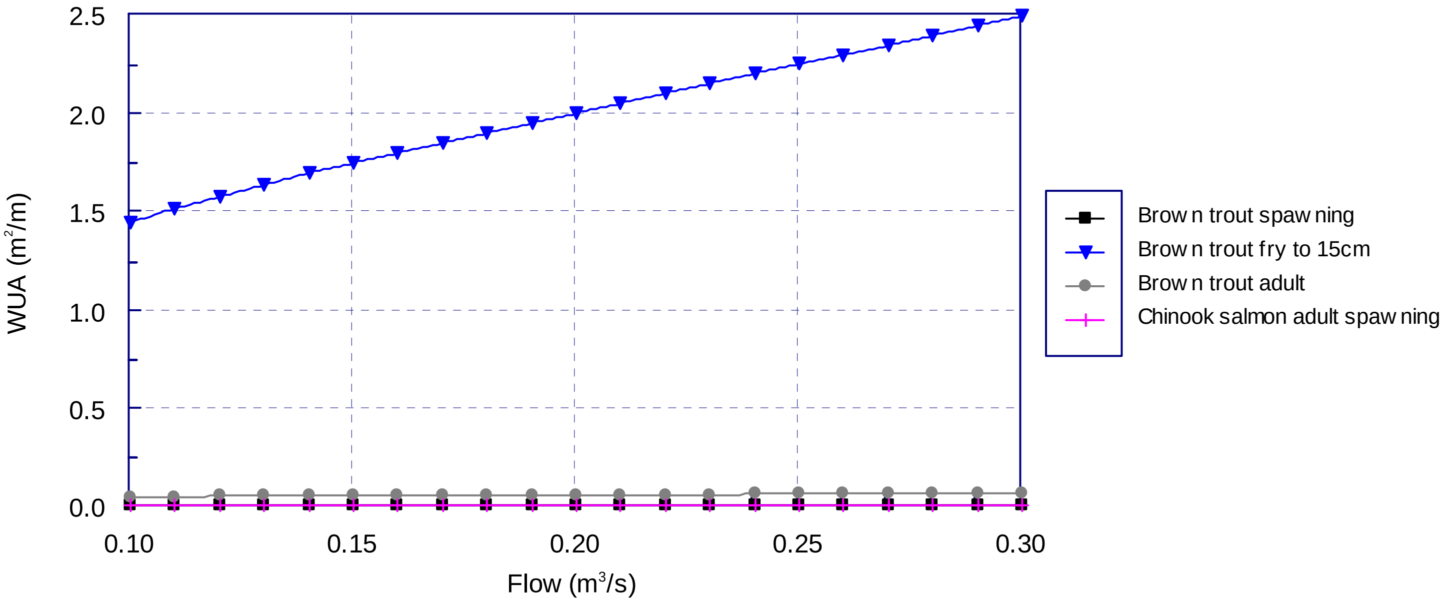


Figure 16: Greigs Drain relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for native fish and invertebrates.



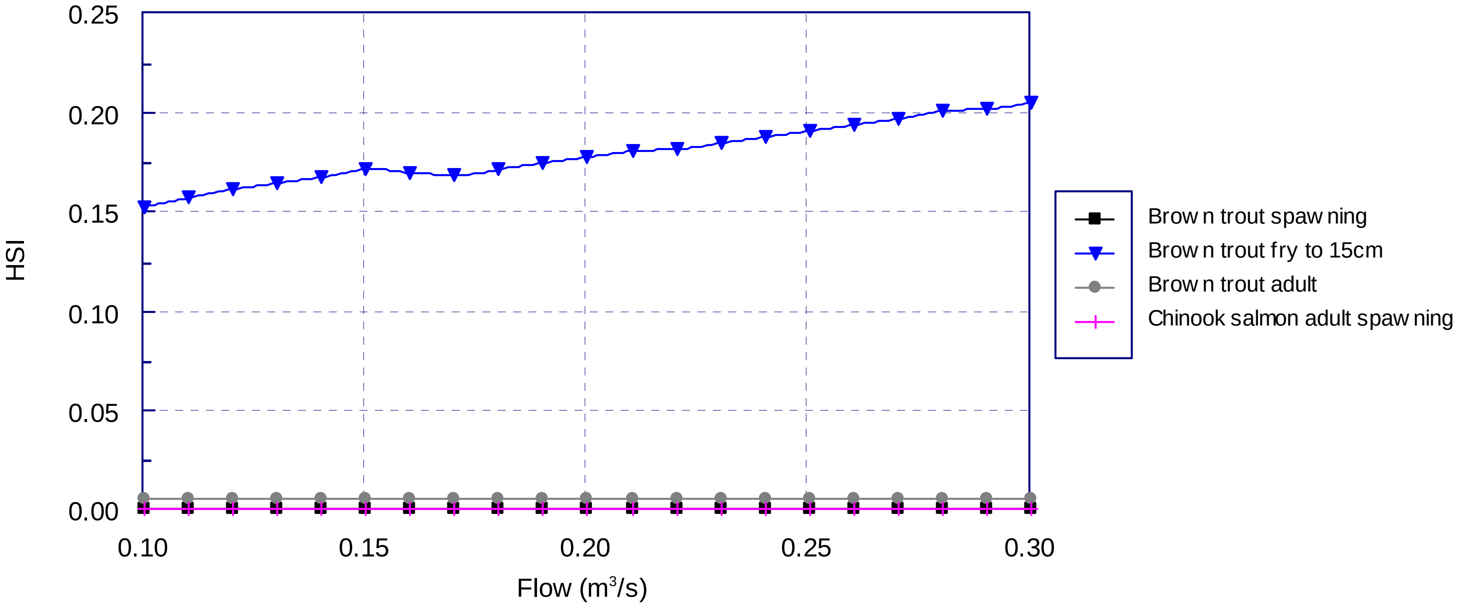
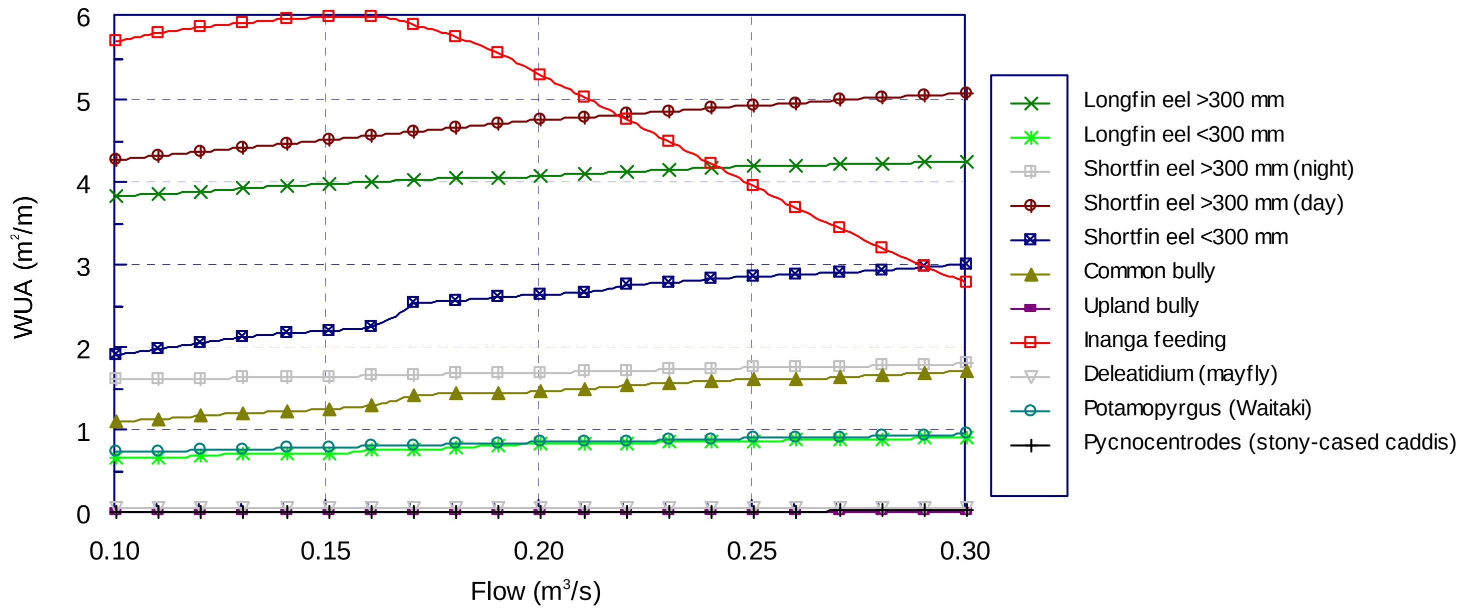


Figure 17: Kaputone Creek relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for salmonids.



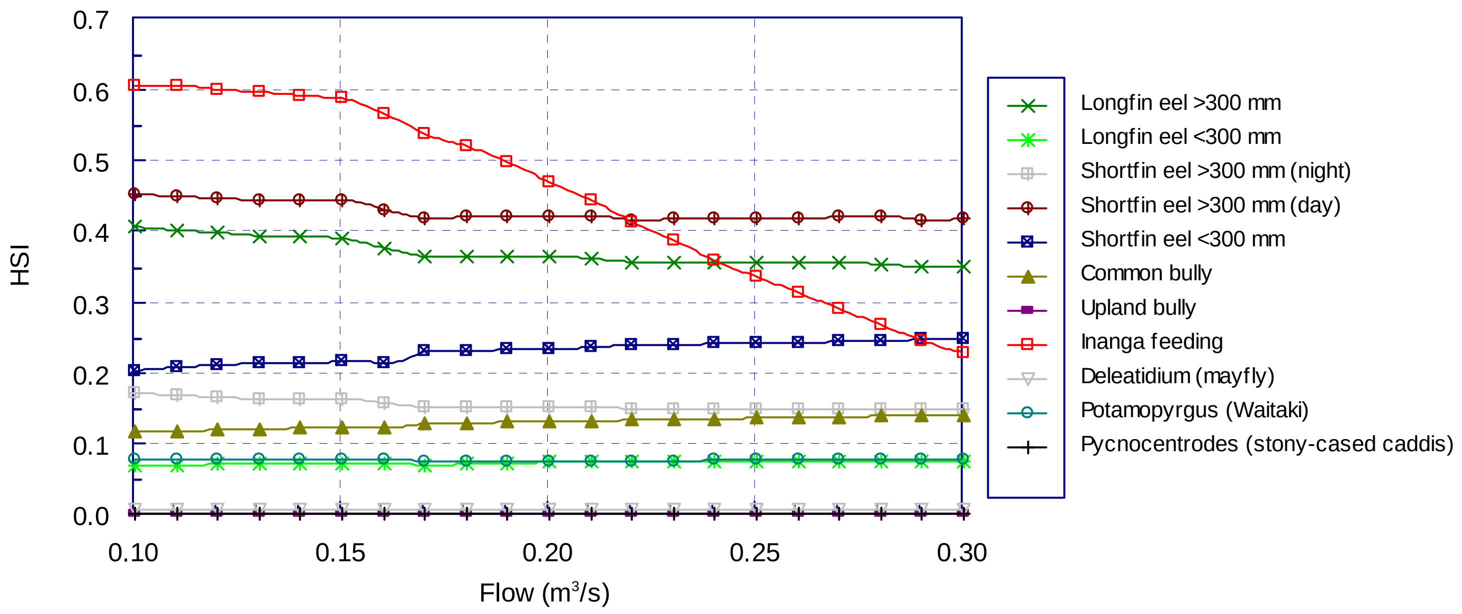


Figure 18: Kaputone Creek relationship between flow and weighted usable area (upper) and habitat suitability index (lower) for native fish and invertebrates.

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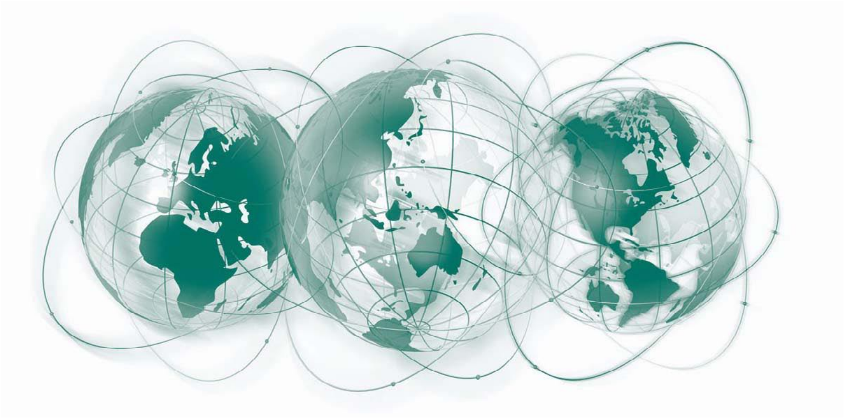

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