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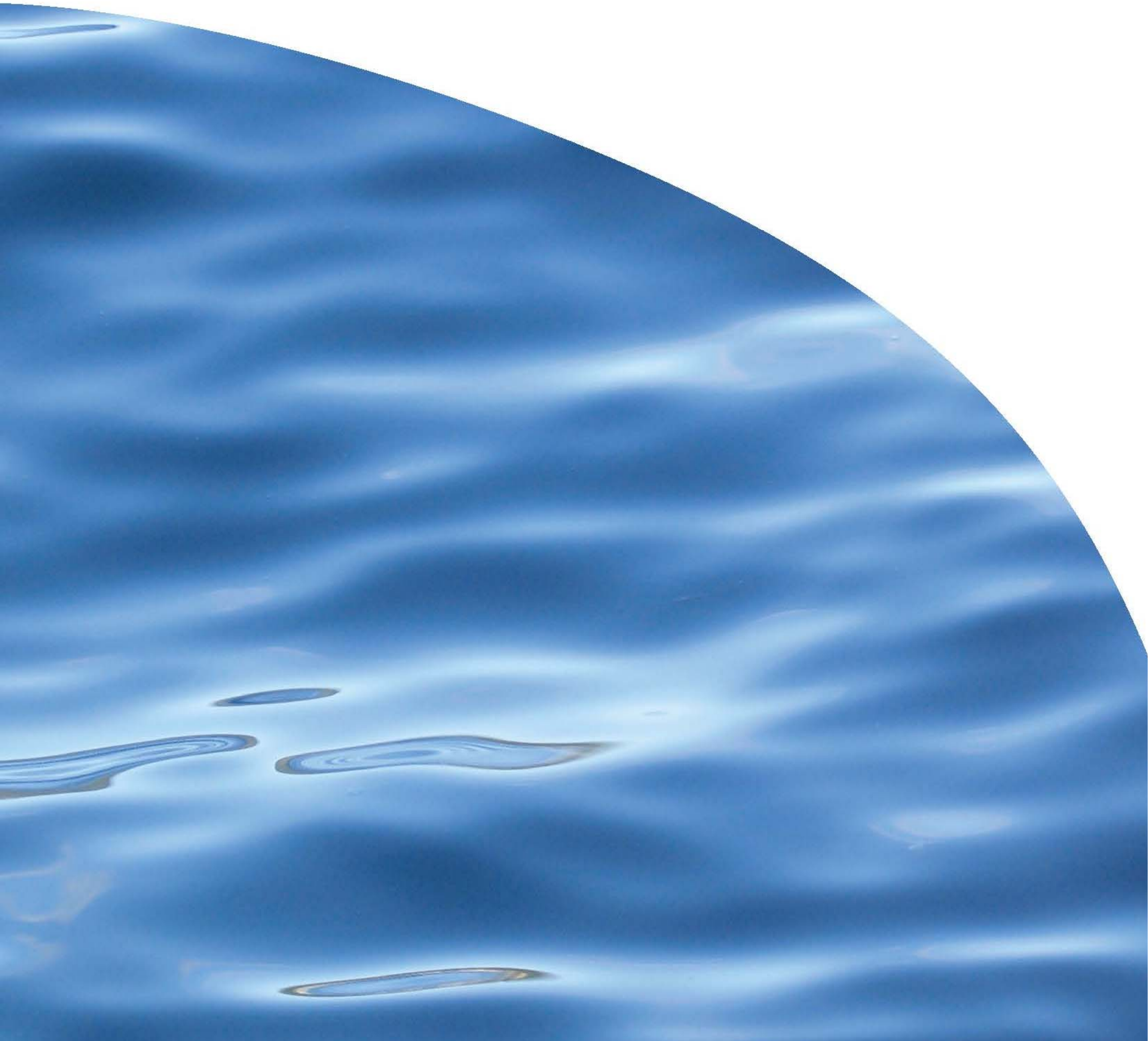
IN-STREAM HABITAT FLOW ASSESSMENT FOR THE WAITAHA RIVER: MORGAN GORGE TO DOUGLAS CREEK



IN-STREAM HABITAT FLOW ASSESSMENT FOR THE WAITAHA RIVER: MORGAN GORGE TO DOUGLAS CREEK

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Prepared for EOS Ecology on behalf of Electronet Services.

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EXECUTIVE SUMMARY

This report provides an assessment of the potential effects of a proposed run-of-river hydroelectric power scheme on in-stream habitat in the Waitaha River, Westland. The report was commissioned by Electronet Services, the contracting subsidiary company of Westpower Ltd, as part of a feasibility study for the proposed scheme. The scope of the report was to assess the likely in-stream habitat effects of a scheme with abstractions of either 19 m^3/s, 21 m^3/s or 23 m^3/s and a residual flow of between 2 and 5 m^3/s. Electronet Services recently expressed a preference for a proposed residual flow of 3.5 m^3/s.

The abstraction reach extends from an intake at the bottom of Kiwi Flat, through Morgan Gorge, to a point approximately 3.3 km downstream, where the diverted water will be returned to the Waitaha mainstem, in the vicinity of the bottom of Douglas Creek. The first 950 m through Morgan Gorge is very steep, turbulent and confined, providing very little suitable habitat for most aquatic organisms and possibly acting as a natural barrier to fish passage (Eikaas & McMurtrie 2010). Below this the channel is single thread, open, fast and bouldery for the remainder of the abstraction reach, shortly after which it becomes braided for the lower 14 km before joining the Kakapotahi River near the coast.

The proposed hydroelectric power scheme will substantially change low to median flow statistics through the abstraction reach, reducing the median flow from 19.9 m^3/s to that of the residual flow — 3.5 m^3/s (Doyle 2012). The frequency of minor floods will reduce by less than 10% and the frequency of large floods will remain unchanged.

Hydraulic-habitat modelling predicts that the modelled residual flow scenarios will cause substantial changes to the habitat quality for periphyton (6%–377% habitat quality retention) compared to that available at the natural low flow. The change in habitat availability (quantity + quality) for the dominant invertebrate taxa varies, ranging from a substantial decrease to a moderate increase (32–161% habitat retention), depending on the habitat criteria used and the species being modelled. Habitat availability for adult brown trout is predicted to be greatly reduced during dry and typical flow months (34–105% habitat retention) and habitat for native fish known to occur in the abstraction reach will generally increase (88–243% habitat retention). Blue duck, which are found in the Waitaha but have not been officially observed in the abstraction reach, are predicted to have more feeding habitat available as a result of the proposed changes in flow (90–175% habitat retention).

Most of the results from the hydraulic-habitat modelling indicate that the most substantial changes in habitat (increases or decreases) occur during dry or typical flow months with the lowest residual flow (2 m^3/s). There is very little (if any) difference between habitat retention values calculated using a 19 m^3/s abstraction verses a 23 m^3/s abstraction.

Hydraulic-habitat modelling also indicates that depths will be sufficient for the upstream passage of salmonids and native fish under all of the residual flow options.

Predictions of habitat retention do not account for the inflow of tributaries within the abstraction reach, which will ameliorate the predicted effects on stream ecology. Predictions are therefore ecologically conservative (*i.e.* results will overestimate the adverse effects and underestimate the positive effects).

The combined effect of lowering the median flow and continued exposure to naturally frequent flood scour through the abstraction reach is likely to result in a reduction in the overall productivity (*i.e.* there is likely to be less food available and hence a lower abundance of aquatic organisms and reduced growth rates). Therefore, the predicted effects of the modelled flows will underestimate the adverse effects (habitat losses) and overestimate the benefits (habitat gains). However, it is important to point out that that this river is likely to naturally support an ecosystem of relatively low productivity, owing to the frequent flood disturbance and low nutrient concentrations.

To put the potential effects of the scheme in perspective with the wider catchment, the abstraction reach below Morgan Gorge is relatively short (2.3km), being approximately 13 % of the 18 km of river between Morgan Gorge and the sea. Whilst the reach represents a large portion (71%) of the single thread open channel habitat below the gorge, there are substantial stretches of river with equivalent habitat upstream, particularly above Waitaha Gorge.

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1. INTRODUCTION

This report provides an assessment of the potential in-stream habitat effects of a proposed hydroelectric power scheme on the Waitaha River, Westland. The report was commissioned by Electronet Services, the contracting subsidiary company of Westpower Ltd, as part of a feasibility study for the proposed scheme.

The scope of the report was to assess the likely in-stream habitat effects of a scheme with non-consumptive abstractions (diversions) of either 19 m^3/s, 21 m^3/s or 23 m^3/s through an intake at the bottom of Kiwi Flat (Figure 1). The scheme will provide a residual flow through the abstraction reach, which extends from below the Kiwi Flat intake (at the top of Morgan Gorge) to a point approximately 3.3 km downstream, where the diverted water will be returned to the Waitaha mainstem, in the vicinity of the bottom of the Douglas Creek (Figure 1).

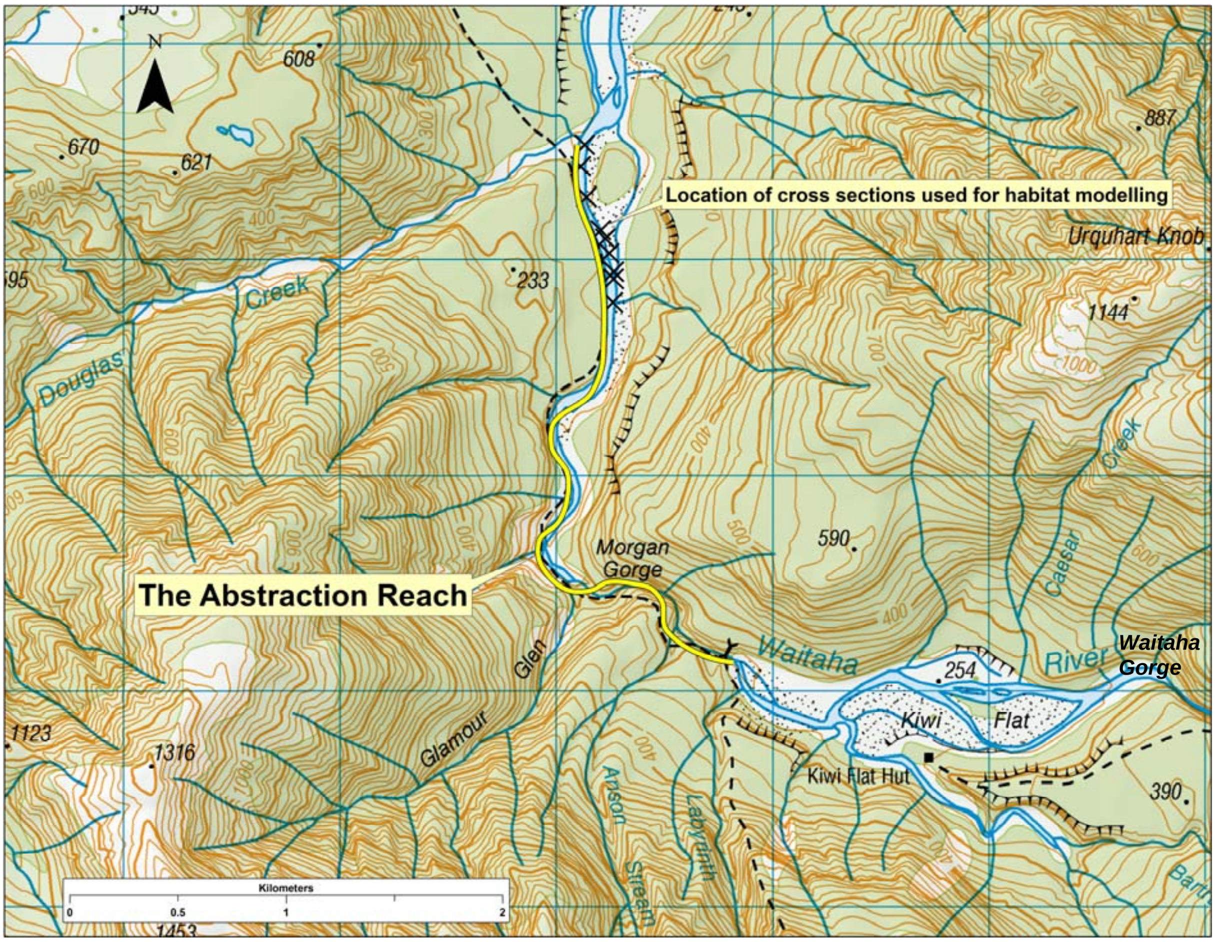

Figure 1. The mid-reaches of the Waitaha River, showing the approximate extent of habitat mapping undertaken in 2007 / 2008. The abstraction reach is the focus of the physical habitat modelling described in this report.

The river through Morgan Gorge (approximately 950 m) is very steep, turbulent and confined, providing very little suitable habitat for most aquatic organisms. Below the Gorge, the 2.3 km mainstem section to Douglas Creek changes in character to a single-thread, open channel and is joined by four small tributaries (Figure 1). The Waitaha channel becomes braided approximately 1 km downstream from the Douglas Creek confluence and remains this way for the lower 14 km, before joining the Kakapotahi River near the coast.

Flow is the driving force of a river, distributing nutrients and food downstream (*e.g.* detritus for invertebrates and drifting insects for fish) and dispersing aquatic life. The hydraulic conditions produced by flowing water also define physical habitat. Many aquatic species are found in similar hydraulic conditions in a wide range of rivers. These hydraulic conditions are components of an aquatic organism’s habitat niche, which includes both physical and biotic characteristics of the environment that are suitable for that organism (Odum 1971).

Flow variation also is an important consideration. The disturbance caused by high flows plays a key role in defining the natural character (including productivity) of a river ecosystem. High flows move sediments and scour parts of the river bed, which resets (reduces) the abundance (or biomass) of periphyton, invertebrates and fish. These organisms must then recolonize areas of suitable habitat. Consequently, the abundance of a particular organism at a site is dependent, not only on present physical habitat conditions, but also on preceding conditions and the species intrinsic rate of colonisation. While aquatic organisms vary in their resistance to disturbance and recovery (resilience), a flow regime featuring very frequent and severe floods will limit most organisms such that they are unable to establish substantial biomass (or abundance), or in some cases even self-sustaining populations.

Altering the flow regime of a river can influence both the prevailing habitat conditions available to aquatic organisms over time and the disturbance regime. Hydraulic-habitat modelling can provide a quantitative description of how the hydraulic habitat conditions (*i.e.* water depth and velocity) change with flow. However, the science of predicting the effects of changing the flood disturbance regime is less well advanced.

This report assesses the effects of various residual flow options for the Waitaha River based on 1-dimensional (1-D) hydraulic-habitat modelling (as commonly applied in the In-stream Flow Incremental Methodology [IFIM]), as well as discussing potential effects of flow disturbance at the conceptual level.

2. METHODS

Hydraulic-habitat modelling and fish passage modelling were undertaken with the computer program RHYHABSIM Version 5.1 (developed by Ian Jowett, http://www.jowettconsulting.co.nz/home/rhyhabsim).

2.1. Hydraulic-habitat modelling within the In-stream Flow Incremental Methodology (IFIM)

The IFIM is a decision-support system (or framework), which provides a process for solving water allocation problems where there are concerns for maintaining in-stream habitat (Bovee *et al.* 1998). Within this system, computer modelling of in-stream habitat availability, and minimum depths for passage, for selected species, over a range of flows, provides a basis for negotiation and decision making over minimum flows and flow allocation.

One-dimensional hydraulic-habitat modelling within the IFIM entails measuring water depths and velocities, as well as substrate composition, across several representative river cross sections at a given flow (referred to as the survey flow). Points on the banks, above water level, along the cross sections are also surveyed to allow model predictions to be made at flows higher than the survey flow. The stage (water level) at zero flow is also estimated at each cross section to facilitate fitting of rating curves and for making model predictions at low flows. Other data for fitting rating curves are obtained from additional measurements of water level at each cross section, relative to flow, on subsequent visits. These data allow calibration of a hydraulic model for predicting how depths, velocities and the area of different substrate types covered by the river will vary with discharge in the surveyed reach.

Modelled depths, velocities and substrate types can then be compared with habitat suitability criteria (HSC) describing the suitability of different depths, velocities and substrate sizes as habitat for given species of interest. These criteria take the form of habitat suitability curves, which have been developed by observing the depths and velocities used by various species, both in New Zealand and overseas. Comparison of the HSC with the modelled physical characteristics of the study river provides a prediction of the availability of habitat in the river. Habitat modelling is undertaken over a range of flows to predict how habitat availability will change with flow.

2.2. Weighted usable area — the currency of flow decision making

Modelled habitat availability is expressed as an index called ‘weighted usable area’ (WUA), which is calculated as the sum of the area weighted products of the combined habitat suitability scores (*i.e.* depth x velocity x substrate suitability) for the measurement points on the cross sections. The area weighting is based on each measurement point representing an area, or proportion, of the modelled reach. Traditionally WUA has often been expressed as an area per linear metre of river reach (m^2/m). WUA is best viewed as an index of the relative quantity and quality of available habitat at a given flow.

An alternative index, HSI or combined (or composite) habitat suitability index (CSI) is the mean of the combined point habitat suitability scores for the modelled reach. This provides an indication of the quality of predicted habitat[1].

It is important to realise that WUA provides only a relative measure of how predicted habitat changes with flow. When interpreting the WUA x flow curves that are the output of modelling, it is the shape of the curve (*e.g.* the flows at which the optimum WUA and major changes in slope occur) that are of interest, rather than the magnitude (or height) of the WUA x flow curves. The outputs provide an indication of how habitat is predicted to change with flow. WUA serves as a currency which stakeholders can use for interpreting effects of flow change on in-stream habitat and for negotiating flow decisions.

2.3. Reach selection for hydraulic-habitat modelling

There are two approaches that can be followed when selecting locations for the cross sections, which form the basis of the field survey component of hydraulic-habitat modelling; habitat mapping or the representative reach (Jowett 2004). In the habitat mapping approach the proportion of each mesohabitat type (*e.g.* run, riffle, pool) comprising a relatively long reach of the river is mapped and each cross section is given a percentage weighting based on the proportion of the habitat in the reach that it represents. The predictions of subsequent modelling then relate to the reach that was mapped.

In the representative reach approach a relatively short (at least one riffle–run–pool sequence ~ 50–150 m) reach of river is selected that is thought to be representative of a longer river segment (Jowett 2004). The cross sections are closely spaced (at a scale of metres) at longitudinal points of habitat change along the reach, with note being taken of the distance between cross sections, and water levels on all cross sections being surveyed to a common datum. The subsequent modelling predictions are then assumed to be applicable to the section of river that the chosen reach represents.

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[1] The habitat suitability index was formerly termed WUA% in RHYHABSIM.

Whichever of these approaches is employed, the underlying assumption is that the cross sections provide a reasonable representation of the variability in habitat throughout the segment of interest.

The number of cross sections required will depend on the morphological variability of the channel; fewer cross sections will be required in relatively homogenous channels. Studies have shown that relatively few cross sections can reproduce the shape of the WUA – flow relationship obtained from a survey with a large number of cross sections. For example, Payne *et al.* (2004) sub-sampled several very large data sets to determine how many cross sections were required to produce a robust WUA versus flow relationship. They found that 18–20 cross sections gave results nearly identical to results for 40–80 cross sections per reach and that only a few cross sections were required to reproduce the general shape of the relationship. Several such studies were summarised in a recent guide to in-stream habitat surveys and modelling (Jowett *et al.* 2008). The recommendation was that the total number of cross sections needed to generate a robust result should be proportional to the complexity of the habitat hydraulics. Jowett *et al*. suggested 6-10 cross sections for simple reaches and 18-20 for hydraulically complex reaches.

2.4. Field data collection

During field studies in 2007 / 2008, two options were being considered for the location of water abstraction in the Waitaha River: one being at the upstream end of Kiwi Flat; the other at the downstream end. Hence two reaches were surveyed using the habitat mapping approach to accommodate these alternative options:

1. The reach where the Waitaha flows through Kiwi Flat (Figure 1), from the bottom of the Waitaha Gorge to the top of the Morgan Gorge (henceforth referred to as the Kiwi Flat reach).
2. The reach from the top of Morgan Gorge to the confluence with Douglas Creek (henceforth referred to as the abstraction reach (Figure 1)).

Since 2008 Westpower have determined that building the intake weir at the bottom of Kiwi Flat, above Morgan Gorge, is the preferred option. Consequently, the survey data from the abstraction reach are most relevant to assessing potential effects of this proposal. The Kiwi Flat reach is not considered further in this report.

Morgan Gorge itself was not considered in the habitat analysis; because it was not feasible to survey and likely to be impossible to accurately model the torrential flow which prevails through this reach. Moreover, because of its torrential nature, it will support little aquatic life of value.

The habitat mapping and cross section selection were carried out by Joe Hay (Cawthron), Shelley McMurtrie (EOS Ecology), and John Porteous (NIWA) on 30 April 2007. Habitat was mapped in a 2 km long segment of river channel in the abstraction reach. Habitat type in the abstraction reach was dominated by fast / bouldery run (69%), along with some relatively slow/deep run habitat types and a few short, steep torrents or cascades (Table 1). The total of nine cross sections in this reach provided sufficient data for hydraulic modelling because of the dominance of fast / bouldery run.

The steep cascades, which comprised only 13 % of the reach, were considered infeasible to survey and likely to be impossible to accurately model, so they were excluded from the habitat survey and analysis. Cross sections were positioned in an attempt to encompass the full range of variability represented in each of the remaining two habitat types (*i.e.* fast / bouldery run and slow run).

Table 1. Summary of habitat mapping and cross section allocation in the abstraction reach.

Habitat type	**Proportion of total length (%)**	**Proportion of total length, without cascades (%)**	**No. of cross sections**	**Weighting per cross section, without cascades (%)**
Fast bouldery run	69	79	6	13.2
Slow run	18	21	3	6.9
Torrent / cascade	13		0	
Total	100	100	9	

The majority of the subsequent field work was completed by NIWA staff between July and October 2008, over a flow range of 8.95–29.39 m^3/s (Table 2). The main habitat survey in the abstraction reach was split over two occasions. The first five cross sections were surveyed on 22 July 2008, and the remaining four cross sections were surveyed on 24 August. The flow was approximately 0.52 m^3/s higher in the survey reach on the latter date.

Table 2. Flow (m^3/s) gauged at the top and bottom of the abstraction reach during the habitat mapping survey, cross section survey and follow-up water level measurements. Flow statistics for the top of the abstraction reach (1-day mean annual low flow (MALF1), and median flow) provided by Martin Doyle 2012.

Location	**MALF1**	**Median flow**	**Cross section selection**	**Water level calibration and habitat surveys**		**Water level calibration**	
			30-Apr 2007	22-Jul 2008	24-Aug 2008	06-Sep 2008	19-Oct 2008
Top of abstraction reach	7.09 m^3/s	19.9 m^3/s	10.13	No data	7.59	13.03	26.89
Bottom of abstraction reach	No data	No data	11.23	8.95	9.47	14.28	29.39

Stage-discharge relationships for each cross section were based on three to four pairs of water level and discharge measurements, including those made at the survey flow. The water level measurements taken during cross section selection on 30 April 2007 were not used in the calibration data set, because they did not fit with the other rating data poorly. This suggested that the channel cross sectional profile at these locations had probably been altered by flooding after the initial cross section mark out. The calibration water level measurements were collected over a broad range of flows (Table 2), ranging from close to the mean annual low flow[2] (MALF1) to above the median flow[3].

Within RHYHABSIM, the default calibration flow for modelling is the average of the flows gauged at all the cross sections during the survey of depths and velocities. However, in this case the flow at which the main habitat survey was undertaken in the abstraction reach varied between days. Consequently, the calibration flow was specified for each cross section individually based on the best available estimate of

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[2] The use of the term 'mean annual low flow' henceforth in this report refers to the '1-day' mean annual low flow' (MALF1). As defined by Jowett et al (2008), "Mean annual low flow can either be the instantaneous, 1-day (MALF1) or 7-day (MALF7). The advantage of the former is the ease of calculation and the advantage of the latter being that 'spikes' in the hydrological record have less influence on its value. Biologically, MALF is potentially a natural 'bottleneck' for aquatic species that have life cycles in the order of three to five years, as it represents the average lowest annual flows, when space might be limiting. If low flows are a 'bottleneck' for a given river, then a reduction in minimum flow would have a detrimental effect, but if the species is not limited by low flows, then a reduction in minimum flow will have no effect." There is no standard use regarding which MALF statistic to use for interpretation of hydraulic-habitat modelling predictions in New Zealand. MALF1 has often been used in the past by Ian Jowett (formerly of NIWA) and Cawthron Institute because it is easier to calculate than MALF7 and there is very little difference between the two. Mike Thompson from Greater Wellington Regional Council recently calculated and compared the ecological consequences of using MALF1 and MALF7 on two Wellington rivers. His conclusions state that "Generally… for the less severe but frequently occurring low flow events, there is likely to be little material difference for the river whether we choose rules based on 1-day or 7-day MALF criteria" (Thompson, unpublished report). Furthermore, flows in steep, fast flowing rivers that feature frequent flood events (like the Waitaha) are likely to rise and fall rapidly, so there will arguably be less difference between the duration of low flow events than with low gradient rivers.

[3] All flow statistics in this report were provided by Martin Doyle, either directly, or in his report "Hydrological effects of Waitaha Hydro" prepared for Electronet Services, September 2012.

flow in that cross section at the time of the respective surveys, as assessed by John Porteous (NIWA).

2.5. Data checking

The data set was imported into RHYHABSIM and checked to ensure that it met expectations of data quality. Aside from the standard checks performed within the program's built-in data checking function:

- Cross sections were plotted and visually checked for any obvious anomalies (*i.e.* unrealistic depth and velocity spikes).
- Rating curves were checked to see that they exhibited a good fit to the expected power curve relationship, and that the different types of rating curves calculated in RHYHABSIM did not substantially differ from one another.
- The velocity distribution factors (VDFs[4]) were edited so that points falling above the water surface at the survey flow were given reasonable VDF values (*i.e.* vary around a value of one, and generally decrease with distance toward the banks (Jowett 2004)); the default is that they are given the same value as the closest point which was below water level at the survey flow). This consideration is important when modelling flows above the survey flow. Anomalously high VDFs (points with VDFs > 3; pers. comm. Ian Jowett, Jowett Consulting) were also reduced to avoid predicting spuriously high velocity at high flows.

In general the data set appeared to meet most data quality expectations. Aside from a few data entry errors, which were corrected when found, there were two other minor issues with the data set:

1. The estimated stage at zero flow for one cross section was lower than the minimum bed level on that cross section. The stage at zero flow was changed to the section minimum.

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[4] Velocity distribution factors (VDFs) are essentially a measure of how the influence of bed-roughness on water velocity varies across the cross section and they are used in RHYHABSIM to reproduce the transverse velocity distribution measured on each cross section at the survey flow. They are calculated from the velocities measured on each cross section at the survey flow and usually vary about the value of 1. If the velocity were distributed across the section according to the conveyance of each measurement point then the VDF for each point would be 1. This occurs in situations with uniform flow and cross section, such as canals. However, in most rivers variations in friction across the section, upstream obstructions such as boulders, and flow patterns caused by bends and eddies cause the VDF to be less than 1 at banks or downstream of obstructions and greater than 1 where flow concentrations occur. Within the model, predictions of water velocity across each cross section follow the velocity distribution that was measured during the survey. The assumption, when using this approach to calculate velocities, is that the velocity distribution does not change significantly with flow. This is the reason that a survey is usually carried out at flows near the flows of interest (usually low flows) and that there is a need to be cautious when extrapolating to much higher or lower flows.

2. The recorded percentage cover of different substrate types at a few points did not sum to 100 %. In these instances reasonable proportions of each substrate type were interpolated based on adjacent data points such that they summed to 100 %.

In the abstraction reach the flow was assumed to be constant between cross sections during modelling, *i.e.* there was assumed to be no significant inflow (from tributaries or groundwater) and no significant losses (to groundwater or abstraction) over the length of the modelled reach.

2.6. Habitat modelling

2.6.1. Habitat suitability criteria

Habitat modelling predictions are sensitive to the habitat suitability criteria (HSC) applied (Jowett 2004; Jowett *et al.* 2008). Therefore, the HSC chosen for a study must be appropriate for the species which are known to (or are likely to) occur in the study river. When several different sets of HSC are available for a given species the suitability criteria should be selected to best represent the study river (*e.g.* similar flow range, gradient and morphology). Consideration must also be given to the transferability of HSC developed on other rivers to the study river. HSC developed on rivers with similar physical characteristics to the study river should be more transferable than HSC developed on rivers with much different geomorphology and flow range. Ideally HSC should be developed for the river under in-stream flow investigation. This was done for benthic invertebrates and blue duck in the Waitaha. Invertebrate HSC from other rivers were also used in the habitat modelling for comparison.

Habitat was modelled for four groups of aquatic organisms: periphyton, macroinvertebrates, fish, and blue ducks. The habitat suitability criteria applied in each case are outlined below, and Appendix 1 provides graphical representations and further details where necessary.

2.6.2. Habitat suitability criteria – Periphyton

Commonly used HSC for short filamentous algae, long filamentous algae, and diatoms were applied. These were developed on the basis of the expert opinion of Barry Biggs (NIWA), based on his own experience with periphyton cover in New Zealand rivers (pers. comm., Ian Jowett, Jowett Consulting, 14 December 2012).

2.6.3. Habitat suitability criteria — Invertebrates

Waitaha-specific HSC were developed for the five most abundant benthic invertebrate taxa found in the Waitaha mainstem (McMurtrie & Suren 2009), as well as a combined ‘all invertebrates’ HSC. The most abundant taxa were also found in blue duck faeces, confirming their relevance for food production for this species. The six Waitaha-specific invertebrate HSC were 'Waitaha *Deleatidium'*, 'Waitaha *Stictocladius',* 'Waitaha Orthocladiinae', 'Waitaha *Neocurupira', '*Waitaha Hydrobiosidae', and 'Waitaha All invertebrates'. *Deleatidium* is New Zealand's most common mayfly genus; *Stictocladius* is a common Orthoclad Chironomid (midge) genus, Orthocladiinae belongs to the family Chronomidae (midges), *Neocurupira* belongs to the family Blephariceridae (flattened larvae of net-winged midges common in very fast water); Hydrobiosidae are free living caddisfly larvae. Graphical representations for these HSC are presented in Appendix 1, and the methodology used to create them is set out below.

To provide a comparison with the Waitaha-specific criteria, invertebrate HSC available from other sources for similar taxa to those found in the Waitaha were also modelled. The reason for this is that while the methodology used to gather the Waitaha HSC data was sound, the HSC may have some bias to the flow range over which the habitat use data were collected. Including HSC developed for the same or similar species in other New Zealand rivers adds to the robustness of the habitat modelling assessment. These criteria included 'Food Producing' (Waters 1976); '*Deleatidium'* and 'Hydrobiosidae' (Jowett 1991); as well as 'Waitaki *Deleatidium'*, 'Waitaki Hydrobiosidae' and 'Waitaki Orthocladiinae'. Graphical representations for these HSC are presented in Appendix 1, as well background information on how they were developed.

A total of 219 invertebrate samples collected by EOS Ecology were used to develop HSC. At each sampling point an invertebrate sample was taken, with the sampling method varying according to the dominant substrate at that point. A Surber sampler was used in sand to small cobble substrate, a kicknet for large cobble and small boulders (kicknet samples involved placing the kicknet directly behind the sample point and lifting the rocks into it, then rubbing the entire surface, to ensure that anything dislodged would be caught in the net. These rocks were then measured to provide an estimate of the surface area sampled), for larger boulder substrate a defined area of a boulder was scraped and anything dislodged was caught in a kicknet. At each sampling point, water depth was measured with a wading rod and substrate composition visually estimated. Mean water column velocity was estimated from 30 second velocity measurements at 0.6 x the depth from the surface (*i.e.* 0.4 x depth from the bottom). Densities of a range of invertebrate taxa were calculated for each sampling location, including zero density for locations where a given taxa was not found, and these data provided the basis for the development of HSC.

The majority of the data analysis involved in developing the HSC were carried out using HABPRF (also called HabSEL), a purpose designed computer program developed by Ian Jowett. The process of developing invertebrate habitat suitability criteria involved exploring the data by:

- Tabulating the range of depths, velocities and substrates that were sampled, and the average depth, velocity and substrate in which each taxon was found (Table 3).
- Plotting histograms, kernel smoothed curves, and scatterplots of habitat use (density) and habitat availability for depth, velocity and substrate index.
- Calculating preference curves, using the forage ratio (defined below), for depth, velocity and substrate index. The forage ratio is a selection index, designed to correct observed habitat use to account for non-uniform habitat availability. The forage ratio is the proportion of used habitat units of a category (for example, velocities between 0.20 and 0.25 m/s) divided by the proportion of habitat units of that category available in the whole sample (*i.e.* in the survey reach in this case):

  $$w_i = \frac{u_i / \sum_{i=1}^{n} u_i}{a_i / \sum_{i=1}^{n} a_i}$$

  Where w_i is the forage ratio for the *i*th of *n* habitat categories, u_i is the number of a given organism in each habitat category *i*, Σu_i is the total number of that organism over all habitat categories, a_i is the number of samples from category *i* and Σa_i is the total number of samples (Manly *et al.* 1993).

- Plotting contours of invertebrate density with depth and velocity using locally weighted regression scatterplot smoothing (LOESS).
- Developing a Poisson generalised additive model (GAM) using depth, velocity and substrate index as predictors and plotting contours of predicted abundance against depth and velocity.
- Comparing the GAM and LOESS contours to determine whether it was necessary to introduce a depth/velocity interaction term.
- Normalising the forage ratio relationships to a maximum value of 1.

Table 3. Summary of the invertebrate data from which the river-specific HSC were developed. SD = standard deviation.

	No. of locations where recorded	**Total recorded**	**Velocity (m/s)**		**Depth (m)**		**Substrate index**	
			Range	**Mean (SD)**	**Range**	**Mean (SD)**	**Range**	**Mean (SD)**
Available habitat	219		0–1.49	0.5 (0.3)	0.08–1.4	0.6 (0.3)	2.2–7	5.4 (1.1)
Total density	219	71013	0–1.49	0.43 (0.3)	0.08–1.4	0.48 (0.29)	2.2–7	5.39 (1.11)
Deleatidium	198	33327	0–1.49	0.48 (0.3)	0.08–1.4	0.51 (0.32)	2.2–7	5.64 (0.7)
Stictocladius	133	15436	0.01–1.07	0.33 (0.26)	0.08–1.25	0.49 (0.24)	2.2–7	4.3 (1.16)
Orthocladiinae	113	8592	0–1.26	0.31 (0.27)	0.08–1.25	0.34 (0.22)	3.4–7	6.21 (1.02)
Neocurupira	78	2671	0.01–1.49	0.68 (0.37)	0.1–1.2	0.58 (0.28)	2.9–7	5.87 (1)
Hydrobiosidae	82	1892	0–1.07	0.42 (0.28)	0.09–1.35	0.49 (0.31)	3.2–7	5.11 (0.97)

The final habitat suitability curves were constructed subjectively, taking all of the above analyses into account, and also bearing in mind:

- the inability for the smoothed curves to adequately describe suitability at the extremes of the habitat distributions (owing to sparse data)
- a range of habitat conditions are likely to be optimal, rather than a single value suggested by the smoothed curves;
- the critical velocity at which the substrate is mobilised and hence can't be colonised by invertebrates.

The Waitaha-specific habitat suitability curves are shown in Appendix 1.

2.6.4. Habitat suitability criteria — Fish

Fish species to be modelled were selected by Shelley McMurtrie (pers. comm., November 2012), on the basis of the known and predicted fish distribution in the vicinity of the abstraction reach — as determined from investigations by EOS Ecology.

The fish distribution surveys confirmed the following species within the abstraction reach: the introduced brown trout (100–250 mm) and the native torrentfish, koaro, and longfin eel. Four high gradient tributaries that join the abstraction reach on the true-left were also surveyed. In these "reasonable numbers" of koaro and one longfin eel were found (pers. comm., Shelley McMurtrie, EOS Ecology, 19 June 2013). The same species recorded from the abstraction reach were found in two tributaries entering immediately below the abstraction reach (Douglas Creek and a small unnamed spring-fed stream); and lamprey were also found there (Eikaas & McMurtrie 2010). Only koaro were found upstream of Morgan Gorge, suggesting that the gorge is a natural barrier for fish unable to ascend steep waterways.

Eleven species of fish were modelled: two size classes of brown trout (*Salmo trutta*) (adult >200-250 mm, and juvenile < 200–250 mm); koaro (*Galaxias brevipinnis*); two size classes of both longfin and shortfin eel (*Anguilla dieffenbachii* and *Anguilla australis*, respectively) (>300 mm and < 300 mm); torrentfish (*Cheimarrichthys forsteri*), lamprey (*Geotria australis*); common bully (*Gobiomorphus cotidianus*); redfin bully (*Gobiomorphus huttoni)*; short jaw kokopu (*Galaxias postvectis*); banded kokopu (*Galaxias fasciatus*) and giant kokopu (*Galaxias argenteus)*.

Several sets of HSC have been developed for brown trout from different rivers, countries and size classes. Four sets of HSC were selected from those available, on the basis of their likely applicability to the Waitaha River. These included ‘Brown trout adult (Hayes & Jowett 1994)’; ‘Brown trout juvenile (Bovee 1995) no substrate’; ‘Brown trout adult (Bovee 1995) no substrate’; and ‘Brown trout 15–25 cm (Raleigh *et al.* 1986)’. Details of these criteria are provided above their respective HSC graphical representations in Appendix 1.

Trout spawning and fry rearing habitat requirements were not modelled, under the assumption that little spawning probably takes place in the abstraction reach given the inappropriate habitat and flow conditions. It is also very unlikely that the high gradient, flood prone tributaries that flow into the abstraction reach are suitable for trout spawning. The majority of spawning activity probably occurs in smaller, low gradient, more stable tributaries lower in the catchment (especially ones that flow over the river terraces). Moreover, flow requirements for adult drift-feeding trout are greater than for spawning, or fry rearing.

Given uncertainty regarding transferability of the HSC, the different WUA — flow relationships predicted using various HSC may be best interpreted as providing an indication of the range of possible responses of habitat to flow changes. The Hayes and Jowett (1994) feeding HSCs are supported by the results of a national study by Jowett (1992) which showed that trout abundance in New Zealand clear-water, gravel-bed rivers was correlated with the habitat quality (HSI) based on these HSC estimated at the MALF. However, subsequent HSC investigations in steep, fast, bouldery lake outlet rivers (Gowan and Arnold) have found that the Hayes and Jowett (1994) feeding HSC underestimate the suitability of fast water (*i.e.* adult brown trout were found feeding in faster water than predicted by the Hayes and Jowett HSC). Bovee’s (1995) adult brown trout HSC may be more applicable in these situations because they give greater weight to higher velocities (Appendix 1). The Raleigh *et al.* (1986)

Brown trout 15–25 cm HSC when applied in New Zealand are intended to represent juvenile feeding habitat in most rivers. However, they are biased by the inclusion of resting habitat (*i.e.* high weighting for zero velocities). The Bovee (1995) brown trout juvenile HSC are based on active drift feeding fish (as the adult criteria are also) so have higher weighting for higher velocity. The Bovee HSC are probably better suited to the Waitaha, given it is steep and fast; they will deliver a more environmentally conservative habitat–flow relationship. Generally speaking, the HSC that have the highest velocity and depth optima will result in the highest habitat–flow predictions, and minimum flow decisions based on these will be the most environmentally conservative.

It is possible that Chinook salmon are also present in the Waitaha catchment, although their presence has never been officially confirmed (Eikaas & McMurtrie, 2010). The lifecycle of this fish is such that adults mature at sea and migrate upstream over summer and autumn months to spawn in late autumn through early winter, after which they die. The nature of the Waitaha mainstem makes it unsuitable for spawning by salmon and trout and it is highly unlikely that adults would be able to negotiate their way upstream through Morgan Gorge. Therefore, if salmon are present in the mainstem they are likely to only be using the river as a corridor to access small tributaries where spawning habitat may be found. There is only one relatively substantial tributary in the abstraction reach, Glamour Glen (Figure 1), which is steep and will have highly unstable flows, so is not suited to salmonid spawning. However, Eikaas & McMurtrie note a very small spring-fed creek where spawning may occur, located on a river terrace immediately downstream of the abstraction reach.

Therefore salmon habitat (for resting and spawning) was not modelled in the abstraction reach. However, for the sake of thoroughness, adult salmon are included in the assessment of fish passage (Section 3.5).

HSC for the native koaro, longfin eels, shortfin eels, torrentfish, common bully, redfin bully and banded kokopu were developed by Jowett and Richardson (2008) and are described in Appendix 1.

None of the native fish HSC used for modelling habitat in this report distinguish between feeding and resting habitat use, nor between day versus night habitat use. Consequently, there is some potential for bias due to the inclusion of resting habitat. However, the native fish considered are predominantly benthic feeders, and so most probably feed in similar habitat to that which they use for cover. This arguably reduces the importance of water velocity in distinguishing feeding habitat from resting habitat for these fish, compared with drift feeding fish (such as trout and inanga), where the rate of food delivery is directly related to water velocity. One the other hand torrentfish are known to move from riffles/cascades to pool habitat to feed at night (*i.e.*the reverse of slow water resting habitat bias associated with drift feeding trout).

Nevertheless, the fast flowing daytime habitat is the most flow critical, so habitat–flow relationships based on the daytime HSC will be more environmentally conservative.

In addition, the scale at which physical habitat features are resolved in in-stream habitat modelling is probably larger than the scale of microhabitat use of many small native fishes, in terms of the size of their immediate foraging area. This applies to both the habitat modelling itself, done at the scale of the hydraulic cell (metres), and the measurements on which most of these native fish HSC are based (with fish sampled by electrofishing in lanes or patches of a few square metres). Therefore, the physical habitat conditions predicted as being suitable should be interpreted as being indicative of the micro-habitat[5] to meso-habitat[6] conditions experienced/preferred by these fish.

2.6.5. Habitat suitability criteria — Blue ducks

Waitaha-specific HSC for blue ducks (Appendix 1) were developed by Cawthron in 2009 using habitat use data supplied by Fred Overmars (Fred Overmars and Associates) following a similar procedure to that described for the Waitaha invertebrate HSC development (see Section 2.6.3). Since the habitat use data were not collected at the same time/flows as the available habitat data, habitat preference curves were not able to be developed. However, as discussed below, it is unlikely that the observed habitat use was constrained by habitat availability.

Water depth and velocity were recorded at a total of 60 sites in Kiwi Flat where blue duck were observed feeding. A depth use curve derived using data from the Waitaha mainstem only (40 sites) was almost identical to that developed with tributary data included (an additional 20 sites). Blue ducks used depths ranging from 0 to 1.1 m, with the optimum for both mainstem and all sites being relatively shallow water (0.21 m, identical for both mainstem and all sites). This optimum is substantially shallower than the average depth under low flow conditions (~0.47m at MALF1 in Kiwi Flat[7]). Therefore, blue ducks are unlikely to be constrained by availability of deep water in the Waitaha. Rather, this use of shallow water is likely to reflect a true preference.

Velocity use ranged from 0 to 1.3 m/s. Velocity use curves derived from data from all 60 sites were similar to those for only the mainstem (0.23 m/s *c.f.* 0.3 m/s; P= 0.55, t = 0.6, d.f. = 18). These optima are also slower than the average velocity under low flow conditions (~0.43 m/s at MALF1 in Kiwi Flat), suggesting that blue ducks prefer low velocity locations.

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[5] Micro-habitat refers to the habitat conditions at, and very close (*e.g.* < 1 m), to the fish's (or other organism's) position.

[6] Meso-habitat usually refers to the habitat conditions at the riffle, run, pool scale.

[7] Note that the Waitaha Blue Duck HSC were developed using data from observations in Kiwi Flat, not the Douglas Creek, abstraction reach.

Substrate use was assessed at 36 of the 60 sites and results were similar between the mainstem and tributary observations. The optimum was around the 'large cobble' to 'small boulder' size range (~200–300 mm).

The Waitaha HSC were very similar to HSC developed by Collier and Wakelin (1996) for blue duck on the Tongariro River (Appendix 1). The substrate optimum was slightly lower for the Waitaha curves, and depth use did not taper off as rapidly above the optimum. The Collier and Wakelin curves were developed using a much larger data set (2,418 feeding events). Both of these sets of HSC were modelled for the Waitaha abstraction reach.

2.6.6. Flow range modelled

The range of flows over which habitat availability can reasonably be modelled is constrained by the flows gauged for the development of rating curves for the survey cross sections. The further outside the measured flow range that predictions are made the less reliable the predictions are likely to be. Denslinger *et al.* (1998) cite IFIM training documents produced by the U.S. Geological Survey, Biological Resources Division as suggesting that the "hydraulic model (in PHABSIM[8]) can reasonably be extrapolated to a flow equal to 1.5 times the highest calibration flow and 0.6 times the lowest calibration flow. The absolute maximum range for extrapolation is to a flow 2.5 times the highest calibration flow and 0.4 times the lowest calibration flow". These limits are likely to be conservative when applied to RHYHABSIM models, due to improvements made in the way rating curve development is handled in this package (pers. comm., Ian Jowett, Jowett Consulting).

The flow range modelled was selected to cover the range likely to be most affected by the proposed hydroelectric power scheme abstraction. It extended from the about the median flow down to approximately 20% of the MALF1. The low end of the modelled flow range extended below the guidelines for extrapolation recommended for PHABSIM. However, flows lower than the calibration flows surveyed for this investigation in the Waitaha River are uncommon. The lowest calibration flow for the abstraction reach was 8.95 m^3/s, and according to the flow exceedance data provided by Doyle (2012) lower flows are expected to occur naturally less than 10% of the time. Also, as discussed above the PHABSIM extrapolation limits are likely to be conservative for RHYHABSIM (pers. comm., Ian Jowett, Jowett Consulting).

2.6.7. Response of habitat to changes in flow

Change in habitat was modelled for species of periphyton, invertebrate, fish and blue duck using four residual flow options: 2, 3, 4 and 5 m^3/s. Habitat available at these

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[8] PHABSIM is the original hydraulic-habitat model used in the IFIM and is still used routinely in North America.

flows was compared to habitat available at the relevant flow statistic (*i.e.* median or MALF1) under the natural flow regime.

The residual flows are for the top of Morgan Gorge, so do not take into account the effect of tributaries flowing into the abstraction reach. Shortly before this report was released, Electronet Services changed the scheme abstraction scenarios to consider the effects of a residual flow of 3.5 m^3/s (top of Morgan Gorge), with abstraction of either 19 m^3/s, 21 m^3/s or 23 m^3/s. At median flow, tributary inflows between the top and bottom of Morgan Gorge (Glamour Glen) are estimated to add approximately 0.7 m^3/s to the Waitaha (pers. comm., Martin Doyle, July 2013)[9]. In fact, with an abstraction of 21 m^3/s and a residual flow of 3.5 m^3/s, flows in the abstraction reach below the gorge will be above 3.7 m^3/s 100% of the time and above 4 m^3/s 80% of the time.

Rather than re-modelling habitat suitability for each species using both the newly proposed 3.5 m^3/s residual flow (at the top of Morgan Gorge) and the corresponding flow below Morgan Gorge (after taking into account the effect of tributary inflow), we have used the original residual flow options (2, 3, 4 and 5 m^3/s) to assess effects, because the range encompasses the new residual flow option. All modelling henceforth in this report considers the residual flow at the top of Morgan Gorge. Estimates of flow (and therefore habitat) throughout the abstraction reach below Morgan Gorge will therefore be conservative because, in reality, flows will not be as low for as long as have been modelled.

All of the proposed abstraction scenarios will reduce the median flow and MALF1 to the level of the residual flow (Table 4). The duration of the residual flow (as a percentage of total time) depends on the level of abstraction. Doyle (2012) calculated flow exceedance percentiles for the Waitaha at the top of Morgan Gorge. From this, the percentage of time that the abstraction reach will be at the residual flow was calculated (Table 4). Across all of the proposed scenarios the residual flow will occur between 53% and 69% of the time.

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[9] This was estimated using an abstraction of 21 m^3/s with a 3.5 m^3/s residual flow.

Table 4. Natural flow statistics (for the bottom of Kiwi Flat) compared with residual flow statistics in the abstraction reach and the estimated time that flows will be at the residual flow under different abstraction scenarios (reproduced from Doyle 2012 with minor alterations, pers. comm., M Doyle, independent consultant hydrologist, January 2013).

Scenario	**Median flow (m^3/s)**			**MALF1 (m^3/s)**			**Residual flow occurrence (% of time)**		
Natural flow	19.9			7.09					
Proposed abstraction	19 m^3/s	21 m^3/s	23 m^3/s	19 m^3/s	21 m^3/s	23 m^3/s	19 m^3/s	21 m^3/s	23 m^3/s
5 m^3/s residual flow	5	5	5	5	5	5	61%	65%	69%
4 m^3/s residual flow	4	4	4	4	4	4	59%	63%	67%
3 m^3/s residual flow	3	3	3	3	3	3	56%	61%	65%
2 m^3/s residual flow	2	2	2	2	2	2	53%	59%	63%

Note that a residual flow of 2 or 3 m^3/s in this reach is below the suggested lower bound of extrapolation when modelling habitat with RHYHABSIM (as discussed in Section 2.6.6). The further outside the recommended range the model is extrapolated the greater the uncertainty in the results. The direction of change is likely to be accurate, but the magnitude will be less precise. This should be borne in mind when interpreting the habitat retention levels.

In Sections 3.1 to 3.4 the effects of the proposed flow regimes are assessed by expressing the habitat retained at the ecologically relevant flow statistic (Section 2.6.8) as a percentage of that under the natural flow regime. This, of itself, does not define the significance of the change, and determining acceptable levels of habitat retention is largely a matter of risk assessment taking account of the in-stream values at stake. If an in-stream value is very high (*e.g.* an important fishery species or species with high conservation status) then the level of habitat retention should be high in order to manage the risk that a reduction in habitat might pose to the maintenance of that value. The inverse also applies. This approach is consistent with the Ministry for the Environment's Flow Guidelines (MfE 1998).

Some account should also be given to whether the fish, bird, or invertebrate populations are likely to be space or food limited. If habitat is limiting then a predicted reduction in habitat is assumed to correspond to reduction in abundance. However, this will not be the case if other factors unrelated to hydraulic habitats depress the population below their theoretical carrying capacity (*e.g.* frequent flood disturbance).

2.6.8. Summarising effects of residual flows on habitat with respect to ecologically relevant flow statistics

Hydraulic-habitat modelling produces continuous relationships between flow and habitat. In order to compare alternative flow regimes in terms of how well they maintain habitat it is helpful to interpret the habitat–flow relationships with respect to ecologically relevant flow statistics.

As mentioned earlier, the mean annual low flow (MALF1) is ecologically relevant to annual spawning fish because it defines the minimum space available each year on average. This rationale is based largely on Jowett (1992) finding that trout abundance in New Zealand rivers was correlated with the quality of adult trout habitat (indexed by adult trout habitat suitability index (HSI)) at the MALF1. He also found that the quality of benthic invertebrate habitat (indexed by ‘food producing’ HSI) at the median flow, was strongly correlated with trout abundance. The correlation was even stronger with aquatic invertebrate biomass.

The MALF1 is also relevant to native fish species with generation cycles longer than one year, at least in small rivers where the amount of suitable habitat declines at flows less than MALF1. Research in the Waipara River, where native fish habitat is limited at low flow, showed that the detrimental effect on fish numbers increased with decreasing magnitude and increasing duration of low flow (Jowett *et al.* 2008). Research on the Onekaka River in Golden Bay also showed that, when habitat availability was reduced by flow reduction, abundance of native fish species responded in accord with predicted changes in habitat availability in both direction and magnitude (Jowett *et al.* 2008).

Aquatic macroinvertebrates have much faster colonisation times than annual spawning, and multi-aged fishes. Denuded habitat is recolonised by invertebrates drifting from refugia and by winged adults laying eggs and some taxa have more than one generation per year. Benthic invertebrate communities have been found to recolonise river braids within 30 days after drying — probably mainly by drift of colonists from permanently flowing braids upstream. Recovery takes much longer after large floods. Due to relatively fast rate of recolonisation by invertebrates, the median flow (which describes typical flow) is an ecologically relevant flow statistic when assessing the effects of flow regime change on benthic invertebrate habitat.

Provision for seasonal flow variation may also allow for seasonally varying food requirements of fish and birds and nesting requirements of the latter. Fish have higher food requirements in summer because their metabolic and consumption rates are higher at warmer water temperatures. If space and or food is limiting, then flows higher than the MALF1 ought to give some respite from limiting conditions, especially space requirements for feeding, at the MALF1. This is the rationale for also assessing fish habitat, but particularly benthic invertebrate habitat with respect to monthly flow statistics. This type of assessment is called a ‘Seasonal habitat retention analysis’, and is described in Section 2.6.9.

For ease of interpretation, changes in habitat from this point forward will be expressed in terms of habitat retention when compared to the relevant natural flow statistic (*i.e.* the natural MALF1 or median flow). For example, if a species has a WUA of 5 at the natural MALF1, and a WUA of 4 at the proposed flow, then the habitat retention under the proposed flow regime is 80% (*i.e.* (4/5)*100) relative to WUA at the MALF1.

2.6.9. Seasonal habitat retention analysis - habitat retention during dry, wet and typical (median flow) months

As described in Section 2.6.8, a seasonal habitat retention analysis is a means of summarising the continuous habitat — flow relationships predicted by RHYHABSIM so that the effects of the proposed flow regime can be assessed on the basis of habitat retention at relevant monthly (or seasonal) flow statistics (*e.g.* flow percentiles). This was deemed necessary for the proposed Waitaha hydro-scheme to take account of the likely high level of hydrological alteration.

A seasonal habitat retention analysis was carried out using residual flows of 2, 3, 4 and 5 m^3/s for selected species of periphyton, macroinvertebrate, fish and blue duck in the abstraction reach. Two abstraction scenarios were modelled that cover the range of abstractions being considered: 19 m^3/s and 23 m^3/s.

The analysis involved comparing the amount of habitat under natural flows in each month with the amount of habitat under the proposed regime and calculating the percentage of habitat retained:

$$\%\ Habitat\ retention = 100\ \times \frac{WUA(i)\ with\ the\ proposed\ flow\ regime}{WUA(i)\ with\ natural\ flow}$$

Where WUA(*i*) is the weighted usable area at the flow statistic for the month (*i.e.* January to December).

In an attempt to encompass natural variations in climate across the hydrological record, this comparison was made for wet, dry and typical months. The summary flow statistic for the dry month was the flow that was exceeded for 90% of the time in that month across the entire flow record (*i.e.*, the 10th percentile). We used the median flow for the month (50th percentile) to represent typical flow conditions (the median having the advantage over the mean because it is not heavily influenced by high flows of short duration). The flow statistic for a wet month was the flow exceeded 10% of the time in that month (*i.e.* the 90th percentile).

This percentile approach is the same method used in (Jowett 2012) to assess the environmental effects of a proposed hydro-scheme on the Waiau River in North Canterbury, as well as (Young *et al.* 2012) to assess the environmental effects of a proposed irrigation storage and hydropower scheme in the Tukituki catchment in Hawkes Bay.

When flows exceeded the long-term median flow under each scenario (*e.g.* 19.9 m^3/s under the natural flow regime), WUA was set to the WUA for the median flow. This is justified because higher flows do not persist for long enough for the additional inundated area to significantly contribute to in-stream production.

3. RESULTS AND DISCUSSION

3.1. Effects of residual flow options on periphyton habitat

Flow abstraction can affect periphyton by changing habitat quality (mainly through changes in depth and velocity). When considering such effects, the primary concerns are the percentage of the bed covered and the local biomass of periphyton, rather than total reach biomass. Thus, analyses to assess the effects of altered flows on periphyton consider the habitat suitability index (HSI, an index of habitat quality), rather than WUA. Weighted useable area provides an indication of a whole-reach effect because it is affected by changes in habitat quantity (wetted area) and quality. This complicates interpretation for periphyton taxa because increases in WUA could result from changes in wetted area, habitat quality, or a combination of both. Changes as a result of changes in wetted area are of little concern as long as there is no increase in habitat quality that may lead to high periphyton biomass. HSI on the other hand is the WUA divided by the wetted area (or wetted width) and can be seen as an index of changes in periphyton on a per unit area basis (*e.g.* per m^2).

McMurtrie and Suren (2009) found that diatoms dominated the periphyton communities at most sites within the abstraction reach. According to the habitat model, average habitat quality (HSI) for diatoms in the abstraction reach will increase with increased flow over the flow range modelled (Figure 2). HSI for long and short filamentous algae followed the opposite trend, increasing with decreasing flows. This was the case for long filamentous algae over the entire flow range modelled, but HSI for short filamentous algae is predicted to increase as flow drops to 3 m^3/s, below which HSI declines.

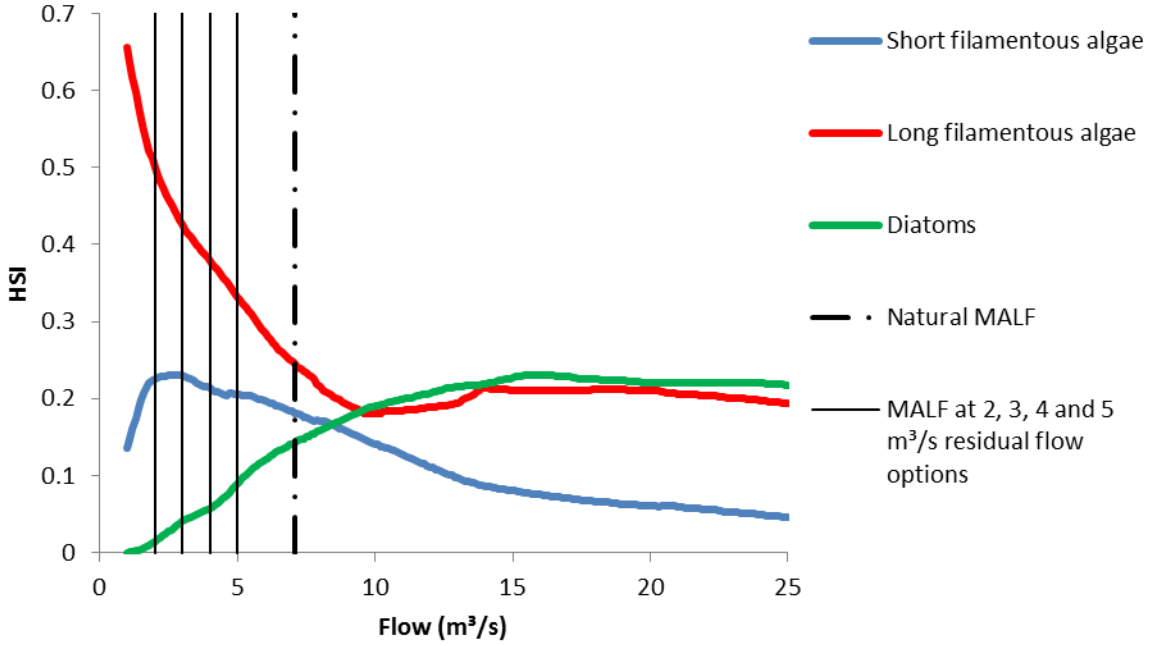

Figure 2. Average habitat quality (HSI) versus flow for filamentous algae and diatoms predicted by the habitat model for the abstraction reach.

Significant decreases in diatom habitat are predicted across all of the proposed residual flows; 62%, 40%, 28%, and 10% retention for residual flows of 5, 4, 3 and 2 m³/s, respectively, relative to habitat quality at the natural MALF1 (Table 5). For example, diatom habitat quality at the 2 m³/s residual flow would be approximately 10% of habitat quality at the natural MALF1. By contrast, substantial increases in habitat quality are predicted for long filamentous algae, with a modest increase for short filamentous algae.

Table 5. Habitat quality (HSI) retention for diatoms, short- and long filamentous algae predicted by the habitat model for residual flow options (HSI at residual flow / HSI at natural MALF1 *100).

	Residual flow options			
	5 m³/s	**4 m³/s**	**3 m³/s**	**2 m³/s**
Diatoms	62	40	28	10
Short filamentous algae	113	118	127	124
Long filamentous algae	136	155	174	204

Key: Habitat quality retention level (as % of habitat quality at the natural MALF1)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Predicted seasonal habitat quality retention for periphyton groups under the proposed residual flows (2–5 m³/s) and abstraction scenarios (19 and 23 m³/s) during dry-, wet-and typical-year monthly flows are summarised in Appendices 2 and 3. Predicted decreases in seasonal habitat quality retention for diatoms were most evident in dry summer months with a 2 m^3/s residual flow, when as little as 6% of the habitat quality under natural conditions was retained (Tables A2.3 and A3.3). Overall, a substantial decrease in diatom habitat quality was predicted for all dry months (6% to 64% retention for both the 19 and 23 m^3/s abstraction) and most typical months (6% to 40% retention between February and November). No change in habitat quality retention was predicted for wet months, other than during mid-winter periods of low flow.

Conversely, habitat quality retention for long and short filamentous algae during dry and typical months was predicted to generally increase substantially (up to 377% retention for short filamentous algae) (Tables A2.1, A2.2, A3.1 and A3.2)). No change in habitat quality retention was predicted for wet months, other than during mid-winter periods of low flow.

Generally, changes in habitat retention (increases and decreases) are predicted to be slightly greater with a 23 m^3/s abstraction compared to a 19 m^3/s abstraction, but the overall trend (monthly increase or decrease) is essentially the same for each. It follows that habitat retention with a 21 m^3/s abstraction will be intermediate.

As discussed in section 2.6.7 these modelling results do not take account of the ameliorating effect of tributary inflow below the intake. Also, Electronet Services has recently expressed a preference for a residual flow of 3.5 m^3/s (at the top of Morgan Gorge). With this residual flow and a 21 m^3/s abstraction, the median flow and residual flow through the abstraction reach below Morgan Gorge, with flow accretion from tributaries, is 4.2 m^3/s and 3.7 m^3/s, respectively (pers. comm., Martin Doyle, independent consulting hydrologist, July 2013). Therefore, the estimates most relevant to assessing the effects of the preferred 3.5 m^3/s residual flow on periphyton communities are those described for the 3 m^3/s and 4 m^3/s residual flow options in Table 5 and tables in Appendices 2 and 3. This is irrespective of the abstraction volume, since there is relatively little difference between the modelling results for the 19 m^3/s and 23 m^3/s abstraction scenarios.

All of the proposed residual flows are predicted to bring about significant change to periphyton communities in the abstraction reach, where the altered habitat conditions will favour filamentous algae over the existing dominant diatom species. However, these habitat analyses do not take account of the influence of flood disturbance to which periphyton communities are very sensitive. This is discussed in Section 3.7.

3.2. Effects of residual flow options on benthic macroinvertebrate habitat

Field investigations by McMurtrie and Suren (2009) found that benthic invertebrate communities in the abstraction reach were dominated by the common New Zealand mayfly *Deleatidium* (36%), chironomid midge larvae (*Stictocladius* (23%) and Orthocladiinae (22%)) and torrent-dwelling blephariceric larvae, *Neocurupira* (6%) (pers. comm., Shelley McMurtrie, EOS Ecology, February 2013). Fourteen other species[10] were present in low numbers (*i.e.* each representing less than 3% of the total abundance).

Habitat analysis (including habitat retention estimates) for benthic invertebrates was based on WUA. Habitat availability for most invertebrate species is predicted to vary little at flows greater than the natural median (Figure 3). With residual flows of 5, 4, 3, and 2 m³/s, habitat (WUA) retention (relative to the natural median flow) estimated with the Waitaha *Deleatidium* HSC is 92%, 90%, 88% and 86%, respectively (Table 6). Habitat predicted for the Waitaha *Deleatidium* HSC and *Deleatidium* (mayfly) HSC varied little with flow, but declined gradually with flow reduction over the five residual flow options (5–2 m^3/s). The habitat — flow relationship based on the *Deleatidium* (Waitaki) HSC was more sensitive to flow variation, declining substantially with flow reduction below 10 m^3/s. This is because the Waitaki *Deleatidium* HSC have a narrower optimal velocity range than the other two sets of *Deleatidium* HSC (Appendix 1). In particular, the Waitaki *Deleatidium* velocity suitability curve has low to zero suitability weighting for zero velocity (Appendix 1), especially the Waitaha *Deleatidium* HSC, probably because the substrate is much coarser in the Waitaha providing fast water refuges. The same explanation applies to the Orthocladiinae HSC from the Waitaki and the food producing HSC. Habitat predictions based on these HSC also decline fairly steeply with flow reduction over the residual flow range.

The velocity suitability curves for most of the Waitaha-specific HSCs have high suitability weighting for low–zero velocities (Appendix 1). The habitat predictions for low flows based on these HSC should be interpreted cautiously because they imply that habitat suitability will be high in ponded water at zero flow. Clearly this is not sensible, as all of the taxa concerned are adapted to flowing water. When flow variation keeps the substrate in a condition suitable for invertebrates, clean, with short periphyton available for grazing, some invertebrate taxa will colonise slow water in the river margins and behind boulders obstructing the flow. Furthermore, in complex current patterns, such as among boulders, the mean column velocity estimate may underestimate the velocity conditions experienced by the invertebrates (*e.g.* there may be flowing water near the river bed but zero, or even reverse, velocities further up in the water column. Multiple measurement points through the water column help to minimise this error, though this was not part of the methodology used by EOS

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[10] Including Hydrobiosidae, which was one of the five taxa for which HSC were developed (Section 2.6.3), but was omitted from these results because of their low abundance in this reach (2%).

Ecology. These points raise concern that the velocity Waitaha-specific velocity suitability curves may overestimate the actual suitability of slow and zero velocities. The habitat predictions for HSC from other sources provide some balance to the interpretation of invertebrate flow needs in the Waitaha — allowing a more environmentally conservative flow effects assessment to be made.

Focusing on the Waitaha-specific HSCs, habitat predictions for the three most abundant invertebrate taxa (*Deleatidium, Stictocladius* and Orthocladiinae) differed over the low flow range spanned by the residual flow options (2–5 m^3/s) (Figure 3). Habitat predicted for *Deleatidium* declines only slightly with decreasing flow over this range, but compared with habitat available at the natural median flow moderate losses are predicted (92–86% habitat retention for 5–2 m^3/s residual flows (Table 6)). The habitat for *Stictocladius* varies little over the residual flow range, peaking at 3 m^3/s, and habitat for Orthocladiinae increases fairly steeply with flow reduction over the range. Relative to habitat at the median flow, the residual flows offer habitat gains for these taxa (110–133%) habitat retention (Table 6).

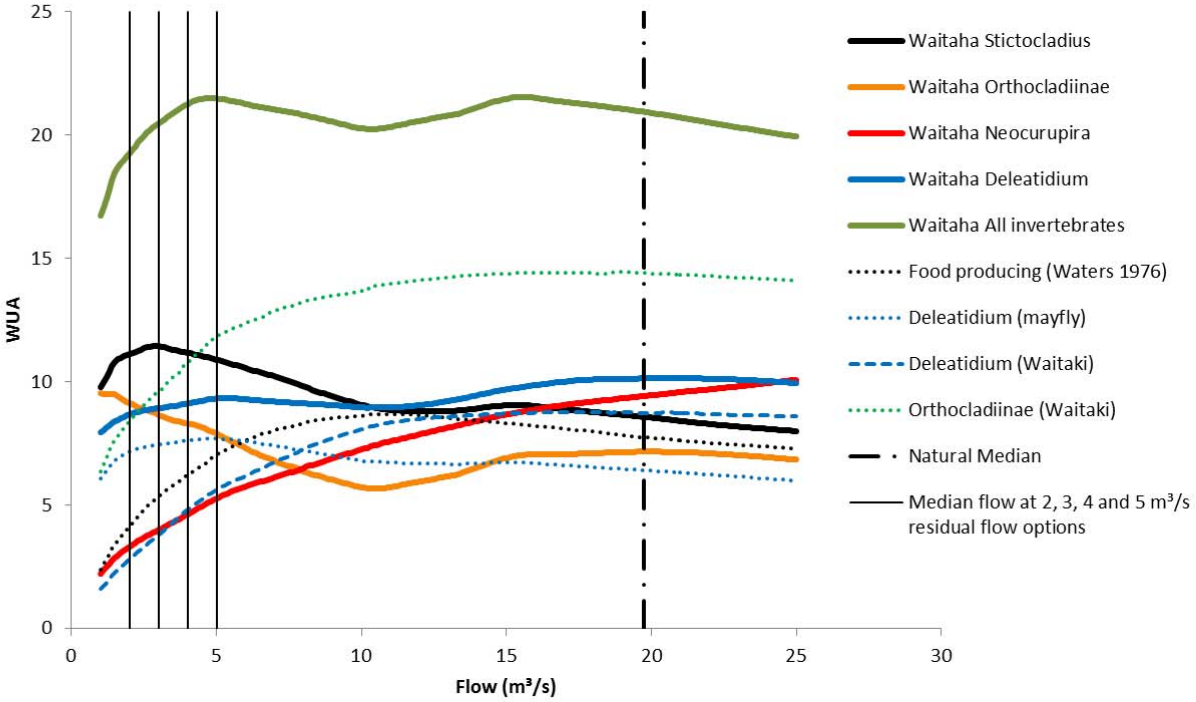


Figure 3. Average habitat availability (WUA) versus flow for macroinvertebrates predicted by the habitat model for the abstraction reach.

Table 6. Invertebrate habitat retention under the residual flow options (WUA at residual flow / WUA at natural median flow *100).

	Residual flow options			
	5 m³/s	**4 m³/s**	**3 m³/s**	**2 m³/s**
Waitaha *Deleatidium*	92	90	88	86
Waitaha *Stictocladius*	127	130	133	130
Waitaha Orthocladiinae	110	116	121	127
Waitaha *Neocurupira*	56	49	42	35
Waitaha All invertebrates	103	102	98	92
***Deleatidium* (mayfly)**	120	119	116	112
***Deleatidium* (Waitaki)**	64	55	43	32
Orthocladinae (Waitaki)	82	75	67	58
Food producing (Waters 1976)	91	80	69	54

Key: Habitat retention level (as % of habitat at the natural median flow)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Predicted seasonal habitat retention for invertebrate species in the abstraction reach under the proposed residual flows (2–5 m³/s) and abstraction scenarios (19 and 23 m³/s) during dry-, wet- and typical-year monthly flows are summarised in Appendices 4 and 5.

Predictions of seasonal habitat retention (*i.e.* compared to the natural flow regime) using the Waitaha *Deleatidium* HSC showed little difference across almost all residual flow and abstraction options (86%–104% retention) (Tables A4.5 and A5.5). There is a general trend of increased habitat availability with flow reduction for Waitaha Orthocladiinae species (Tables A4.2 and A5.2) and decreased habitat availability with flow reduction for Waitaha *Neocurupira* species (Tables A4.3 and A5.3). This trend is present only in dry and typical months. Seasonal habitat retention for Waitaha *Stictocladius* species showed moderate increases during dry and typical months, with little difference brought about by the level of abstraction or residual flow (Tables A4.1 and A5.1). There is generally little or no change in habitat retention during wet months for all of the modelled species, other than during winter months when flows are naturally lower. As with the habitat retention estimates based on the habitat available at the annual median flow (Table 6), the Waitaha 'All invertebrates' HSC predicts no change in seasonal habitat retention across all residual flow (2–5 m³/s) and abstraction options (19 and 23 m³/s abstraction) during dry-, wet- and typical-year monthly flows (90–106% retention) (Tables A4.6 and A5.6).

Generally, changes in habitat retention (increases and decreases) are predicted to be slightly greater with a 23 m³/s abstraction compared to a 19 m³/s abstraction, but the overall trend (monthly increase or decrease) is essentially the same for each.

As discussed in Section 2.6.7, these modelling results do not take account of the ameliorating effect of tributary inflow below the intake or the fact that Electronet Services has indicated a preference for a 3.5 m^3/s residual flow. The estimates most relevant to assessing the effects of the preferred 3.5 m^3/s residual flow on invertebrates are those described for the modelled impact of the 3 m^3/s and 4 m^3/s residual flows in Table 6 and tables in Appendices 4 and 5. This is irrespective of the abstraction volume, since there is relatively little difference between the modelling results for the 19 m^3/s and 23 m^3/s abstraction scenarios.

Overall, the proposed residual flows are predicted to bring about either a small increase or no change in the habitat available for the dominant invertebrate taxa (*Deleatidium, Stictocladius* and Orthocladiinae species) at the natural median flow. However, these habitat analyses do not take account of the influence of disturbance / flood flows, which are known to have a strong influence on invertebrate populations. This is discussed in Section 3.7.

3.3. Effects of residual flow options on fish habitat

As noted in Section 2.6.4, eleven fish species were modelled on the basis of the known and predicted fish distribution in the abstraction reach. Some of these species were represented by more than one set of HSC. Those species known to be present in the abstraction reach include brown trout, torrentfish, longfin eel and koaro (pers. comm., Shelley McMurtrie, EOS Ecology, July 2013).

As for benthic invertebrates, habitat analysis (including habitat retention estimates) for fish was based on WUA. Habitat modelling predictions indicate that habitat availability for adult brown trout decreases at flows below the natural MALF1 (Figure 4), whereas it increases for juvenile/small trout (*c.f.* Brown trout juvenile [Bovee 1995] and Brown trout 15–25 cm [Raleigh *et al.* 1986]). Adult brown trout are the species / life-stage that is most flow critical, *i.e.* they have the steepest decline in habitat with flow reduction. With residual flows of 5, 4, 3, and 2 m^3/s, predicted habitat retention levels for adult brown trout (using the Hayes and Jowett [1994] HSC and Bovee [1995] HSC) are 84%–91%, 73%–83%, 59%–70% and 41%–50%, respectively, when compared to habitat availability at the natural MALF1 (Table 7).

Modelling predictions for native fish (Figure 5) indicate that habitat availability for most species will either not change or increase slightly when the flow drops below the natural MALF1 as low as 2 m^3/s (Table 7). An exception is large longfin eel (>300 mm), habitat for which is predicted to decline over the residual flow range down to 84% habitat retention at 2 m^3/s.

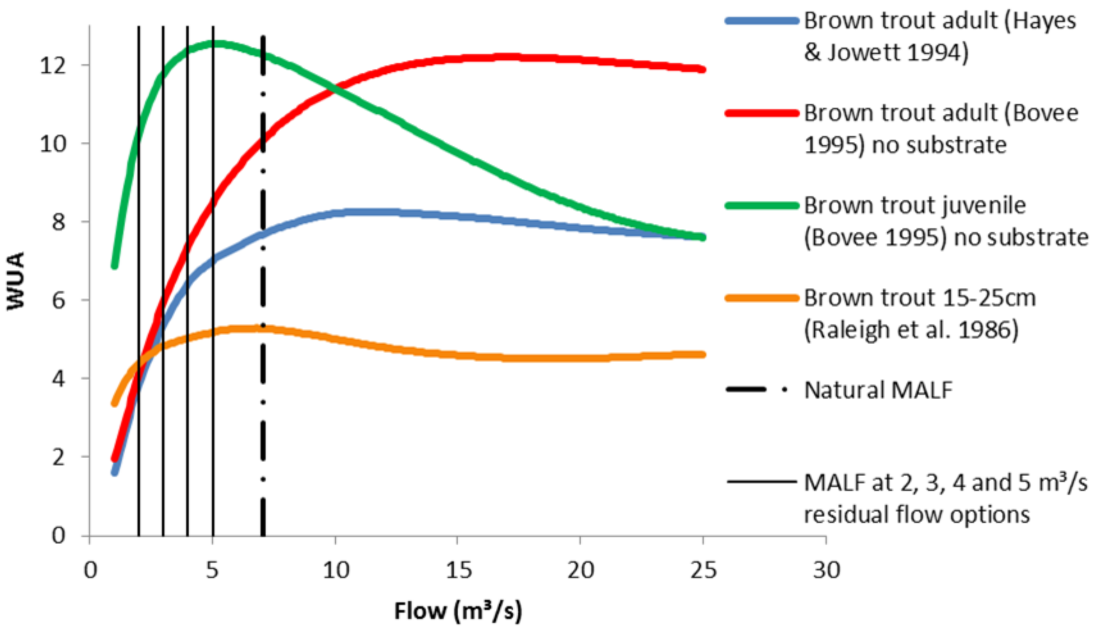


Figure 4. Average habitat availability (WUA) versus flow for brown trout predicted by the habitat model for the abstraction reach.

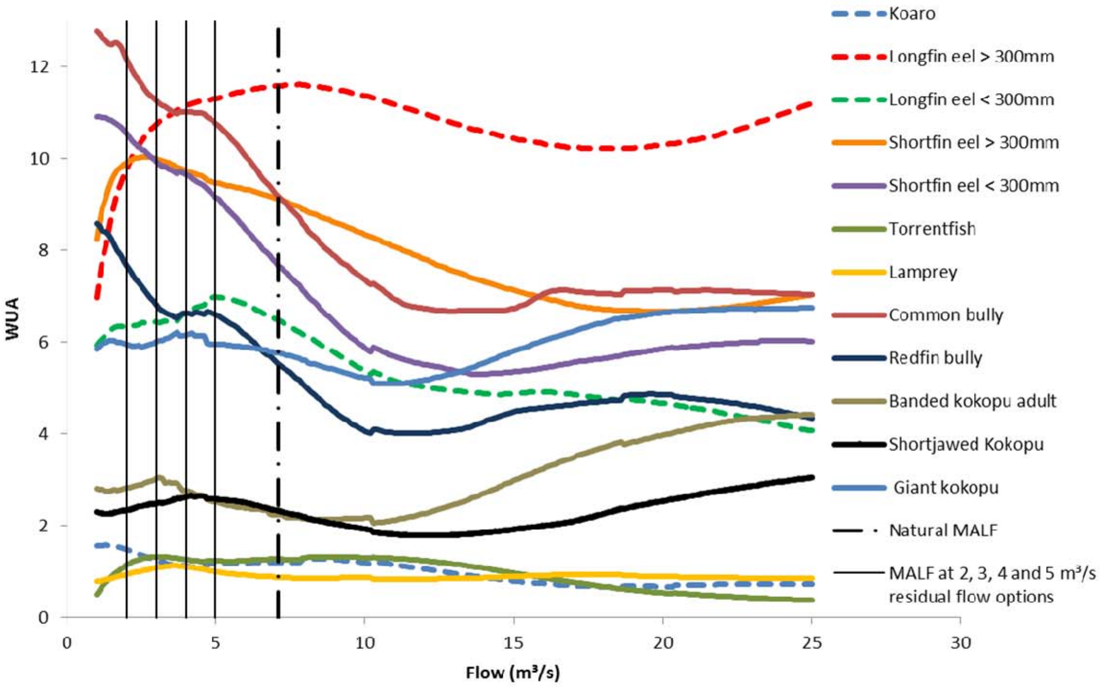
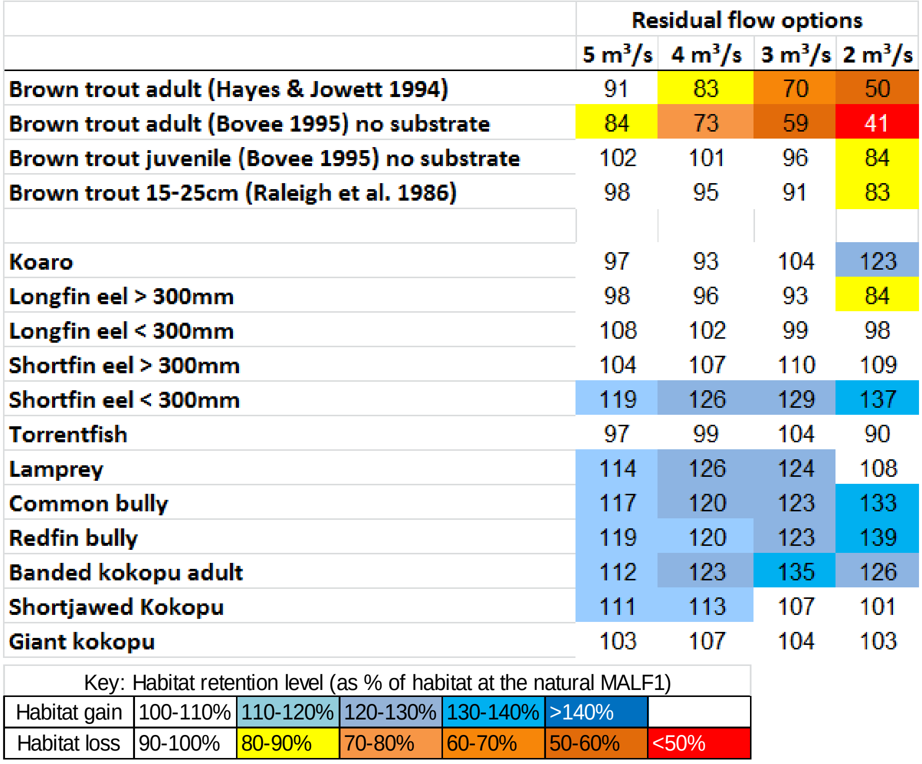


Figure 5. Average habitat availability (WUA) versus flow for native fish predicted by the habitat model for the abstraction reach.

Table 7. Fish habitat retention under the residual flow options (WUA at residual flow / WUA at natural MALF1 *100)



	Residual flow options			
	5 m³/s	4 m³/s	3 m³/s	2 m³/s
Brown trout adult (Hayes & Jowett 1994)	91	83	70	50
Brown trout adult (Bovee 1995) no substrate	84	73	59	41
Brown trout juvenile (Bovee 1995) no substrate	102	101	96	84
Brown trout 15-25cm (Raleigh et al. 1986)	98	95	91	83
Koaro	97	93	104	123
Longfin eel > 300mm	98	96	93	84
Longfin eel < 300mm	108	102	99	98
Shortfin eel > 300mm	104	107	110	109
Shortfin eel < 300mm	119	126	129	137
Torrentfish	97	99	104	90
Lamprey	114	126	124	108
Common bully	117	120	123	133
Redfin bully	119	120	123	139
Banded kokopu adult	112	123	135	126
Shortjawed Kokopu	111	113	107	101
Giant kokopu	103	107	104	103

Key: Habitat retention level (as % of habitat at the natural MALF1)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Predicted seasonal habitat retention for fish species in the abstraction reach under the proposed residual flows (2–5 m³/s) and abstraction scenarios (19 and 23 m³/s) during dry-, wet- and typical-year monthly flows are summarised in Appendices 6 and 7.

As with the predictions of habitat retention at MALF1 (Table 7), the seasonal habitat retention analysis predicts substantial reductions in habitat retention for adult brown trout, particularly for residual flows of 2-3 m³/s (as low as 34% retention) (Tables A6.1, A6.2, A7.1, and A7.2). Habitat retention in dry months is reduced year round whereas in typical months reductions occur over autumn–winter–early spring. Habitat retention during wet months is generally not impacted by the modelled flow regimes, other than during winter months when flows are naturally low.

Seasonal habitat retention for koaro mainly increases substantially with the proposed flow regimes in dry and typical months (up to 221% for both the 19 m³/s and 23 m³/s abstraction). During dry months, habitat gains are greater during the summer and at the lowest residual flow (2 m³/s). During typical months, habitat gains occur through more of the year, and more so at the lowest residual flow (2 m³/s). In wet months habitat gains are predicted for mid-winter (July and August) but no change in other months.

As for periphyton and macroinvertebrates, changes in habitat retention (increases and decreases) are predicted to be slightly greater with a 23 m^3/s abstraction compared to a 19 m^3/s abstraction, but the overall trend (monthly increase or decrease) is essentially the same for each.

As discussed in Section 2.6.7, these modelling results do not take account of the ameliorating effect of tributary inflow below the intake or the fact that Electronet Service has indicated a preference for a 3.5 m^3/s residual flow. The estimates most relevant to assessing the effects of the preferred 3.5 m^3/s residual flow on fish are those described for the 3 m^3/s and 4 m^3/s residual flow options in Table 7 and tables in Appendices 6 and 7)Table 6. This is irrespective of the abstraction volume, since there is relatively little difference between the modelling results for the 19 m^3/s and 23 m^3/s abstraction scenarios.

Overall, the proposed residual flows are predicted to reduce habitat availability for adult trout; the reduction is substantial for the lower residual flows (2 or 3 m^3/s). Habitat availability generally increases for native fish as a result of the proposed flow reduction (*i.e.* at 3.5 m^3/s or alternative residual flow over the range 2 – 5 m^3/s). However, these habitat analyses do not take account of the change in food availability, which is likely to be strongly influenced by disturbance / flood flows through this reach. This is discussed in Section 3.7.

3.4. The effect of residual flow options on blue duck habitat

As noted in Section 2.6.5, the Waitaha blue duck HSC were developed from observations of duck foraging behaviour in the Kiwi Flat area in 2009 (*i.e.* not including the abstraction reach). More recent surveys by Fred Overmars failed to find blue duck in the abstraction reach. Nevertheless, given the high value of this nationally endangered species we have included habitat–flow predictions for blue duck in the abstraction reach so that they are available to the bird experts and stakeholders to use as they see fit.

Habitat modelling predictions indicate that blue duck feeding habitat increases with flow reduction below about 12 m^3/s (Figure 6). The pattern is consistent between the Waitaha-specific and Collier's HSC. Habitat retention relative to the MALF1 ranges between 119% and 154%, depending on the HSC, with decreasing flow over the residual flow range (Table 8).

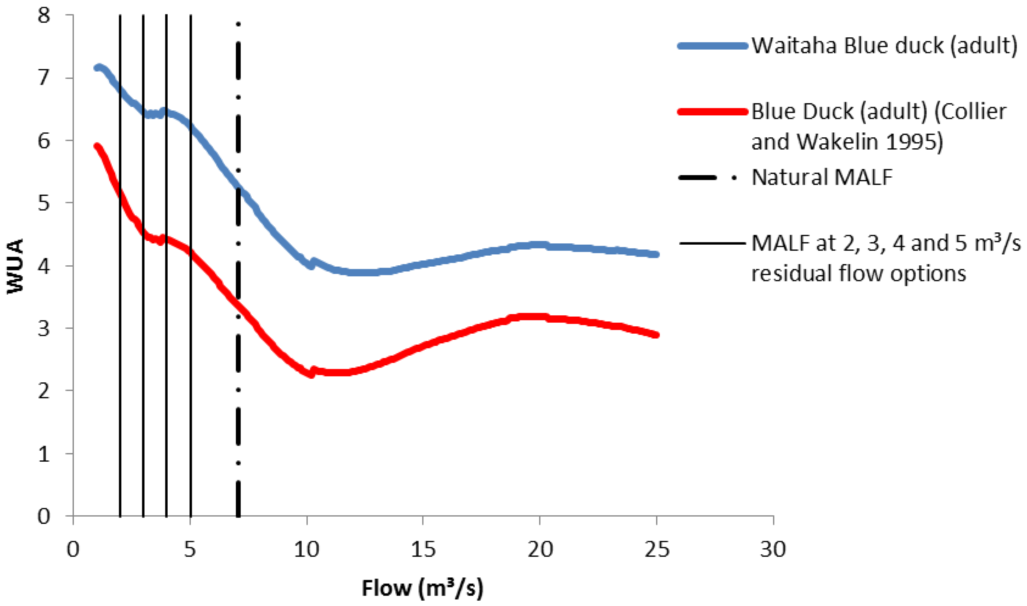


Figure 6. Average habitat availability (WUA) versus flow for blue duck predicted by the habitat model for the abstraction reach.

Table 8. Blue duck habitat retention under the residual flow options (WUA at residual flow / WUA at natural MALF1 *100).

	Residual flow options			
	5 m^3/s	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
Waitaha Blue duck (adult)	119	124	124	130
Blue Duck (adult) (Collier and Wakelin 1995)	126	133	136	154

Key: Habitat retention level (as % of habitat at the natural MALF1)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Predicted seasonal habitat retention under the proposed residual flows (2–5 m^3/s) and abstraction scenarios (19 and 23 m^3/s) during dry-, wet- and typical-year monthly flows are summarised in Appendices 8 and 9.

Seasonal habitat retention gains occur to a greater degree during dry months under all residual flow options (Tables A8.1, A8.2, A9.1 and A9.2), with the biggest increases occurring with the lowest residual flow (2 m^3/s). Using the Waitaha-specific HSC, there is little change to habitat retention during typical December and January flows, but habitat gains range up to 172% in other months. During wet months, habitat retention remains relatively unaffected by the modelled flow regimes.

As for periphyton, macroinvertebrates and fish, changes in habitat retention (increases and decreases) are predicted to be slightly greater with a 23 m^3/s abstraction compared to a 19 m³/s abstraction, but the overall trend (monthly increase or decrease) is essentially the same for each.

As discussed in Section 2.6.7, these modelling results do not take account of the ameliorating effect of tributary inflow below the intake or the fact that Electronet Service has indicated a preference for a 3.5 m³/s residual flow. The estimates most relevant to assessing the effects of the preferred 3.5 m^3/s residual flow on blue duck are those described for the 3 m^3/s and 4 m^3/s residual flow options in Table 8 and tables in Appendices 8 and 9Table 6. This is irrespective of the abstraction volume, since there is relatively little difference between the modelling results for the 19 m^3/s and 23 m^3/s abstraction scenarios.

Overall, the proposed residual flows are predicted to increase habitat for blue duck, with a slightly greater increase at lower residual flows (2 or 3 m³/s). However, these habitat analyses do not take account of the change in food availability, which is likely to be strongly influenced by disturbance / flood flows through this reach. This is discussed in Section 3.7.

3.5. Fish passage

3.5.1. Introduction

Fish species found in the abstraction reach include brown trout, torrentfish, koaro and longfin eel (pers. comm., Shelley McMurtrie, EOS Ecology, June 2013). Two of these, koaro and longfin eel, were also found in tributaries that flow into the abstraction reach and there are populations of koaro upstream of the abstraction reach. Therefore the abstraction reach is likely to be important as a conduit for migrating fish.

This section discusses the predicted effects of the residual flow options (2 – 5 m^3/s) on fish passage within the abstraction reach. It is important to note that the 2007 / 2008 hydraulic-habitat survey (Section 2.4) was intended for in-stream habitat modelling, and hence did not target cross sections critical to fish passage (*i.e.* those with the shallowest depths). Therefore the modelling results may not accurately assess effects on minimum depths for fish passage.

3.5.2. Brown trout and spawning Chinook salmon

Stable tributaries that enter the Waitaha mainstem immediately below the abstraction reach provide nursery habitat for juvenile brown trout and, in the case of the small spring-fed channel noted in Section 2.6.4, may provide spawning habitat for adult brown trout and Chinook salmon (Eikaas & McMurtrie 2010).

Brown trout found in Douglas Creek and the aforementioned stable tributaries ranged in size from 48 mm to 237 mm (mean length 110 mm). Eikaas and McMurtrie (2010) considered that the larger of these were of reproductive age, though this was not physically verified.

Although not common in the West Coast region, there are established populations of Chinook salmon in the Paringa, Taramakau and Hokitika Rivers, as well as a few land-locked populations in a few of the region's lakes (Eikaas & McMurtrie 2010). No salmon (adult or juvenile) were found by Eikaas and McMurtrie (2010) in the Waitaha catchment, but the timing of the survey may not have coincided with salmon spawning migration. As mentioned, the Waitaha mainstem does not provide suitable habitat for salmonid spawning, and it is also highly unlikely that tributaries within the abstraction reach provide such habitat (see Section 2.6.4).

Minimum depth and velocity criteria for trout and salmon passage were sourced from guidelines on fish passage past stream road crossings, produced by the Oregon Department of Fish and Wildlife[11]. The criteria for large salmonids (> 50 cm length) stipulate a minimum passage depth of 25 cm. These criteria can be considered conservative, since 25 cm is deeper than the likely body depth of most trout and west coast salmon of this size class[12]. Also trout and salmon are known to be able to negotiate short sections of shallow water with much of their body protruding above the water surface.

The maximum velocity criterion was removed from the analysis because the hydraulic model predicts mean column velocity, which may be substantially higher than the water velocity actually experienced by fish close to the bed, particularly in deeper water and where the substrate elements are large. Consequently, fish (especially relatively small fish) are likely to be able to progress upstream by taking advantage of near-bed velocity refuges and turbulence.

Figure 7 shows how the predicted passage width for large salmonids varies with flow in the shallowest cross section in the abstraction reach of the Waitaha River. The total width > 25 cm deep declines with reductions in the modelled residual flow (5, 4, 3, and 2 m^3/s), and there is little difference between the minimum contiguous widths > 25 cm deep for all four of the modelled residual flows. The change in contiguous width is more relevant for this analysis as large fish may not be able to negotiate the narrower gaps included in the total width prediction. More importantly, the model predicts that more than 5 m of both total and contiguous width > 25 cm deep remains at the lowest residual flow option (2 m^3/s), so fish passage is not likely to be adversely affected by the proposed hydroelectric power scheme.

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[11] Sourced from: http://www.oregon.gov/odf/privateforests/docs/rdstrmcrossrestorguidea.pdf. Accessed 22 February 2013

[12] West coast salmon are not known to grow as large as those on the east coast.

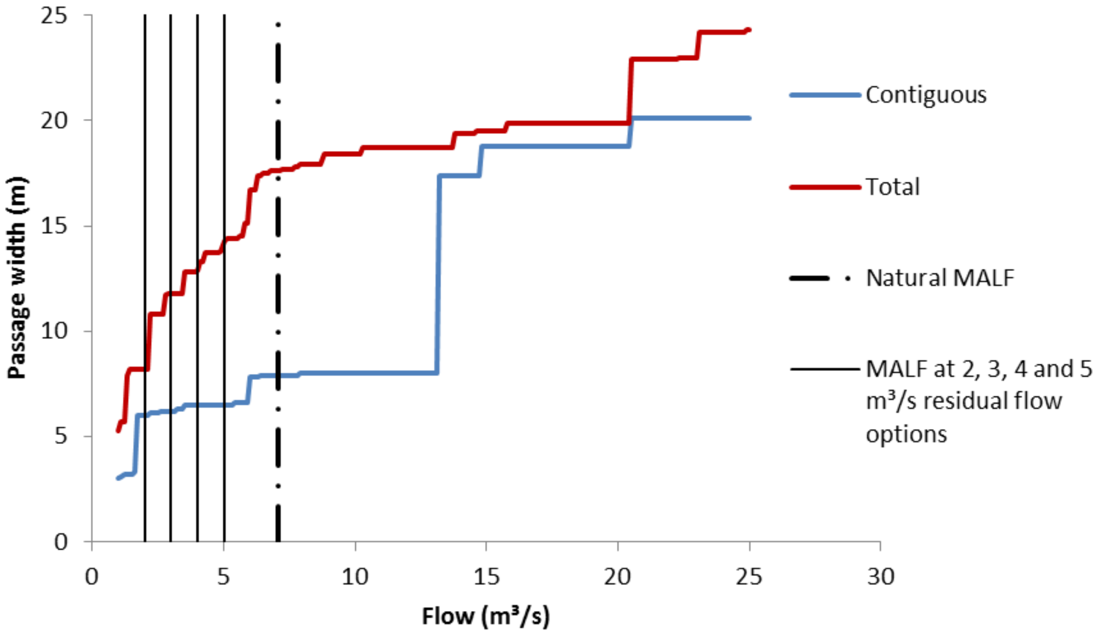

Figure 7. Passage width versus flow predicted for large trout and salmon (> 50 cm length) in the shallowest cross section surveyed in the abstraction reach of the Waitaha River. Also shown are the MALF1 and the various residual flow options. 'Contiguous' = width of cross section with contiguous depths > 25 cm. 'Total' = total width of cross section > 25 cm deep.

3.5.3. Native fish

The minimum depth criterion (5 cm) used to model native fish passage was sourced from Allibone (2000). It appears to be based on expert opinion, because Allibone did not cite any research to support it. Nevertheless, in our opinion 5 cm is a conservative minimum depth criterion for native fish passage, since it is greater than the body depth of most native fishes, especially the juvenile migratory life stages of the diadromous species. Adult eels are an exception but they are able to progress upstream overland, and downstream migration tends to be associated with flood flows, so passage depth is unlikely to be an issue. Koaro and elvers (young juvenile eels) are also able to progress upstream with minimal water depth, providing there are wet surfaces available.

Minimum passage width for native fish was predicted to decrease slightly with the various residual flow options compared to that at the natural MALF1 (Figure 8). As with the analysis for large salmonids there is predicted to be more than 5 m of both total and contiguous width remaining at the lowest residual flow option (2 m³/s), so native fish passage will not be adversely affected by the proposed hydroelectric power scheme. The passage modelling predictions are conservative since many native fish are still likely to be able to move upstream in the very shallow margins as they are known to be able to pass through water shallower than the 5 cm minimum depth criterion applied here.

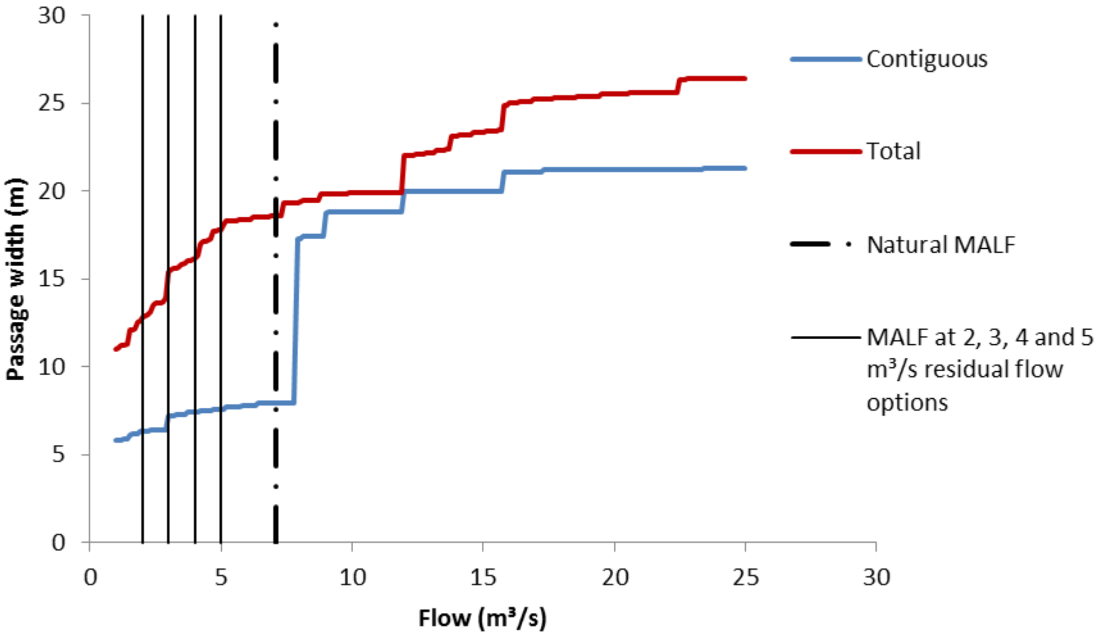

Figure 8. Passage width versus flow predicted for native fish in the shallowest cross section surveyed in the abstraction reach of the Waitaha River. Also shown are the MALF1 and the various residual flow options. 'Contiguous' = width of cross section with contiguous depths > 5 cm. 'Total' = total width of cross section > 5 cm deep.

3.6. The effect of extended periods of low flow

During prolonged periods of stable low flow, periphyton and fine sediments can accumulate to excessive levels on the riverbed, adversely affecting water quality, habitat quality for benthic macroinvertebrates and aesthetic values. Flushing flows capable of removing such accumulations are important for maintaining the health of a river ecosystem.

Clausen and Biggs (1997) developed the concept of FRE3 flushing flows based on research showing a strong negative relationship between periphyton (measured using chlorophyll-a concentration) and the frequency of floods > 3 times the median flow (*i.e.* FRE3). This provided a rule of thumb that has been used to determine the appropriate size of periphyton flushing flows. For example, the natural median flow of the Waitaha River in the abstraction reach is 19.9 m^3/s (Table 4); so this rule of thumb would suggest that a flushing flow of 3 x 19.9 m^3/s = 59 m^3/s is sufficient to remove accumulations of periphyton. Doyle (2012) shows that the annual frequency of flows of this magnitude under all of the proposed abstraction scenarios will be reduced by less than 10% compared to the natural flow regime (Table 9), and so on average the abstraction reach will be flushed once every two weeks. Note that the slight reduction in FRE3 flushing flows predicted in Table 9 actually overestimates effects on flushing because periphyton is conditioned by preceding flows (Biggs & Close 1989). Also note that the analysis used a residual flow of 3.5 m^3/s at the top of Morgan Gorge, so does not include tributary inflows within Morgan Gorge (as discussed in Section 2.6.9).

When the base flow is reduced by abstraction, periphyton that colonises at the reduced flow will be susceptible to sloughing and scouring at lower flushing flows than would occur under the natural (higher) base flow. The lack of marked change in flushing predicted for the Waitaha in Table 9 is to be expected because the proposed scheme does not involve large scale water storage, so flushing flows will not be 'captured'.

Table 9. Annual occurrence of FRE3 flows at the top of Morgan Gorge with a residual flow of 3.5 m^3/s (pers. comm., Martin Doyle, independent consulting hydrologist, July 2013).

	Natural flow	**19 m^3/s abstraction**	**21 m^3/s abstraction**	**23 m^3/s abstraction**
Annual number of flows > 59 m^3/s (FRE3)	26.2	24.2	23.8	23.6

Studies on the accumulation of periphyton in New Zealand rivers have found that in the absence of adequate flushing flows, accrual of aquatic algae potentially increases exponentially to reach 'nuisance' levels after a period of around six weeks, if there are abundant nutrients and sunlight available (Scrimgeour & Winterbourn 1989; Biggs & Stokseth 1996). Water quality data collected by EOS ecology in 2009 show that nutrient concentrations are low in the Waitaha (McMurtrie & Suren 2009), so it will take longer than six weeks for periphyton to accrue to nuisance levels.

It should be remembered that a flow of three times the median flow is not a threshold flow — some periphyton and sediment flushing will still occur at lower flows, and more effective flushing will potentially occur at higher flows.

Martin Doyle (pers. comm., July 2013) provided an analysis of residual flow occurrence for the Waitaha River (Figure 9). There are only minor differences between the various abstraction options in terms of how long the hydrograph 'flat-lines' at the residual flow. Moreover, the figure clearly shows that the likelihood of a long period of flat-lining sufficient for periphyton to exceed nuisance levels (> six weeks) is extremely low. Again this is expected, given that high flow events beyond the capacity of the intake will not be captured, although their magnitude may be reduced (*i.e.* by up to 23 m^3/s) affecting smaller freshes proportionately more than large floods.

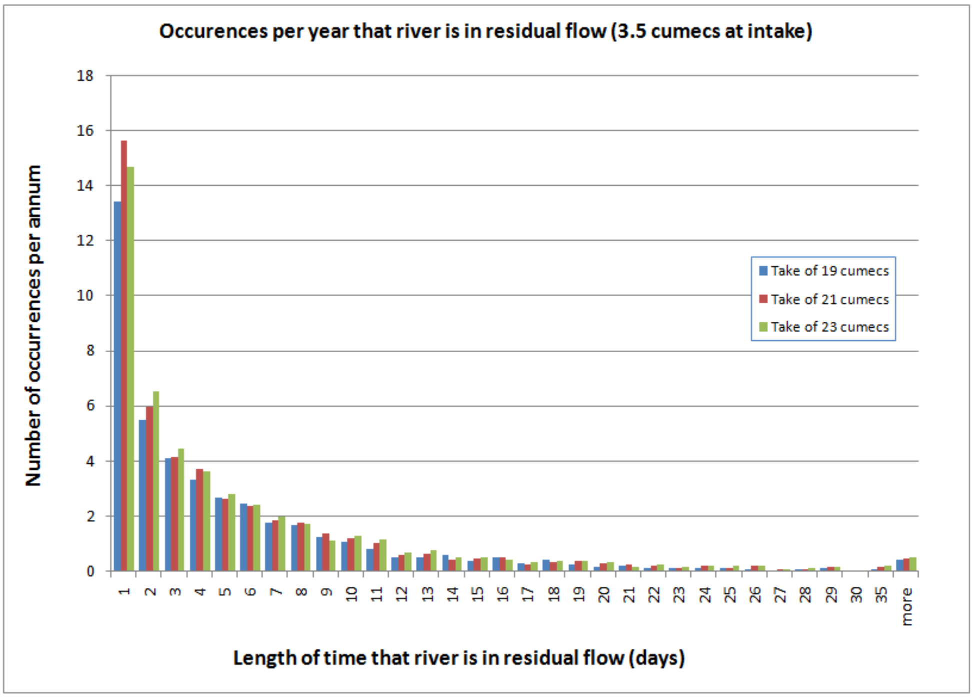

Figure 9. The length of time that flow would not exceed the residual flow (3.5 m^3/s) under abstraction options of 19, 21 and 23 m^3/s (pers. comm., Martin Doyle, independent consulting hydrologist, July 2013).

3.7. The effect of floods

The headwaters of the Waitaha River receive some of the highest annual rainfall volumes in the world (Doyle 2008), so a typical annual Waitaha hydrograph features frequent large floods, particularly during spring snow melt.

In stream ecology, floods are termed ‘disturbances’, which can be defined as “any relatively discrete event in time that disrupts ecosystem community, or population, structure, and that changes resources, availability of substratum or the physical environment” (Resh *et al.* 1988). As discussed in Section 1, high flows move sediments and scour parts of the river bed, which resets (reduces) the abundance (or biomass) of periphyton, invertebrates and fish, thus temporarily reducing productivity.

In the abstraction reach the frequency of floods remains essentially unchanged under all modelled abstraction scenarios (Table 9), whilst the median flow is significantly reduced (Table 4). Notwithstanding the habitat modelling results described in the previous sections, a reduced median flow ought to translate to a reduction in usable habitat, because the habitat in the channel margins are lost to drying as the wetted width is reduced, while the portion of the channel that is scoured by floods remains unchanged (Figure 10). Habitat (WUA) — flow relationships for some of the benthic invertebrate HSC demonstrate the former point in Figure 3. During a flood, assuming a simple channel cross section (*i.e.* no significant bends in the channel upstream), the part of the channel bed that is furthest from the margins will be subject to the highest water velocities and most erosive flows (Figure 11). Therefore, when a river has a reduced median flow but still frequent flood flows, such is the case with the proposed hydroelectric power scheme, a greater proportion of the habitat will be subject to flood scour and loss than would occur under the natural flow regime.

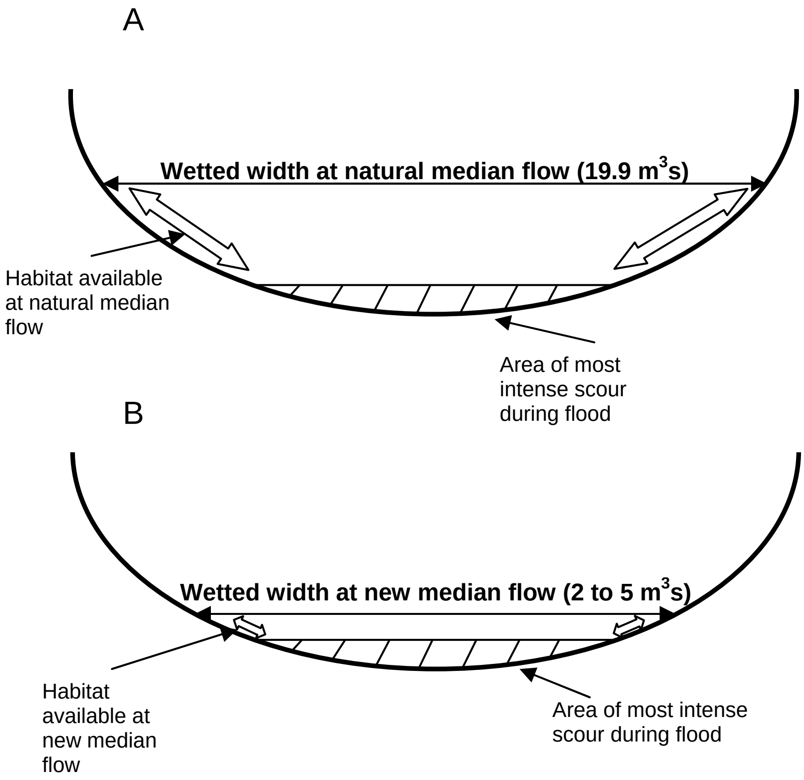

Figure 10. Conceptual model of a river cross section with A) natural flow, and B) reduced flow. Loss of habitat on channel margins occurs due to a reduction in wetted width associated with a decrease in the median flow. The same central portion of the channel is scoured by frequent floods under the natural and abstracted flow regimes negating its value as habitat even though depths and velocities may appear suitable at the residual flow.

As noted in the habitat modelling sections, the effects of disturbance / flooding is not accounted for in the modelling, hence it follows that the results, depending on the taxa/life-stage will be underestimating the effects of habitat loss, and overestimating habitat gains. This is particularly pertinent to organisms with limited capacity to move laterally as flow increases (*e.g.* periphyton and invertebrates) to avoid the scour zone.

The improvement in habitat for short and long filamentous algae suggested by the habitat modelling results is not likely to result in additional periphyton proliferation over much of the channel, since much of this habitat will be subject to regular flushing / scouring. Conversely, the reduction in habitat for diatoms is likely to be worse than predicted for the same reason. Overall, this is likely to translate to a reduction in food for invertebrates in the abstraction reach.

The useable habitat for invertebrates will also be reduced in the abstraction reach by the same mechanism, exacerbating the predicted reduction in habitat relative to that at the natural median as flow is reduced below 5 m^3/s (Section 3.2). Taken together with the expected reduction in usable habitat for periphyton, this is likely to lead to a reduced food resource for fish and blue ducks in this reach (if the latter do sometimes feed there). Consequently, the benefits of increases in habitat availability with reduced flow predicted for many of the native fish and blue ducks are likely to be reduced to some extent, while the detrimental effects on trout habitat are likely to be exacerbated.

The predicted changes in wetted width with different residual flow options can be interpreted as providing a coarse indication of the likely magnitude of this effect. If the width of channel subjected to scour during flooding is assumed to be constant between residual flow scenarios, then the change in the width of remaining usable habitat (*i.e.* the proportion of the channel not subject to scour) will be directly proportional to the change in wetted width.

The average wetted width in the abstraction reach at the natural median flow is 35.3 m[13] and 27.4 m at the natural MALF1[14]. A reduction in the wetted width corresponds to a reduction in habitat availability for different species at the various residual flow options (Table 10). A residual flow of 5 m^3/s, for example, would result in 74% retention of the invertebrate habitat available at the natural median flow, and 95% retention of fish habitat available at the MALF1. The rate of decline increases steadily as the residual flow is drawn below 4 m^3/s. A 2 m^3/s residual flow would result in approximately a 14 m reduction in average wetted width relative to the natural median flow (*i.e.* ~ 40% reduction) and a 6.1 m reduction relative to the natural MALF1 (*i.e.* ~ 22 % reduction).

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[13] The change from median flow is relevant for invertebrate habitat.

[14] The change from MALF1 is relevant for periphyton, fish and blue duck habitat.

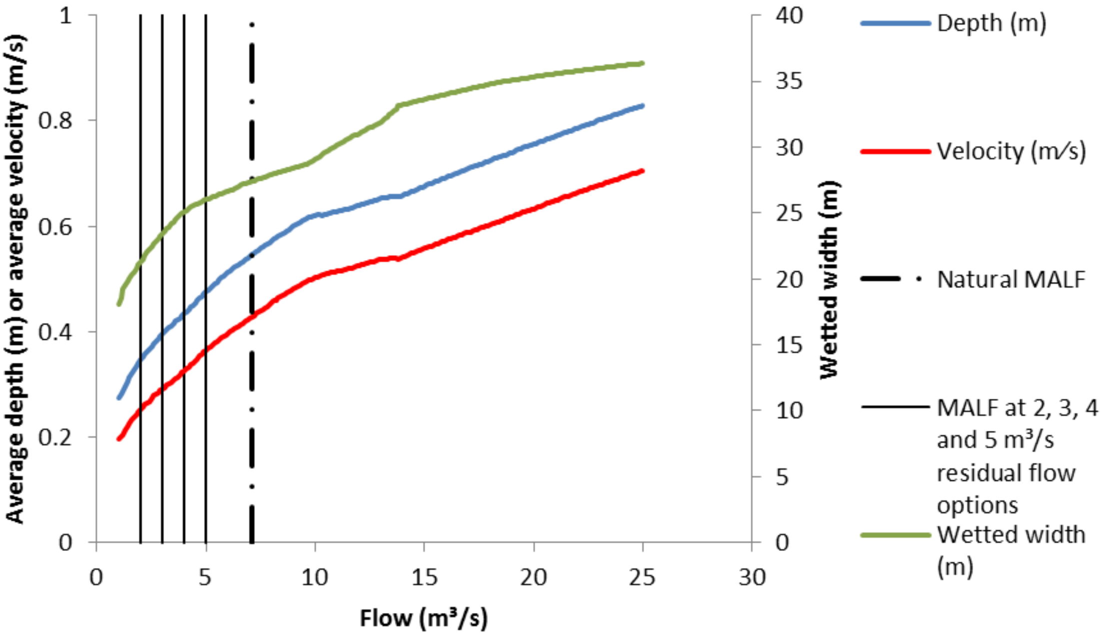

Figure 11. Change in predicted average wetted width, depth and velocity with flow in the abstraction reach of the Waitaha River.

Table 10. Change in average wetted width at the proposed residual flows and the relative influence on habitat availability

	Natural median flow (19.9 m^3/s)	Natural MALF1 (7.09 m^3/s)	Residual flow options 5 m^3/s	 4 m^3/s	 3 m^3/s	 2 m^3/s
Wetted width (m)	35.3	27.4	26	25.1	23.4	21.3
Wetted width retained for invertebrate habitat (%) [1]	-	-	74	71	66	60
Wetted width retained for periphyton, fish and blue duck habitat (%)[2]	-	-	95	92	85	78

[1] WW@residual flow / WW@median flow * 100; where WW = wetted width

[2] WW@residual flow / WW@MALF1 * 100;

4. CONCLUSIONS

The proposed hydroelectric power scheme will substantially change the low to median flow regime through the 3.3 km abstraction reach of the Waitaha River. The median flow and one day mean annual low flow (MALF1) will reduce from 19.9 m^3/s and 7.09 m^3/s, respectively, to that of the residual flow — 3.5 m^3/s now preferred by Electronet Services. This equates to a major shift in the average amount of space available to aquatic organisms.

All of the proposed residual flow options modelled (2, 3, 4 and 5 m^3/s) are predicted to bring about substantial change to periphyton communities in the abstraction reach, where the altered habitat conditions will favour filamentous algae over the existing dominant diatom species. Whilst little or no change in habitat quality is predicted during wet months, diatom habitat retention reduces to as low as 6% of that predicted at the natural MALF1 during dry and typical (median flow) months. Similarly, increases in habitat retention for filamentous algae are greatest during dry and typical months (up to 377% retention for short filamentous algae). The reduction in diatom habitat and increase in filamentous algae habitat is more substantial the lower the residual flow.

However filamentous algae are not likely to proliferate to nuisance levels because of the high frequency of flushing floods that will continue to flow through the abstraction reach. The 'run-of-river' type hydroelectric power scheme allows flows greater than the abstraction volume to flow through the abstraction reach, and it is predicted that the annual frequency of flows greater than three times the median flow will be reduced by less than 10% under the proposed abstraction scenarios (19 and 23 m^3/s).

The predicted effects of the residual flow (2–5 m^3/s) and abstraction scenarios (19 and 23 m^3/s) on habitat availability for the dominant invertebrate taxa (*Deleatidium*, *Stictocladius* and Orthocladiinae) depended on the habitat suitability criteria (HSC) used in the habitat modelling. Predictions based on the Waitaha-specific HSC indicate either a small decrease, no change, or a moderate increase in habitat availability for the various flow options, relative to the natural median flow (*e.g.* with a 19 m^3/s abstraction predicted habitat retention ranges are 86–104% for *Deleatidium;* 79–161% for Orthocladiinae; and 100–134% for *Stictocladius*). Conversely, predictions based on macroinvertebrate HSC from other sources indicate more substantial reductions in habitat, particularly during dry months with residual flows of 4 m^3/s or less (*e.g.* with a 19 m^3/s abstraction predicted habitat retention ranges are 32–100% for *Deleatidium (Waitaki HSC)* and 58–100% retention for Orthocladiinae *(Waitaki HSC))*. The most environmentally conservative predictions are those based on the HSC from other rivers.

The residual flow options are predicted to substantially reduce habitat availability for adult brown trout relative to the natural MALF1, particularly at the lower residual flows (*i.e.* 2 or 3 m^3/s) (*e.g.* with a 19 m^3/s abstraction predicted habitat retention ranges are 47-105% using the Hayes and Jowett HSC; and 34-100% using the Bovee HSC). Habitat retention in dry months is reduced year round, whereas in typical months reductions occur over autumn–winter–early spring. During wet months habitat generally remains unaffected under all of the modelled residual flows. Habitat for juvenile brown trout is predicted to either increase moderately or stay the same (*e.g.* with a 19 m^3/s abstraction predicted habitat retention ranges are 84–149%).

Habitat availability for native fish will generally either increase or remain unchanged under the modelled residual flows for those species known to be present in the abstraction reach (torrentfish, longfin eel, koaro and lamprey), relative to the natural MALF1 (*e.g.* with a 19 m^3/s abstraction, habitat retention ranges for these species were 88–243% for torrentfish; 97–149% for juvenile longfin eel; 88–221% for koaro; and 94–132% for lamprey). Habitat for koaro (the only fish species found upstream of Morgan Gorge) is predicted to increase substantially in many of the spring, summer and autumn months, particularly during typical (median flow) months.

Blue duck feeding habitat is predicted to increase as a result of the proposed flow reduction in dry and typical months, with no change in wet months (*e.g.* with a 19 m^3/s abstraction, habitat retention was 90–175%). Blue duck have not yet been officially observed within the abstraction reach.

Most of the results from the seasonal habitat modelling indicate that the most substantial changes in habitat (increases or decreases) occur during dry or typical flow months with the lowest residual flow (2 m^3/s). There is very little (if any) difference between habitat retention values calculated using a 19 m^3/s abstraction versus a 23 m^3/s abstraction - the range of retention values for most species is the same for each of these abstraction rates, whilst the mean and median changes by 5% or less. Therefore, the overall trend (monthly increase or decrease) is essentially the same for both abstraction scenarios.

Depths will be sufficient for the upstream passage of salmonids and native fish under all of the residual flow options.

Predictions of habitat retention do not account for the inflow of tributaries within the abstraction reach, which will ameliorate the predicted effects on stream ecology. Predictions are therefore ecologically conservative (*i.e.* results will overestimate the adverse effects and underestimate the positive effects).

The combined effect of lowering the median flow and continued exposure to naturally frequent flood scour through the abstraction reach is likely to result in a reduction in the overall productivity (*i.e.* there is likely to be less food available and hence a lower abundance of aquatic organisms and reduced growth rates). Therefore, the predicted effects of the modelled flows will underestimate the adverse effects (habitat losses) and overestimate the benefits (habitat gains). However, the Waitaha naturally supports an ecosystem of relatively low productivity, owing to the frequent flood disturbance and low nutrient concentrations.

To put the potential effects of the scheme in perspective with the wider catchment, the abstraction reach below Morgan Gorge[15] is relatively short (2.3 km), being approximately 13 % of the 18 km of river between Morgan Gorge and the sea. Whilst the reach represents a large portion (71%) of the single thread open channel habitat below the gorge, there are substantial stretches of river with equivalent upstream, particularly above Waitaha Gorge.

5. ACKNOWLEDGEMENTS

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John Hayes supervised the project and provided peer review of the report. Cherie Johansson provided editorial support.

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[15] Habitat within Morgan Gorge is not suitable for most aquatic organisms.

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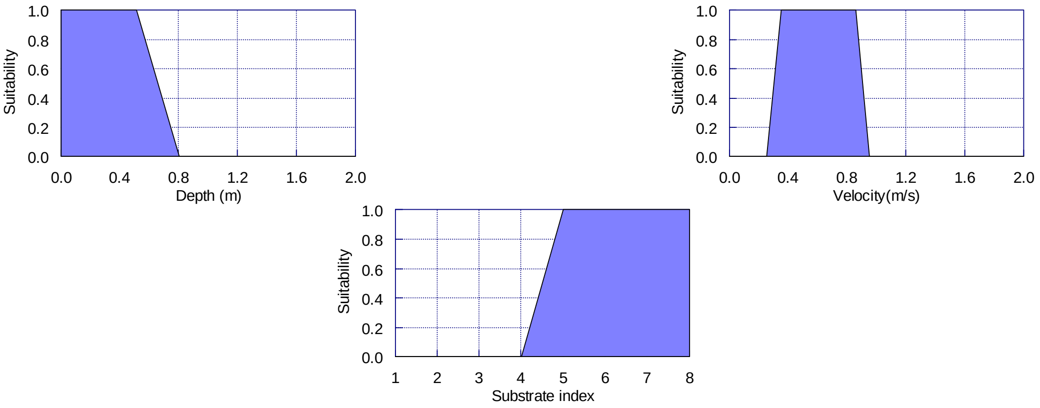
7. APPENDICES

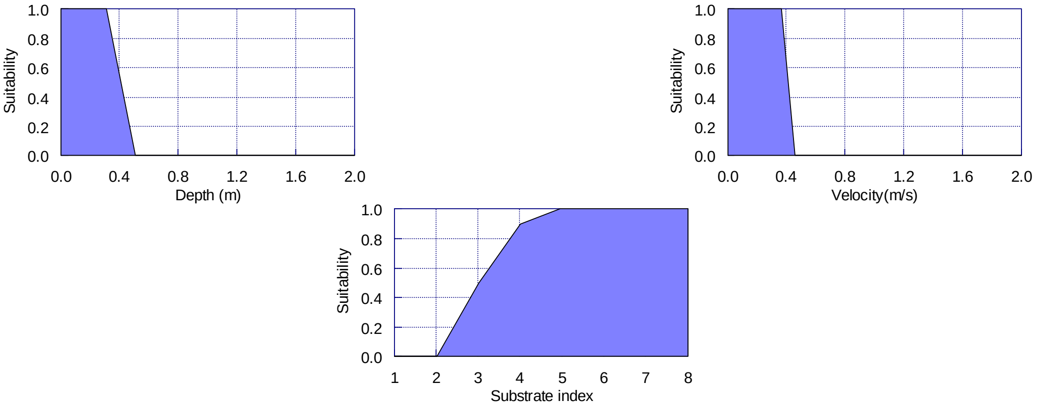
Appendix 1. Habitat suitability criteria (HSC) used for habitat modelling in this report.

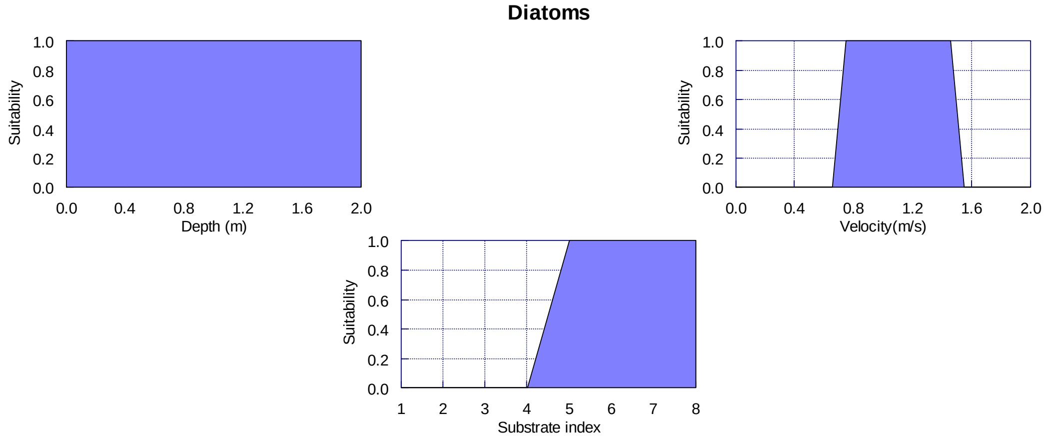
Periphyton habitat suitability criteria

Short filamentous algae



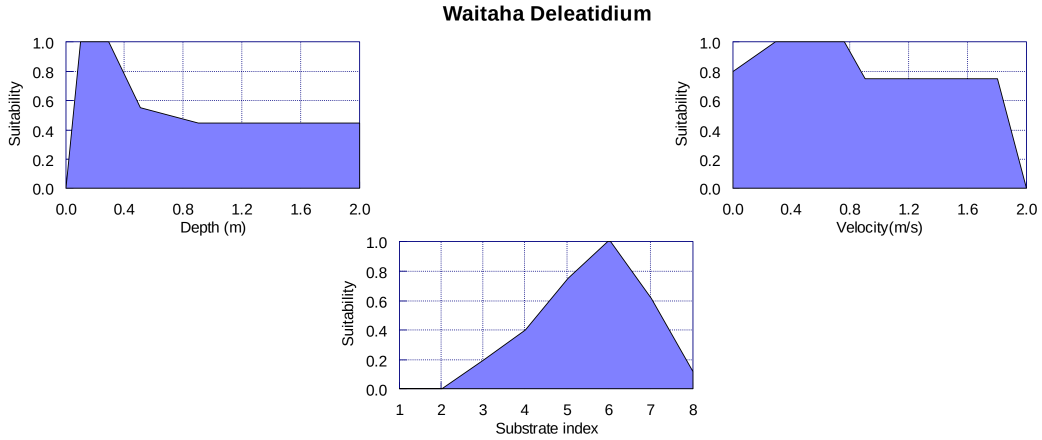
Long filamentous algae



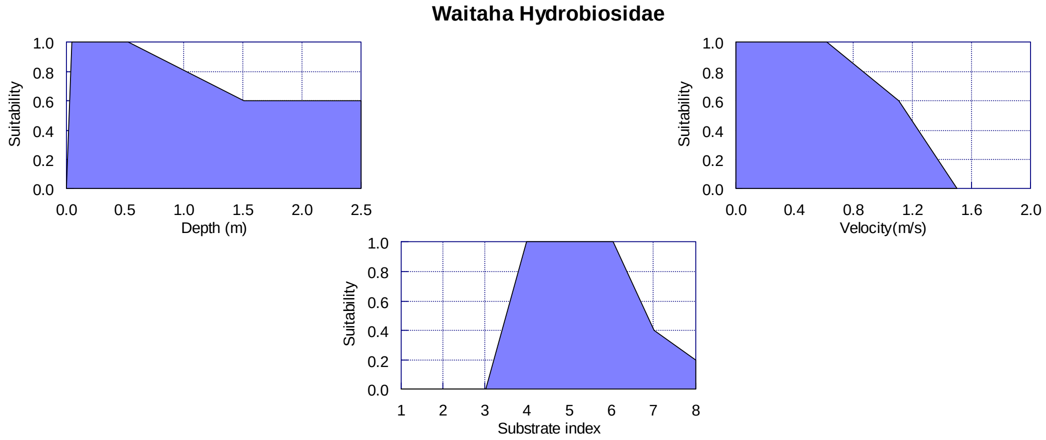


Diatoms

Waitaha macroinvertebrate habitat suitability criteria

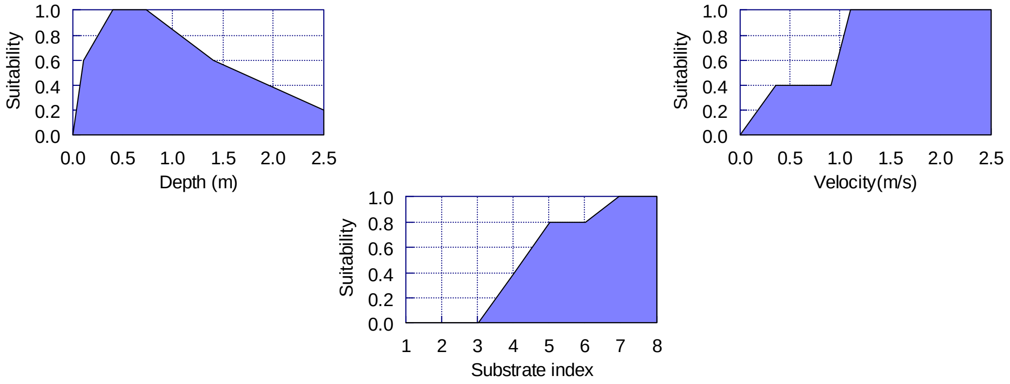


Waitaha Deleatidium

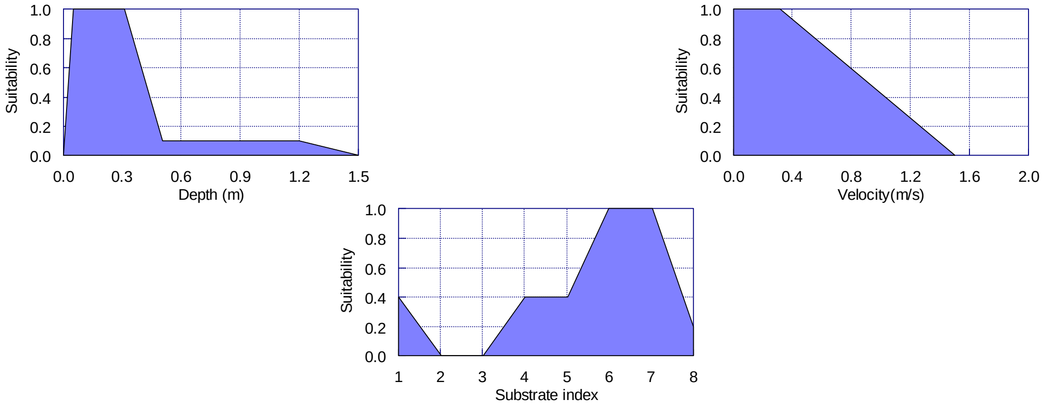


Waitaha Hydrobiosidae

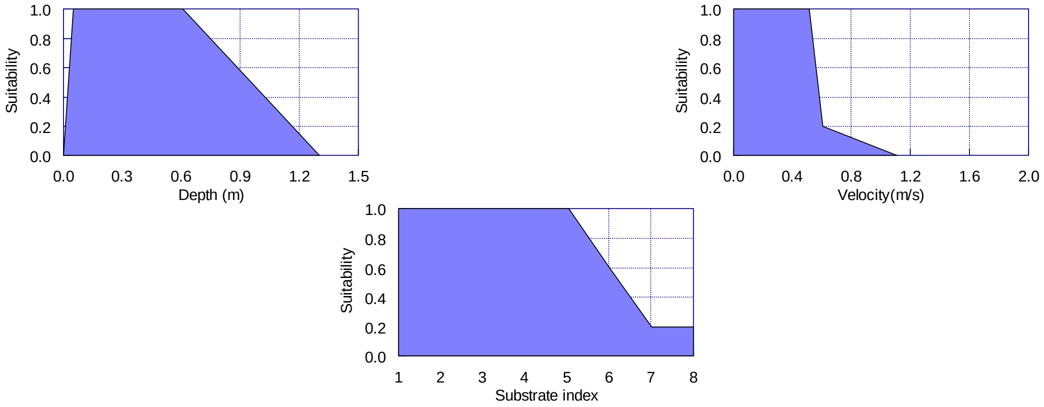
Waitaha Neocurupira

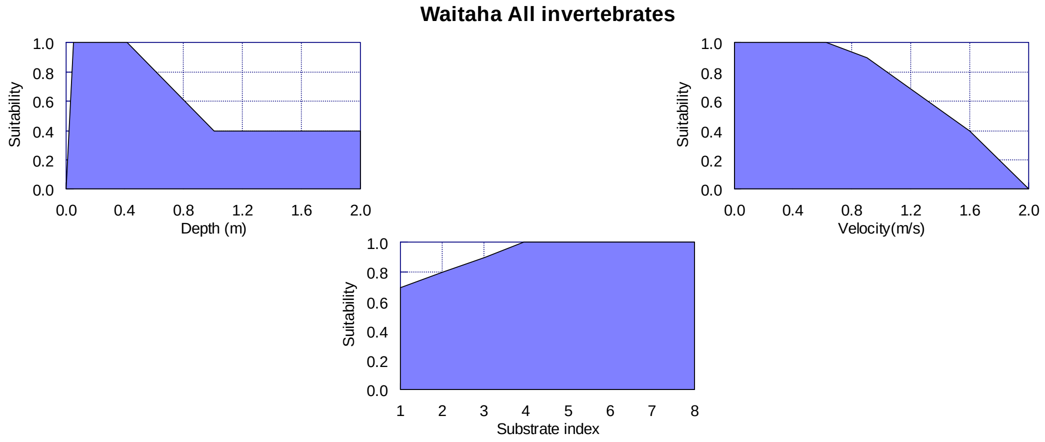


Waitaha Orthocladiinae



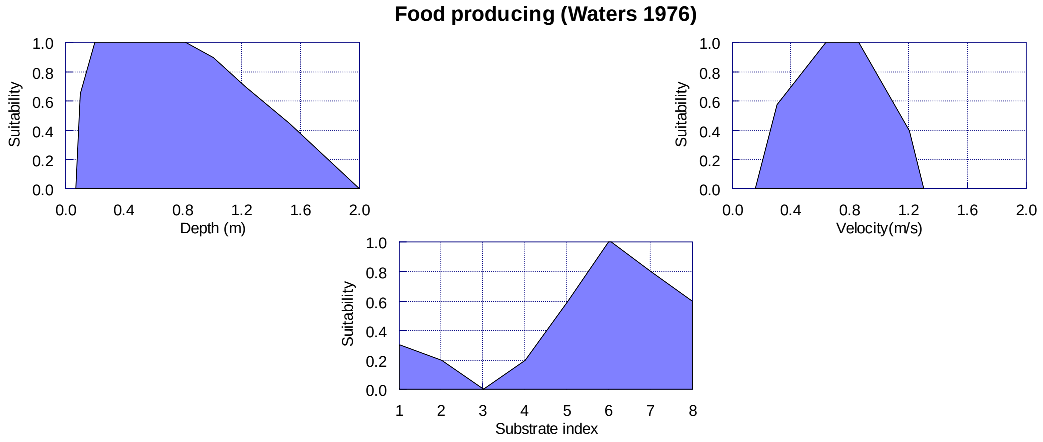
Waitaha Stictocladius



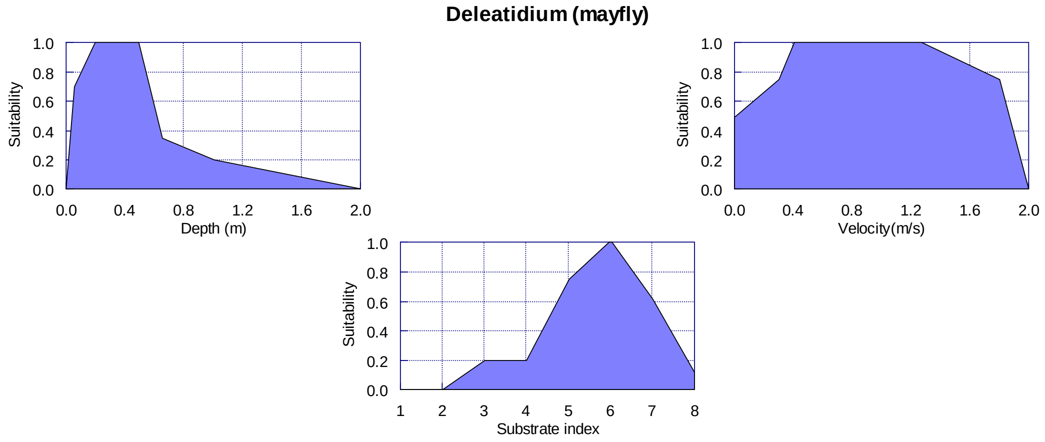

Waitaha All invertebrates

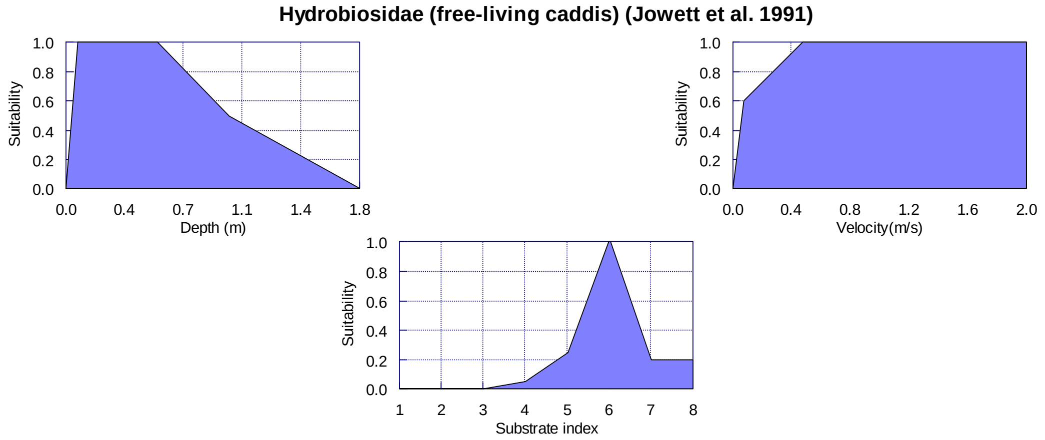
Macroinvertebrate habitat suitability criteria from other rivers

Food producing (Waters 1976) (below), was developed in the United States of America to describe the general instream habitat requirements of benthic macroinvertebrates for food production (*i.e.* food for fish) in trout streams. These general HSC for macroinvertebrates have been widely applied to habitat analyses in New Zealand, and Jowett (1992) found that WUA predictions based on them were correlated with trout abundance in New Zealand rivers.


Food producing (Waters 1976)

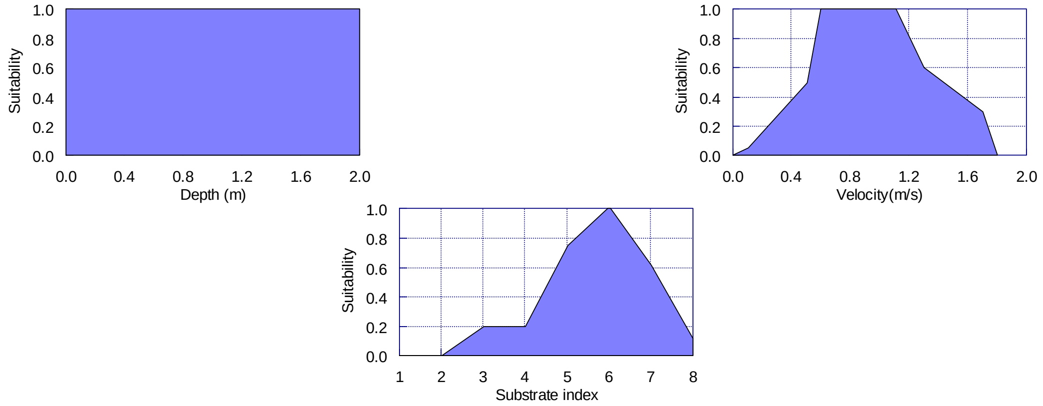
Deleatidium (mayfly) and Hydrobiosidae (free-living caddis) (below) were developed from observations in the Clutha, Mangles, Mohaka, and Waingawa rivers, as described by Jowett *et al.* (1991). These criteria are labelled ‘*Deleatidium* (mayfly)’ and ‘Hydrobiosidae (free-living caddis)’, respectively, in the tables and figures of this report. Invertebrates were sampled by Surber sampler over a similar depth and velocity range to that sampled in the Waitaha (depth range 0.05–1.55 m, velocity range 0.10–1.62 m/s (Jowett *et al.* 1991) *c.f.* Table 3).


Deleatidium (mayfly)

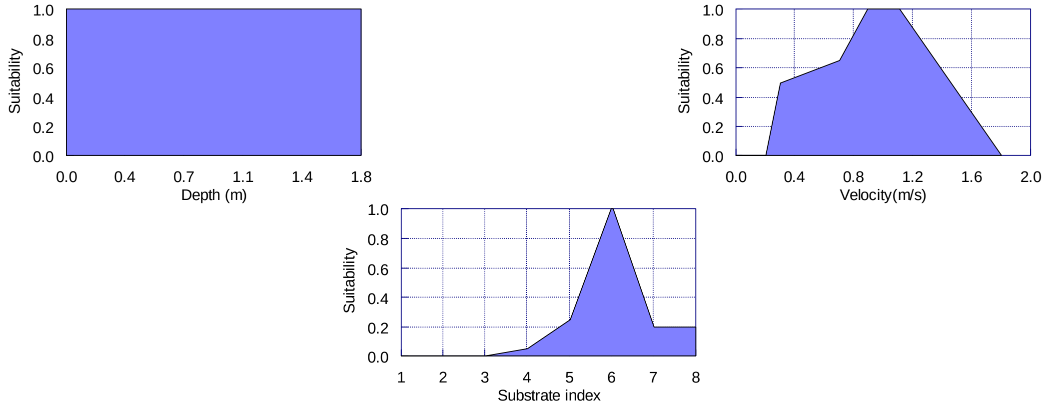

Hydrobiosidae (free-living caddis) (Jowett et al. 1991)

Deleatidium, Hydrobiosidae and Orthocladiinae (Waitaki) (below) were developed from observations in the Waitaki River, as described by Jowett (2002) and Stark and Suren (2002). These criteria are labelled '*Deleatidium* (Waitaki)', 'Hydrobiosidae (Waitaki)', and 'Orthocladiinae (Waitaki)', respectively, in the tables and figures of this report. Stark and Suren (2002) also employed Surber samplers and sampled over a broad range of depths and velocities, using SCUBA divers to sample deeper water. However, no depth suitability curve was included in these HSC, since most invertebrate species appeared to be equally abundant over a wide range of depths and there was insufficient sampling of deep zones to confidently characterise depth criteria (Jowett 2002).

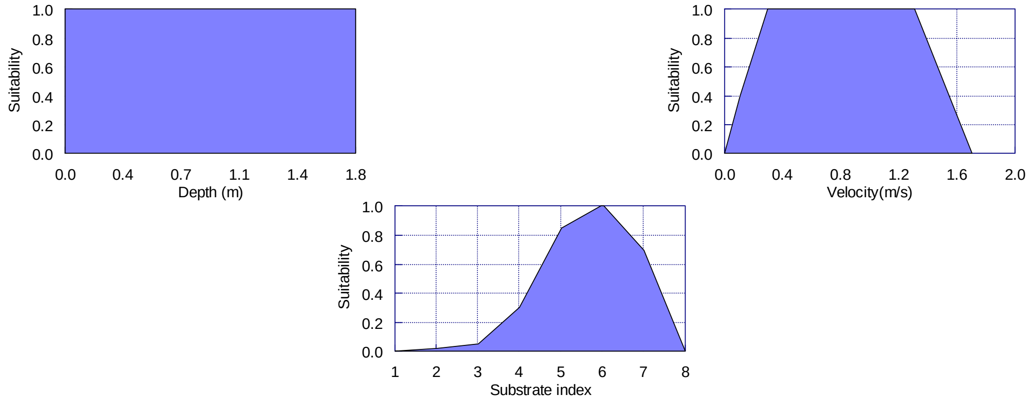
Deleatidium (Waitaki)



Hydrobiosidae (Waitaki)

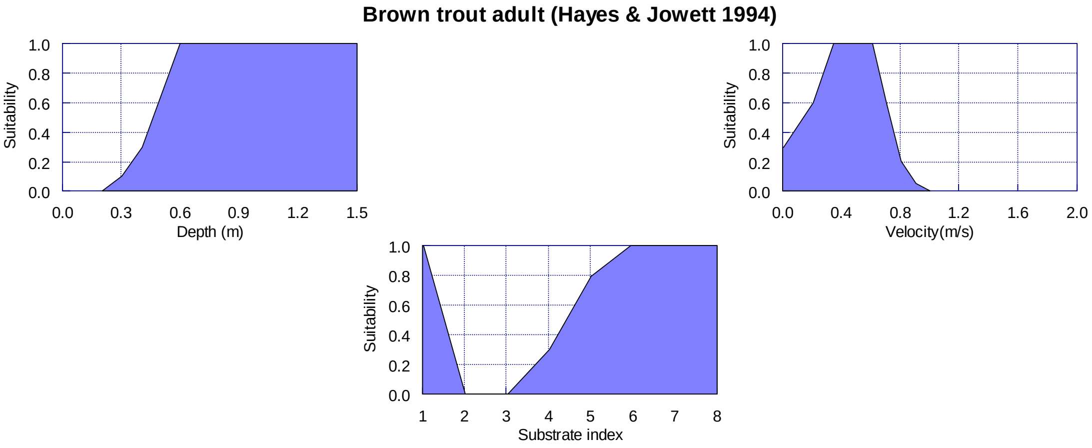


Orthocladinae (Waitaki)

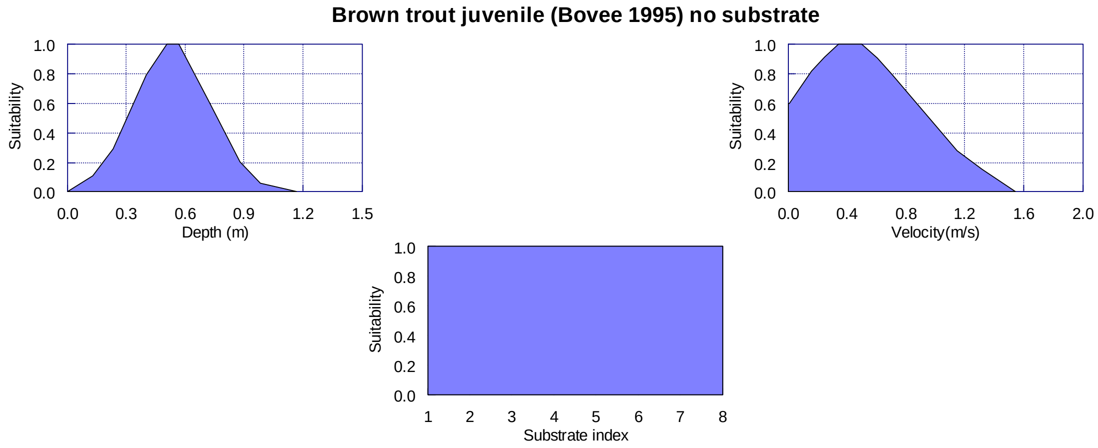


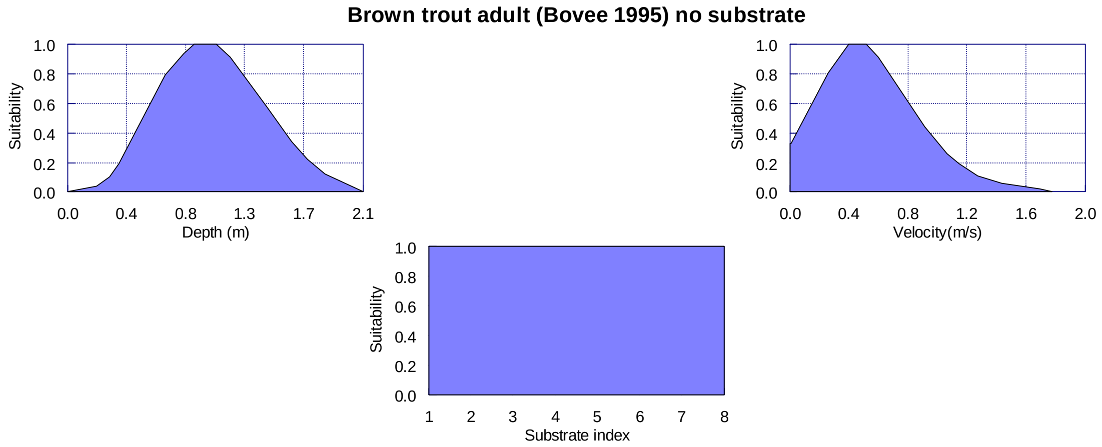
Trout habitat suitability criteria

Hayes and Jowett (1994) habitat suitability criteria have been used most widely in New Zealand for modelling adult drift-feeding brown trout habitat since their development. These HSC were developed based on observations of habitat preferences of large (45–65 cm) actively feeding brown trout on moderate-sized rivers (upper Mataura, Travers, upper Mohaka) over the flow range 2.8–4.6 m^3/s. This flow range is slightly lower than generally experienced during periods of low flow in the abstraction reach (MALF1 7.09 m^3/s at the bottom of the Kiwi Flat reach). The channel gradient in the abstraction reach is higher than that of Hayes and Jowett's (1994) study rivers (approximately 0.017 m/m in the abstraction reach *c.f.* 0.0016–0.0074 m/m in Hayes and Jowett's study rivers).

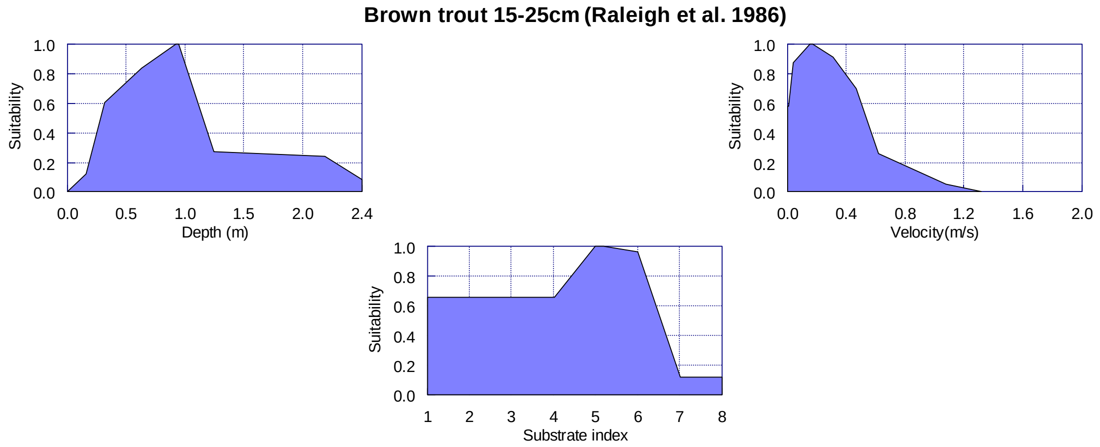


Bovee's (1995) criteria for adult and for juvenile brown trout were developed from observations over a more comparable flow range (7–18 m^3/s) to those in the low to median flow range (*i.e.* the range of interest in minimum flow setting) experienced in the Waitaha. However, the South Platte River (Colorado, United States of America), where these observations were made, also has a gradient that is less steep than that of the Waitaha (0.0058 m/m). Bovee's (1995) habitat suitability criteria are based on unpublished data sourced from Ken Bovee, one of the original developers of the IFIM. The study site and methods used to gather these data are described in Thomas and Bovee (1993), which also presents rainbow trout habitat suitability data. The brown trout adult HSC are based on observations of actively feeding fish > 200 mm (but the majority were 300-400 mm), while the juvenile criteria are for fish < 200 mm. Bovee's (1995) criteria were originally provided without substrate suitability criteria. Rather than adding substrate suitability criteria from another source, these criteria were applied here without substrate suitability criteria. Setting the index of substrate suitability to a uniform value of 1 effectively removes substrate from the calculation of WUA. This is because the weighted usable area (WUA) is calculated as the area weighted product of the three habitat suitability criteria (depth, velocity and substrate).





The HSC for juvenile brown trout (15–25 cm) developed by (Raleigh *et al.* 1986) have been used extensively in New Zealand IFIM habitat modelling applications in the past, although they may underestimate flow requirements due to the inclusion of resting fish observations in the development of the criteria, which tends to give them a bias toward slower water habitat (a common problem in older habitat suitability criteria; Hayes 2004). For this reason the criteria developed by Bovee (1995) and Hayes and Jowett (1994) may provide a more conservative estimate of habitat availability, since they were based solely on observations of actively feeding fish. The HSC developed by Raleigh *et al.* (1986) were based on observations over a comparable flow range (1.1–7.8 m^3/s) to the low flow range in the Waitaha, and in reasonably high gradient rivers (Logan River (Utah, USA) and Martis Creek (California, USA). However, it has been found that these HSC are not transferable to streams other than those on which they were developed in Colorado, and so are no longer in common use there (pers. comm. K. Bovee). Nevertheless, they used to be used extensively in New Zealand (as mentioned above) and so were applied here to provide a comparison with habitat availability predictions based on the Bovee (1995) juvenile brown trout HSC.



Native fish habitat suitability criteria

Koaro HSC were developed by Jowett and Richardson (2008) based on observations in nine rivers, but koaro were comparatively abundant in only two of these, the Onekaka and Ryton. A total of 286 koaro were caught at 153 locations, with sampled water depths ranging from 0.04 to 0.8 m and mean column velocities from 0 to 1.42 m/s. The Ryton and Onekaka are substantially smaller than the Waitaha. However, koaro are generally considered to prefer small to moderate sized streams (McDowall 2000) and consequently the mainstem of the Waitaha is not likely to offer much suitable habitat for this species. This is reflected in the observations of Eikaas and McMurtrie (incomplete draft 2010), who note that 31 out of 32 koaro caught in the Waitaha catchment were found in tributaries, as opposed to the mainstem.

The HSC for longfin and shortfin eels were developed by Jowett and Richardson (2008). Habitat preferences were assigned using data from 2641 locations in 70 New Zealand rivers. Based on these observations, separate sets of HSC were developed for large eels (> 300 mm long) and small eels (< 300 mm long) for each species, with the smaller size class generally preferring shallower, faster water (Appendix 1).

The HSC applied for torrentfish (Appendix 1) were also based on Jowett and Richardson (2008). They were based on 784 fish samples at 200 locations in 37 New Zealand rivers. The habitats sampled ranged in depth from close to zero to approximately 0.75 m, and average velocities in the sampling units ranged from 0.07 to 1.24 m/s. Observations by Eikaas and McMurtrie (incomplete draft 2010) confirm Jowett and Richardson's note that torrentfish are rarely found in small bush streams. Eighteen of the 22 torrentfish found in the Waitaha were caught in mainstem rather than tributary waters.

Lamprey HSC were based on Jellyman and Glova (2002); 422 juvenile lamprey samples at 63 sites in the Mataura River catchment. The flow in the lower reaches of the Mataura is significantly greater than that of the Waitaha, though the gradient is much lower. The habitat preferences ranged in depth from close to zero to approximately 0.6 m, and average velocities in the sampling units ranged from 0 to 0.24 m/s.

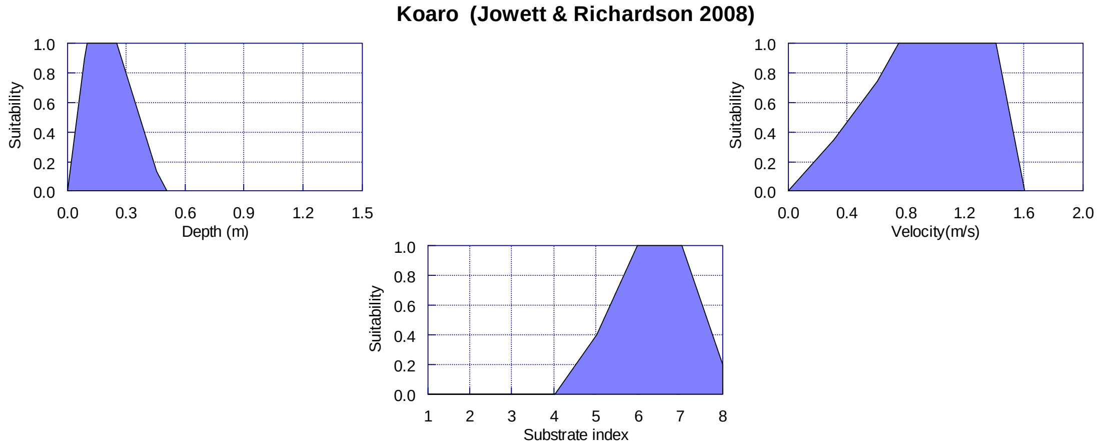
The HSC applied for common bully were developed by Jowett and Richardson (2008); 1224 fish sampled at 226 locations in 31 New Zealand rivers. The habitats sampled ranged in depth from close to zero to approximately 0.7 m, and average velocities in the sampling units ranged from 0 to 1.07 m/s.

Redfin bully HSC were developed by Jowett and Richardson (2008); 564 fish samples at 197 locations across 28 New Zealand rivers. The habitats sampled ranged in depth from close to zero to approximately 0.75 m, and average velocities in the sampling units ranged from 0 to 1.07 m/s.

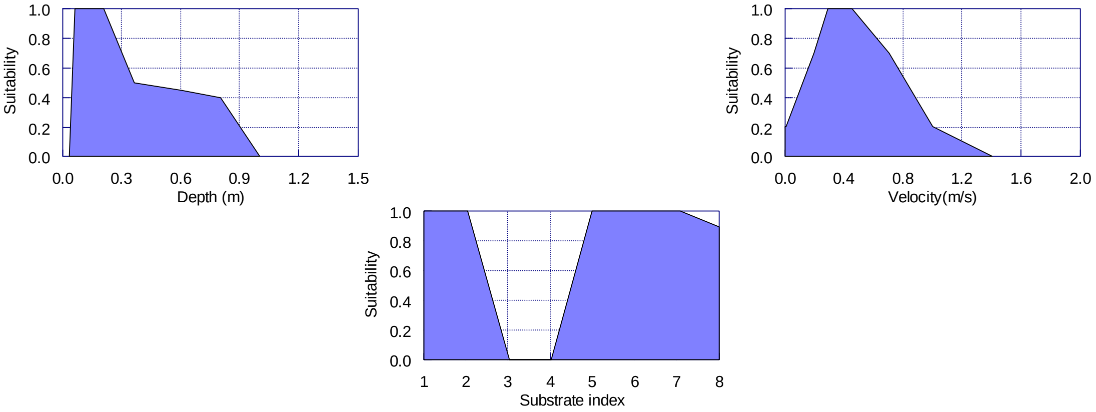
The HSC for banded kokopu were developed by (Jowett & Richardson 2008) using data collected during day and night observations. A total of 204 adult kokopu (> 80 mm) were caught at 87 locations in five rivers. Habitats sampled ranged in depth from 0.02 m to 0.8 m, and had average velocities of between 0 and 0.2 m/s. HSC were also developed for juvenile banded kokopu (< 80 mm).

Few data are available for defining the habitat preferences of shortjaw kokopu; daytime observations on only four shortjaw kokopu found at four locations in two West Coast tributary streams (McDowall *et al.* 1996). Habitats sampled ranged in depth from 0.12 m to 0.4 m, and had average velocities of between 0 and 0.56 m/s.

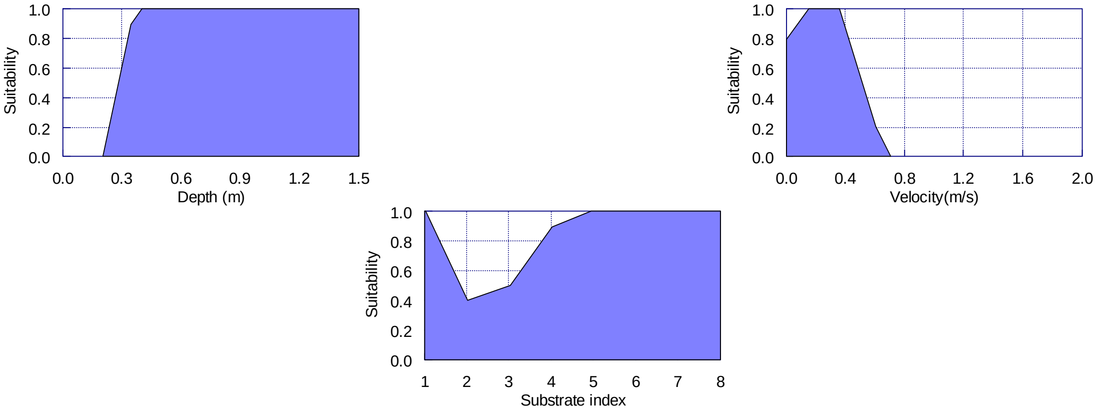
The HSC for giant kokopu were developed using data collected by (Bonnett *et al.* 2002); 39 fish samples at 39 locations across 18 rivers in Westland and Southland. Habitats sampled ranged in depth from 0.1 m to 1.5 m, and had average velocities of between 0 and 0.15 m/s.



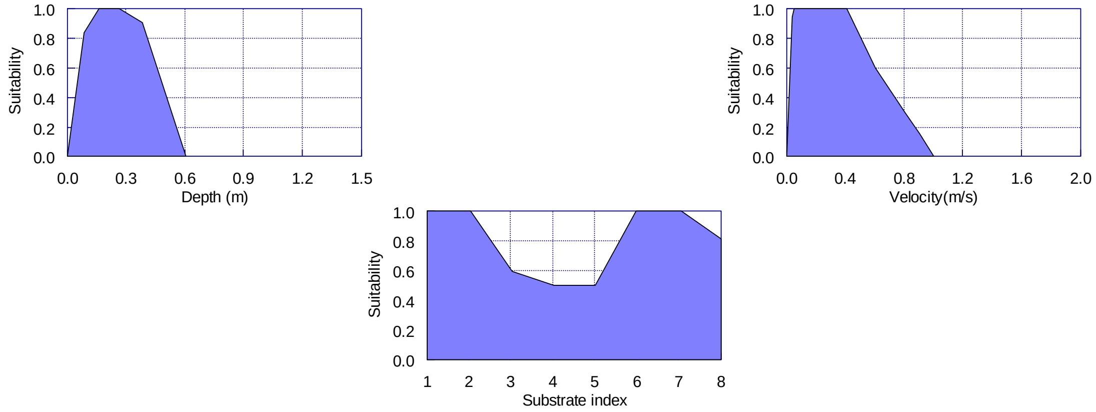
Longfin eel < 300mm (Jowett & Richardson 2008)



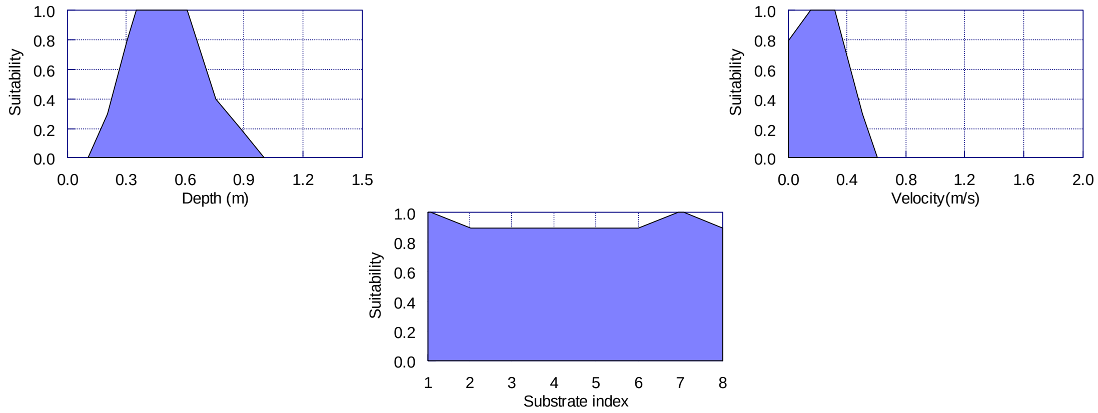
Longfin eel > 300mm (Jowett & Richardson 2008)



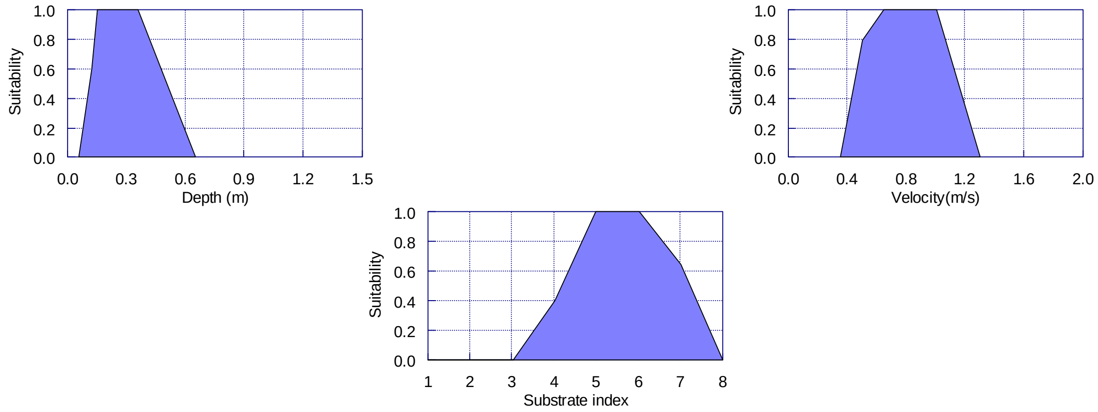
Shortfin eel < 300mm (Jowett & Richardson 2008)



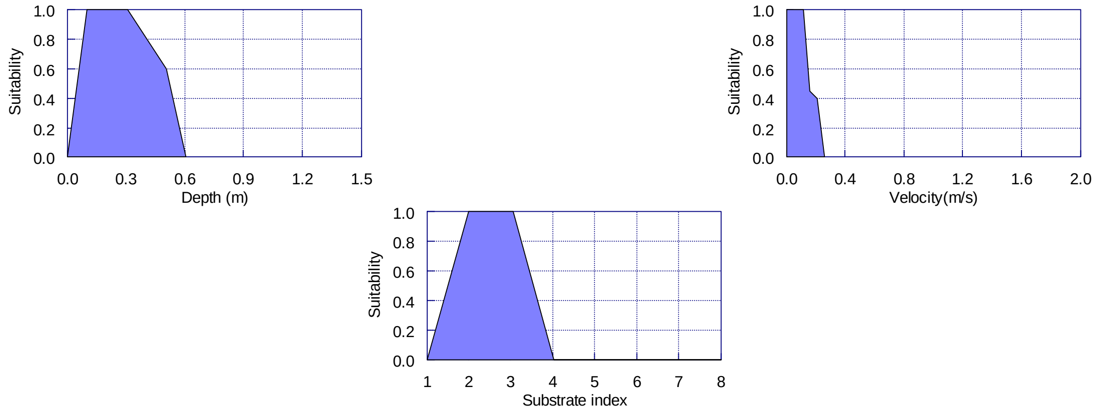
Shortfin eel > 300mm (Jowett & Richardson 2008)



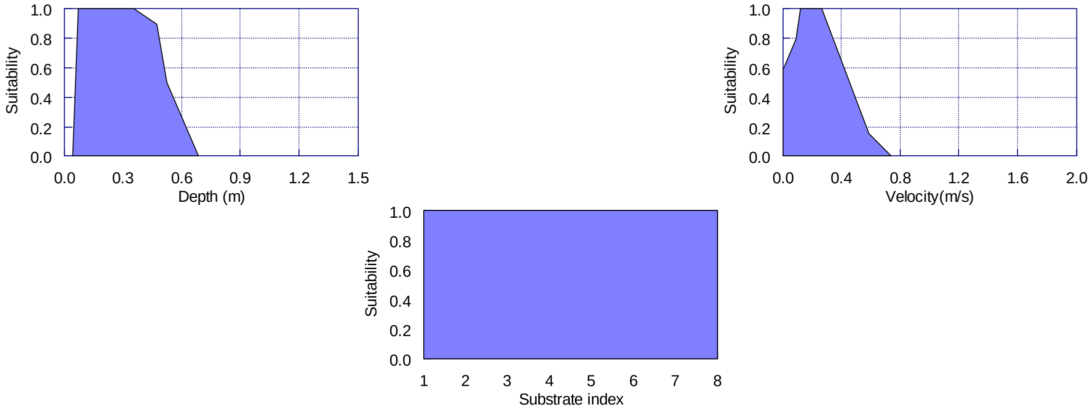
Torrentfish (Jowett & Richardson 2008)



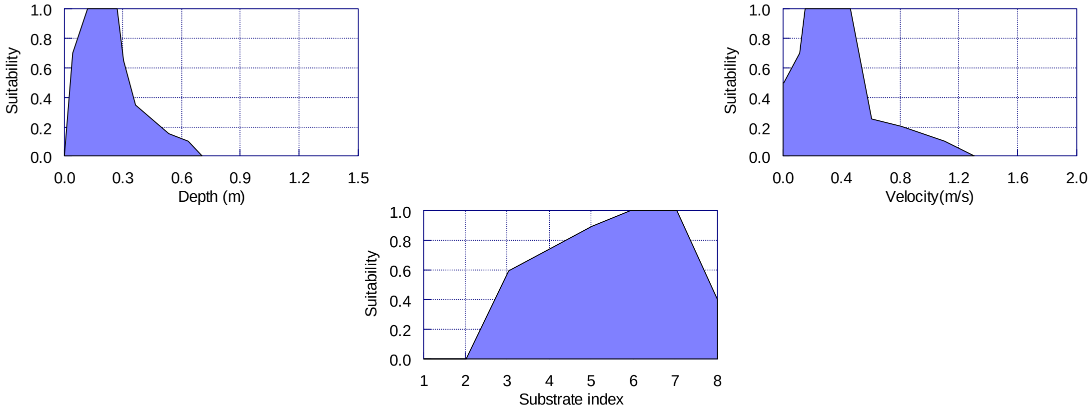
Lamprey (Jowett & Richardson 2008)



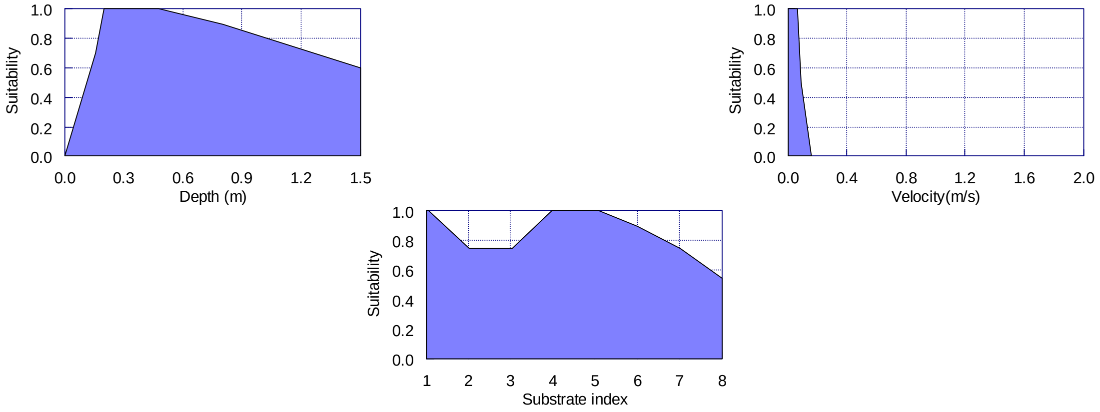
Common bully (Jowett & Richardson 2008)

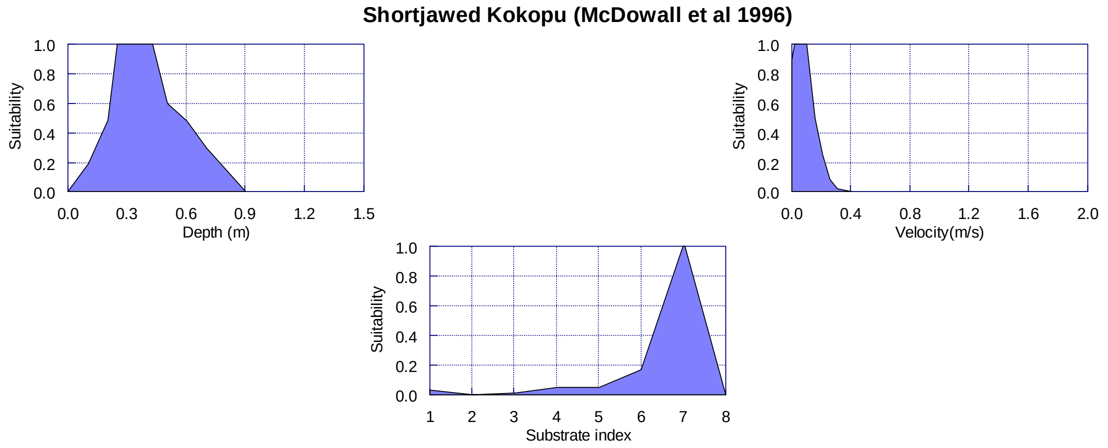


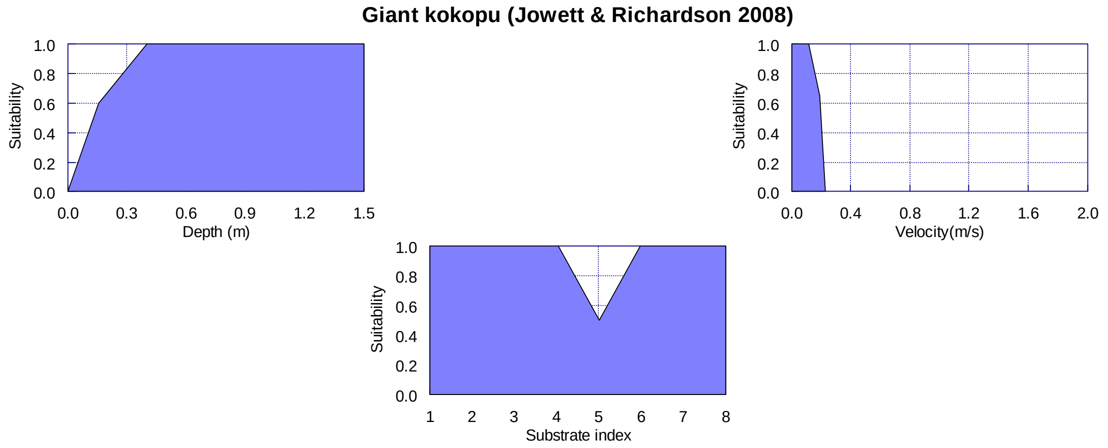
Redfin bully (Jowett & Richardson 2008)



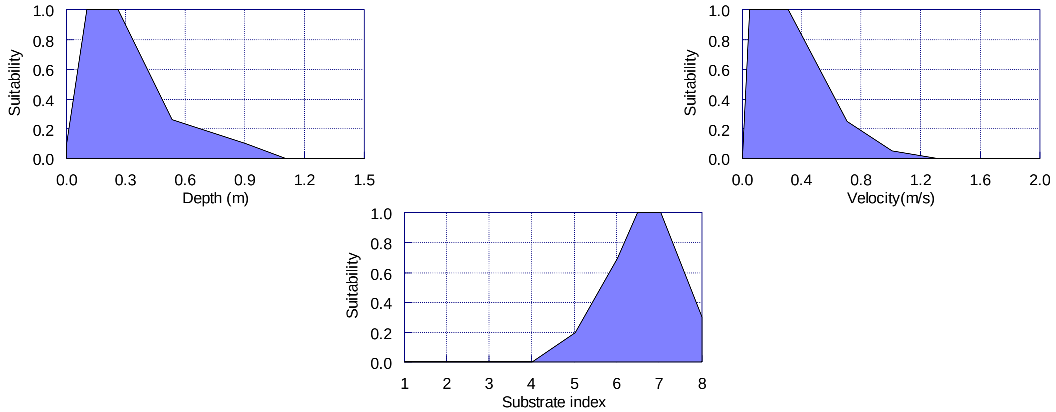
Banded kokopu adult (Jowett & Richardson 2008)

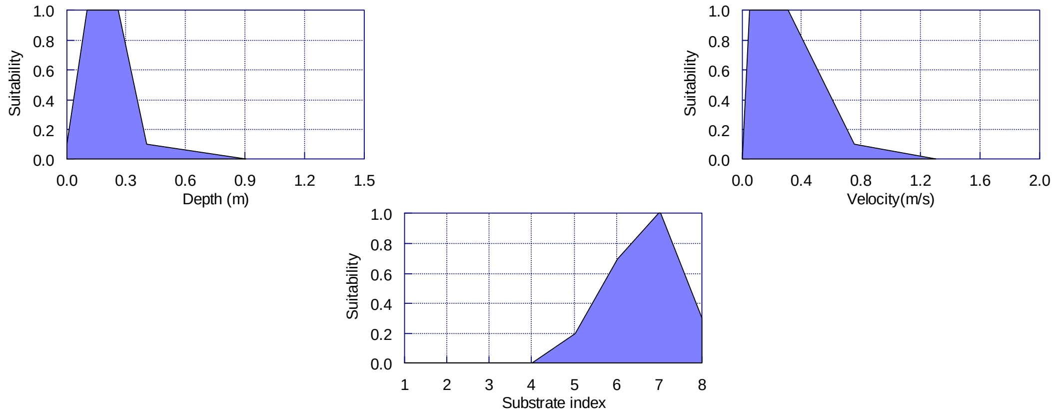



Shortjawed Kokopu (McDowall et al 1996)
Suitability
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.3
0.6
0.9
1.2
1.5
Depth (m)
Velocity(m/s)
0.0
0.4
0.8
1.2
1.6
2.0
1
2
3
4
5
6
7
8
Substrate index


Giant kokopu (Jowett & Richardson 2008)
Suitability
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.3
0.6
0.9
1.2
1.5
Depth (m)
Velocity(m/s)
0.0
0.4
0.8
1.2
1.6
2.0
1
2
3
4
5
6
7
8
Substrate index

Blue duck habitat suitability criteria


Waitaha Blue duck (adult)


Blue Duck (adult) (Collier and Wakelin 1995)

Appendix 2. Results for seasonal periphyton habitat quality retention analysis: Percentage of habitat suitability index (HSI) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime.

Table A2.1. Short filamentous algae: Percentage of habitat suitability index (HSI) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (HSI at proposed flow / HSI at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	315	328	354	346	223	223	223	223	100	100	100	100
F	253	263	284	278	336	339	339	339	100	100	100	100
M	223	232	250	245	336	349	377	369	100	100	100	100
A	159	165	178	174	336	349	377	369	100	100	100	100
M	149	154	167	163	306	318	343	336	100	100	100	100
J	123	128	139	136	244	254	274	268	100	100	100	100
J	111	116	125	122	149	154	167	163	334	334	338	338
A	113	118	127	124	160	166	180	176	223	223	223	223
S	119	124	134	131	241	251	271	265	100	100	100	100
O	174	181	195	191	336	349	377	369	100	100	100	100
N	253	263	284	278	325	326	326	326	100	100	100	100
D	325	338	365	357	164	164	164	164	100	100	100	100

Key: Habitat quality retention levels (as % of habitat quality at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 2. *continued*

Table A2.2. Long filamentous algae: Percentage of habitat suitability index (HSI) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (HSI at proposed flow / HSI at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	157	179	201	236	87	87	87	87	100	100	100	100
F	157	180	202	237	157	162	162	164	100	100	100	100
M	164	188	211	248	157	180	202	237	100	100	100	100
A	180	206	232	272	157	180	202	237	100	100	100	100
M	184	211	237	278	157	179	201	236	100	100	100	100
J	162	185	208	244	157	179	201	236	100	100	100	100
J	132	151	170	199	184	211	237	278	151	167	169	169
A	136	155	174	204	180	206	232	272	87	87	87	87
S	152	174	195	229	157	179	201	236	100	100	100	100
O	178	203	228	267	157	180	202	237	100	100	100	100
N	157	180	202	237	137	140	140	140	100	100	100	100
D	157	179	201	236	91	91	91	91	100	100	100	100

Key: Habitat quality retention levels (as % of habitat quality at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 2. *continued*

Table A2.3. Diatoms: Percentage of habitat suitability index (HSI) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (HSI at proposed flow / HSI at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	40	25	18	6	87	87	87	87	100	100	100	100
F	39	25	18	6	40	37	37	35	100	100	100	100
M	41	26	18	6	40	26	18	6	100	100	100	100
A	45	29	20	7	40	26	18	6	100	100	100	100
M	46	30	21	7	40	25	18	6	100	100	100	100
J	54	34	24	8	40	26	18	6	100	100	100	100
J	64	41	29	10	46	30	21	7	46	33	32	32
A	62	40	28	10	45	29	20	7	87	87	87	87
S	57	36	25	9	40	26	18	6	100	100	100	100
O	44	28	20	7	40	26	18	6	100	100	100	100
N	39	25	18	6	53	52	52	52	100	100	100	100
D	40	26	18	6	97	97	97	97	100	100	100	100

Key: Habitat quality retention levels (as % of habitat quality at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 3. Results for seasonal periphyton habitat quality retention analysis: Percentage of habitat suitability index (HSI) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m^3/s abstraction regime.

Table A3.1. Short filamentous algae: Percentage of habitat suitability index (HSI) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m^3/s abstraction regime (HSI at proposed flow / HSI at natural flow * 100).

	Dry months				Typical months				Wet months			
Month	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
J	315	328	354	346	313	313	313	313	100	100	100	100
F	253	263	284	278	336	349	377	369	100	100	100	100
M	223	232	250	245	336	349	377	369	100	100	100	100
A	159	165	178	174	336	349	377	369	100	100	100	100
M	149	154	167	163	306	318	343	336	100	100	100	100
J	123	128	139	136	244	254	274	268	102	102	102	102
J	111	116	125	122	149	154	167	163	336	349	377	369
A	113	118	127	124	160	166	180	176	311	311	313	313
S	119	124	134	131	241	251	271	265	107	107	107	107
O	174	181	195	191	336	349	377	369	100	100	100	100
N	253	263	284	278	336	349	377	369	100	100	100	100
D	325	338	365	357	262	262	262	262	100	100	100	100

Key: Habitat quality retention levels (as % of habitat quality at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 3. *continued*

Table A3.2. Long filamentous algae: Percentage of habitat suitability index (HSI) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (HSI at proposed flow / HSI at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	157	179	201	236	127	127	127	127	100	100	100	100
F	157	180	202	237	157	180	202	237	100	100	100	100
M	164	188	211	248	157	180	202	237	100	100	100	100
A	180	206	232	272	157	180	202	237	100	100	100	100
M	184	211	237	278	157	179	201	236	100	100	100	100
J	162	185	208	244	157	179	201	236	100	100	100	100
J	132	151	170	199	184	211	237	278	157	180	202	237
A	136	155	174	204	180	206	232	272	125	125	127	127
S	152	174	195	229	157	179	201	236	100	100	100	100
O	178	203	228	267	157	180	202	237	100	100	100	100
N	157	180	202	237	157	180	202	237	100	100	100	100
D	157	179	201	236	93	93	93	93	100	100	100	100

Key: Habitat quality retention levels (as % of habitat quality at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 3. *continued*

Table A3.3. Diatoms: Percentage of habitat suitability index (HSI) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (HSI at proposed flow / HSI at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	40	25	18	6	59	59	59	59	100	100	100	100
F	39	25	18	6	40	26	18	6	100	100	100	100
M	41	26	18	6	40	26	18	6	100	100	100	100
A	45	29	20	7	40	26	18	6	100	100	100	100
M	46	30	21	7	40	25	18	6	100	100	100	100
J	54	34	24	8	40	26	18	6	100	100	100	100
J	64	41	29	10	46	30	21	7	40	26	18	6
A	62	40	28	10	45	29	20	7	60	60	59	59
S	57	36	25	9	40	26	18	6	101	101	101	101
O	44	28	20	7	40	26	18	6	100	100	100	100
N	39	25	18	6	40	26	18	6	100	100	100	100
D	40	26	18	6	78	78	78	78	100	100	100	100

Key: Habitat quality retention levels (as % of habitat quality at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. Results for seasonal macroinvertebrate habitat retention analysis: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime.

Table A4.1. Waitaha *Stictocladius*: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	125	128	131	127	105	105	105	105	100	100	100	100
F	121	124	127	123	127	128	128	128	100	100	100	100
M	123	126	129	126	127	131	134	130	100	100	100	100
A	123	126	129	125	127	131	134	130	100	100	100	100
M	121	124	127	123	124	127	130	127	100	100	100	100
J	113	116	119	115	122	125	128	124	100	100	100	100
J	106	109	112	109	121	124	127	123	126	129	129	129
A	107	110	112	109	123	126	129	126	105	105	105	105
S	111	113	116	113	122	125	128	124	100	100	100	100
O	124	127	130	126	127	130	133	130	100	100	100	100
N	121	124	127	123	124	124	124	124	100	100	100	100
D	126	129	132	128	103	103	103	103	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. *continued*

Table A4.2. Waitaha Orthocladiinae: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	111	117	122	128	79	79	79	79	100	100	100	100
F	115	121	126	133	110	112	112	112	100	100	100	100
M	126	132	138	145	110	116	121	127	100	100	100	100
A	138	146	152	160	110	116	121	127	100	100	100	100
M	139	146	152	161	111	117	122	129	100	100	100	100
J	127	134	139	147	119	125	130	137	100	100	100	100
J	115	122	127	133	139	146	152	161	108	113	114	114
A	117	123	128	135	138	145	151	159	79	79	79	79
S	123	129	135	142	119	126	131	138	100	100	100	100
O	135	142	148	156	110	116	121	127	100	100	100	100
N	115	121	126	133	103	104	104	104	100	100	100	100
D	110	116	121	128	86	86	86	86	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. continued

Table A4.3. Waitaha *Neocurupira*: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	57	50	43	36	79	79	79	79	100	100	100	100
F	61	54	46	38	56	55	55	54	100	100	100	100
M	64	56	48	40	56	49	42	35	100	100	100	100
A	70	61	53	44	56	49	42	35	100	100	100	100
M	72	63	55	45	57	50	43	36	100	100	100	100
J	79	70	60	50	62	55	47	39	100	100	100	100
J	87	76	66	55	72	63	55	45	58	53	52	52
A	86	75	65	54	70	61	53	44	79	79	79	79
S	82	72	62	51	62	55	47	39	100	100	100	100
O	68	60	52	43	56	49	42	35	100	100	100	100
N	61	54	46	38	61	60	60	60	100	100	100	100
D	57	50	43	36	86	86	86	86	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. *continued*

Table A4.4. Waitaha Hydrobiosidae: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	101	99	95	88	100	100	100	100	100	100	100	100
F	99	97	93	86	103	103	103	102	100	100	100	100
M	101	99	95	88	103	101	96	90	100	100	100	100
A	103	101	97	90	103	101	96	90	100	100	100	100
M	103	101	97	90	101	99	94	88	100	100	100	100
J	101	99	95	88	99	97	93	87	100	100	100	100
J	100	98	94	87	103	101	97	90	103	102	102	102
A	100	98	94	88	103	101	97	90	100	100	100	100
S	101	99	94	88	100	98	93	87	100	100	100	100
O	103	101	96	90	103	101	96	90	100	100	100	100
N	99	97	93	86	103	103	103	103	100	100	100	100
D	102	100	95	89	101	101	101	101	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. *continued*

Table A4.5. Waitaha *Deleatidium*: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	92	90	88	86	88	88	88	88	100	100	100	100
F	96	94	92	90	92	92	92	92	100	100	100	100
M	100	98	96	93	92	90	88	86	100	100	100	100
A	104	102	100	97	92	90	88	86	100	100	100	100
M	104	102	100	97	92	90	89	86	100	100	100	100
J	103	100	98	96	98	96	94	91	100	100	100	100
J	101	99	97	94	104	102	100	97	92	91	91	91
A	101	99	97	95	104	102	100	97	88	88	88	88
S	102	100	98	95	98	96	94	91	100	100	100	100
O	104	101	99	97	92	90	88	86	100	100	100	100
N	96	94	92	90	92	92	92	92	100	100	100	100
D	92	90	88	86	91	91	91	91	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. *continued*

Table A4.6. Waitaha All invertebrates: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	101	100	97	91	97	97	97	97	100	100	100	100
F	100	99	95	90	103	103	103	103	100	100	100	100
M	103	102	98	92	103	102	98	92	100	100	100	100
A	106	105	101	95	103	102	98	92	100	100	100	100
M	106	105	101	95	101	100	97	91	100	100	100	100
J	104	103	99	93	101	100	96	91	100	100	100	100
J	102	101	97	92	106	105	101	95	102	103	103	103
A	102	101	97	92	106	105	101	95	97	97	97	97
S	103	102	98	92	101	100	97	91	100	100	100	100
O	105	104	100	94	103	102	98	92	100	100	100	100
N	100	99	95	90	102	102	102	102	100	100	100	100
D	102	101	97	92	99	99	99	99	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. *continued*

Table A4.7. Food producing (Waters 1976): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	89	78	68	52	112	112	112	112	100	100	100	100
F	84	75	64	50	91	89	89	88	100	100	100	100
M	83	73	63	49	91	80	69	54	100	100	100	100
A	81	72	62	48	91	80	69	54	100	100	100	100
M	82	72	62	48	88	78	67	52	100	100	100	100
J	84	74	64	49	84	74	64	49	100	100	100	100
J	88	78	67	52	82	72	62	48	94	86	85	85
A	87	77	67	51	81	72	62	48	112	112	112	112
S	85	75	65	50	84	74	64	49	100	100	100	100
O	81	72	62	48	91	80	69	54	100	100	100	100
N	84	75	64	50	98	97	97	97	100	100	100	100
D	90	79	68	53	111	111	111	111	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. *continued*

Table A4.8. *Deleatidium* (mayfly): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m^3/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
J	118	117	114	110	106	106	106	106	100	100	100	100
F	114	113	111	106	120	120	120	120	100	100	100	100
M	115	114	112	107	120	119	116	112	100	100	100	100
A	114	113	111	107	120	119	116	112	100	100	100	100
M	114	113	110	106	118	117	114	110	100	100	100	100
J	108	107	105	101	115	114	111	107	100	100	100	100
J	104	103	100	96	114	113	110	106	120	120	120	120
A	104	103	101	97	114	114	111	107	106	106	106	106
S	106	106	103	99	115	114	111	107	100	100	100	100
O	115	114	111	107	120	119	116	112	100	100	100	100
N	114	113	111	106	119	119	119	119	100	100	100	100
D	119	118	115	111	104	104	104	104	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. *continued*

Table A4.9. *Deleatidium* (Waitaki): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m^3/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				Typical months				Wet months			
Month	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
J	64	55	43	32	94	94	94	94	100	100	100	100
F	64	55	44	32	64	63	63	62	100	100	100	100
M	65	56	44	33	64	55	43	32	100	100	100	100
A	67	58	46	34	64	55	43	32	100	100	100	100
M	69	59	47	35	64	55	43	32	100	100	100	100
J	75	64	51	38	65	55	44	32	100	100	100	100
J	84	72	57	42	69	59	47	35	66	61	60	60
A	83	71	56	41	67	58	45	34	94	94	94	94
S	78	67	52	39	65	55	44	32	100	100	100	100
O	66	57	45	33	64	55	43	32	100	100	100	100
N	64	55	44	32	70	70	70	70	100	100	100	100
D	64	55	43	32	98	98	98	98	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. *continued*

Table A4.10. Hydrobiosidae (Jowett *et al.* 1991): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	104	98	91	83	105	105	105	105	100	100	100	100
F	102	97	90	81	104	104	104	103	100	100	100	100
M	101	96	89	81	104	99	92	83	100	100	100	100
A	100	95	88	79	104	99	92	83	100	100	100	100
M	100	95	88	80	103	98	91	82	100	100	100	100
J	98	93	86	78	102	97	90	81	100	100	100	100
J	98	93	86	78	100	95	88	80	105	102	102	102
A	98	93	86	78	100	95	88	79	105	105	105	105
S	98	93	86	78	102	97	90	81	100	100	100	100
O	100	95	88	80	104	99	92	83	100	100	100	100
N	102	97	90	81	106	106	106	106	100	100	100	100
D	104	99	92	83	103	103	103	103	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. *continued*

Table A4.11. Hydrobiosidae (Waitaki): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	64	55	47	35	90	90	90	90	100	100	100	100
F	65	56	48	36	64	63	63	62	100	100	100	100
M	67	57	48	36	64	55	47	35	100	100	100	100
A	70	60	51	38	64	55	47	35	100	100	100	100
M	72	61	52	39	64	55	47	35	100	100	100	100
J	77	66	56	42	66	56	48	36	100	100	100	100
J	84	72	61	46	72	61	52	39	67	60	59	59
A	83	71	61	46	70	60	51	38	90	90	90	90
S	79	68	58	43	66	56	48	36	100	100	100	100
O	69	59	50	38	64	55	47	35	100	100	100	100
N	65	56	48	36	71	70	70	70	100	100	100	100
D	64	55	47	35	96	96	96	96	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 4. *continued*

Table A4.12. Orthocladiinae (Waitaki): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	82	75	67	58	96	96	96	96	100	100	100	100
F	82	75	67	58	82	81	81	81	100	100	100	100
M	83	76	67	59	82	75	67	58	100	100	100	100
A	85	77	69	60	82	75	67	58	100	100	100	100
M	86	79	70	61	82	75	67	58	100	100	100	100
J	88	81	72	63	82	75	67	59	100	100	100	100
J	92	84	75	66	86	79	70	61	83	79	78	78
A	92	84	75	65	85	77	69	60	96	96	96	96
S	89	82	73	64	82	75	67	59	100	100	100	100
O	84	77	68	60	82	75	67	58	100	100	100	100
N	82	75	67	58	86	85	85	85	100	100	100	100
D	82	75	67	58	99	99	99	99	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. Results for seasonal macroinvertebrate habitat retention analysis: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime.

Table A5.1. Waitaha *Stictocladius*: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	125	128	131	127	122	122	122	122	100	100	100	100
F	121	124	127	123	127	131	134	130	100	100	100	100
M	123	126	129	126	127	131	134	130	100	100	100	100
A	123	126	129	125	127	131	134	130	100	100	100	100
M	121	124	127	123	124	127	130	127	100	100	100	100
J	113	116	119	115	122	125	128	124	101	101	101	101
J	106	109	112	109	121	124	127	123	127	131	134	130
A	107	110	112	109	123	126	129	126	121	121	122	122
S	111	113	116	113	122	125	128	124	102	102	102	102
O	124	127	130	126	127	130	133	130	100	100	100	100
N	121	124	127	123	127	131	134	130	100	100	100	100
D	126	129	132	128	111	111	111	111	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.2. Waitaha Orthocladiinae: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	111	117	122	128	99	99	99	99	100	100	100	100
F	115	121	126	133	110	116	121	127	100	100	100	100
M	126	132	138	145	110	116	121	127	100	100	100	100
A	138	146	152	160	110	116	121	127	100	100	100	100
M	139	146	152	161	111	117	122	129	100	100	100	100
J	127	134	139	147	119	125	130	137	100	100	100	100
J	115	122	127	133	139	146	152	161	110	116	121	127
A	117	123	128	135	138	145	151	159	98	98	99	99
S	123	129	135	142	119	126	131	138	99	99	99	99
O	135	142	148	156	110	116	121	127	100	100	100	100
N	115	121	126	133	110	116	121	127	100	100	100	100
D	110	116	121	128	85	85	85	85	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.3. Waitaha *Neocurupira*: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	57	50	43	36	63	63	63	63	100	100	100	100
F	61	54	46	38	56	49	42	35	100	100	100	100
M	64	56	48	40	56	49	42	35	100	100	100	100
A	70	61	53	44	56	49	42	35	100	100	100	100
M	72	63	55	45	57	50	43	36	100	100	100	100
J	79	70	60	50	62	55	47	39	99	99	99	99
J	87	76	66	55	72	63	55	45	56	49	42	35
A	86	75	65	54	70	61	53	44	63	63	63	63
S	82	72	62	51	62	55	47	39	98	98	98	98
O	68	60	52	43	56	49	42	35	100	100	100	100
N	61	54	46	38	56	49	42	35	100	100	100	100
D	57	50	43	36	72	72	72	72	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.4. Waitaha Hydrobiosidae: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	101	99	95	88	103	103	103	103	100	100	100	100
F	99	97	93	86	103	101	96	90	100	100	100	100
M	101	99	95	88	103	101	96	90	100	100	100	100
A	103	101	97	90	103	101	96	90	100	100	100	100
M	103	101	97	90	101	99	94	88	100	100	100	100
J	101	99	95	88	99	97	93	87	101	101	101	101
J	100	98	94	87	103	101	97	90	103	101	96	90
A	100	98	94	88	103	101	97	90	103	103	103	103
S	101	99	94	88	100	98	93	87	102	102	102	102
O	103	101	96	90	103	101	96	90	100	100	100	100
N	99	97	93	86	103	101	96	90	100	100	100	100
D	102	100	95	89	101	101	101	101	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.5. Waitaha *Deleatidium*: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	92	90	88	86	91	91	91	91	100	100	100	100
F	96	94	92	90	92	90	88	86	100	100	100	100
M	100	98	96	93	92	90	88	86	100	100	100	100
A	104	102	100	97	92	90	88	86	100	100	100	100
M	104	102	100	97	92	90	89	86	100	100	100	100
J	103	100	98	96	98	96	94	91	100	100	100	100
J	101	99	97	94	104	102	100	97	92	90	88	86
A	101	99	97	95	104	102	100	97	91	91	91	91
S	102	100	98	95	98	96	94	91	100	100	100	100
O	104	101	99	97	92	90	88	86	100	100	100	100
N	96	94	92	90	92	90	88	86	100	100	100	100
D	92	90	88	86	89	89	89	89	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.6. Waitaha All invertebrates: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	101	100	97	91	101	101	101	101	100	100	100	100
F	100	99	95	90	103	102	98	92	100	100	100	100
M	103	102	98	92	103	102	98	92	100	100	100	100
A	106	105	101	95	103	102	98	92	100	100	100	100
M	106	105	101	95	101	100	97	91	100	100	100	100
J	104	103	99	93	101	100	96	91	100	100	100	100
J	102	101	97	92	106	105	101	95	103	102	98	92
A	102	101	97	92	106	105	101	95	101	101	101	101
S	103	102	98	92	101	100	97	91	101	101	101	101
O	105	104	100	94	103	102	98	92	100	100	100	100
N	100	99	95	90	103	102	98	92	100	100	100	100
D	102	101	97	92	98	98	98	98	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.7. Food producing (Waters 1976): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m^3/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
J	89	78	68	52	101	101	101	101	100	100	100	100
F	84	75	64	50	91	80	69	54	100	100	100	100
M	83	73	63	49	91	80	69	54	100	100	100	100
A	81	72	62	48	91	80	69	54	100	100	100	100
M	82	72	62	48	88	78	67	52	100	100	100	100
J	84	74	64	49	84	74	64	49	101	101	101	101
J	88	78	67	52	82	72	62	48	91	80	69	54
A	87	77	67	51	81	72	62	48	102	102	101	101
S	85	75	65	50	84	74	64	49	103	103	103	103
O	81	72	62	48	91	80	69	54	100	100	100	100
N	84	75	64	50	91	80	69	54	100	100	100	100
D	90	79	68	53	110	110	110	110	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.8. *Deleatidium* (mayfly): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	118	117	114	110	117	117	117	117	100	100	100	100
F	114	113	111	106	120	119	116	112	100	100	100	100
M	115	114	112	107	120	119	116	112	100	100	100	100
A	114	113	111	107	120	119	116	112	100	100	100	100
M	114	113	110	106	118	117	114	110	100	100	100	100
J	108	107	105	101	115	114	111	107	101	101	101	101
J	104	103	100	96	114	113	110	106	120	119	116	112
A	104	103	101	97	114	114	111	107	117	117	117	117
S	106	106	103	99	115	114	111	107	102	102	102	102
O	115	114	111	107	120	119	116	112	100	100	100	100
N	114	113	111	106	120	119	116	112	100	100	100	100
D	119	118	115	111	110	110	110	110	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.9. *Deleatidium* (Waitaki): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	64	55	43	32	73	73	73	73	100	100	100	100
F	64	55	44	32	64	55	43	32	100	100	100	100
M	65	56	44	33	64	55	43	32	100	100	100	100
A	67	58	46	34	64	55	43	32	100	100	100	100
M	69	59	47	35	64	55	43	32	100	100	100	100
J	75	64	51	38	65	55	44	32	100	100	100	100
J	84	72	57	42	69	59	47	35	64	55	43	32
A	83	71	56	41	67	58	45	34	74	74	73	73
S	78	67	52	39	65	55	44	32	100	100	100	100
O	66	57	45	33	64	55	43	32	100	100	100	100
N	64	55	44	32	64	55	43	32	100	100	100	100
D	64	55	43	32	88	88	88	88	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.10. Hydrobiosidae (Jowett *et al.* 1991): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	104	98	91	83	106	106	106	106	100	100	100	100
F	102	97	90	81	104	99	92	83	100	100	100	100
M	101	96	89	81	104	99	92	83	100	100	100	100
A	100	95	88	79	104	99	92	83	100	100	100	100
M	100	95	88	80	103	98	91	82	100	100	100	100
J	98	93	86	78	102	97	90	81	100	100	100	100
J	98	93	86	78	100	95	88	80	104	99	92	83
A	98	93	86	78	100	95	88	79	107	107	106	106
S	98	93	86	78	102	97	90	81	101	101	101	101
O	100	95	88	80	104	99	92	83	100	100	100	100
N	102	97	90	81	104	99	92	83	100	100	100	100
D	104	99	92	83	106	106	106	106	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.11. Hydrobiosidae (Waitaki): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	64	55	47	35	74	74	74	74	100	100	100	100
F	65	56	48	36	64	55	47	35	100	100	100	100
M	67	57	48	36	64	55	47	35	100	100	100	100
A	70	60	51	38	64	55	47	35	100	100	100	100
M	72	61	52	39	64	55	47	35	100	100	100	100
J	77	66	56	42	66	56	48	36	100	100	100	100
J	84	72	61	46	72	61	52	39	64	55	47	35
A	83	71	61	46	70	60	51	38	74	74	74	74
S	79	68	58	43	66	56	48	36	100	100	100	100
O	69	59	50	38	64	55	47	35	100	100	100	100
N	65	56	48	36	64	55	47	35	100	100	100	100
D	64	55	47	35	85	85	85	85	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 5. *continued*

Table A5.12. Orthocladiinae (Waitaki): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	82	75	67	58	87	87	87	87	100	100	100	100
F	82	75	67	58	82	75	67	58	100	100	100	100
M	83	76	67	59	82	75	67	58	100	100	100	100
A	85	77	69	60	82	75	67	58	100	100	100	100
M	86	79	70	61	82	75	67	58	100	100	100	100
J	88	81	72	63	82	75	67	59	100	100	100	100
J	92	84	75	66	86	79	70	61	82	75	67	58
A	92	84	75	65	85	77	69	60	88	88	87	87
S	89	82	73	64	82	75	67	59	100	100	100	100
O	84	77	68	60	82	75	67	58	100	100	100	100
N	82	75	67	58	82	75	67	58	100	100	100	100
D	82	75	67	58	93	93	93	93	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. Results for seasonal fish habitat retention analysis: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime.

Table A6.1. Brown trout adult (Hayes & Jowett 1994): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				Typical months				Wet months			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	88	81	68	49	105	105	105	105	100	100	100	100
F	86	79	66	47	89	88	88	88	100	100	100	100
M	85	78	65	47	89	82	68	49	100	100	100	100
A	85	78	65	47	89	82	68	49	100	100	100	100
M	85	78	65	47	88	81	67	48	100	100	100	100
J	88	80	67	48	86	79	66	47	100	100	100	100
J	92	84	70	50	85	78	65	47	91	87	86	86
A	91	83	70	50	85	78	65	47	105	105	105	105
S	89	81	68	49	86	79	66	47	100	100	100	100
O	85	78	65	47	89	82	68	49	100	100	100	100
N	86	79	66	47	94	93	93	93	100	100	100	100
D	89	81	68	49	105	105	105	105	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.2. Brown trout adult (Bovee 1995) no substrate: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	70	61	49	34	95	95	95	95	100	100	100	100
F	70	61	49	34	70	68	68	67	100	100	100	100
M	71	61	49	34	70	61	49	34	100	100	100	100
A	73	63	51	35	70	61	49	34	100	100	100	100
M	74	64	52	36	70	61	49	34	100	100	100	100
J	79	68	55	38	70	61	49	34	100	100	100	100
J	85	74	60	41	74	64	52	36	72	67	66	66
A	84	73	59	41	73	63	51	35	95	95	95	95
S	80	70	56	39	70	61	49	34	100	100	100	100
O	72	63	51	35	70	61	49	34	100	100	100	100
N	70	61	49	34	77	76	76	76	100	100	100	100
D	70	61	49	34	99	99	99	99	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.3. Brown trout juvenile (Bovee 1995) no substrate: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m^3/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				Typical months				Wet months			
Month	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
J	143	141	134	117	134	134	134	134	100	100	100	100
F	128	126	120	105	149	149	149	149	100	100	100	100
M	122	120	114	100	149	147	140	122	100	100	100	100
A	113	111	106	92	149	147	140	122	100	100	100	100
M	111	109	104	90	141	139	132	115	100	100	100	100
J	105	104	99	86	125	124	118	103	100	100	100	100
J	102	101	96	83	111	109	104	90	149	149	149	149
A	102	101	96	84	113	112	106	93	134	134	134	134
S	104	103	98	85	125	123	117	102	100	100	100	100
O	115	114	108	94	149	147	140	122	100	100	100	100
N	128	126	120	105	149	149	149	149	100	100	100	100
D	146	144	137	119	125	125	125	125	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.4. Brown trout 15–25cm (Raleigh *et al.* 1986): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	115	112	107	98	110	110	110	110	100	100	100	100
F	113	109	105	96	115	114	114	114	100	100	100	100
M	111	107	103	94	115	112	107	98	100	100	100	100
A	106	102	98	90	115	112	107	98	100	100	100	100
M	104	101	97	88	115	111	107	97	100	100	100	100
J	100	97	93	85	112	109	104	95	100	100	100	100
J	98	95	91	83	104	101	97	88	116	114	113	113
A	98	95	91	83	106	103	99	90	110	110	110	110
S	99	96	92	84	112	108	104	95	100	100	100	100
O	107	104	100	91	115	112	107	98	100	100	100	100
N	113	109	105	96	117	117	117	117	100	100	100	100
D	115	112	107	98	105	105	105	105	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.5. Koaro: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	175	167	186	221	179	179	179	179	100	100	100	100
F	145	139	155	184	173	172	172	172	100	100	100	100
M	127	121	135	160	173	165	184	219	100	100	100	100
A	101	96	107	127	173	165	184	219	100	100	100	100
M	99	95	106	126	173	165	184	219	100	100	100	100
J	92	88	97	116	138	132	146	174	100	100	100	100
J	98	93	104	123	99	95	106	126	173	163	163	163
A	97	93	104	123	101	97	108	128	179	179	179	179
S	94	89	100	118	137	131	145	173	100	100	100	100
O	107	102	114	135	173	165	184	219	100	100	100	100
N	145	139	155	184	175	175	175	175	100	100	100	100
D	172	164	183	217	144	144	144	144	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.6. Longfin eel > 300 mm: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	111	109	105	96	110	110	110	110	100	100	100	100
F	108	107	103	94	110	110	110	110	100	100	100	100
M	106	104	101	91	110	108	105	95	100	100	100	100
A	101	100	96	87	110	108	105	95	100	100	100	100
M	100	98	95	86	111	109	105	96	100	100	100	100
J	98	96	93	84	107	106	102	93	100	100	100	100
J	98	96	93	84	100	98	95	86	110	110	110	110
A	98	96	93	84	101	100	96	88	110	110	110	110
S	97	96	93	84	107	106	102	93	100	100	100	100
O	102	101	97	89	110	108	105	95	100	100	100	100
N	108	107	103	94	111	111	111	111	100	100	100	100
D	111	109	105	96	105	105	105	105	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.7. Longfin eel < 300 mm: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	147	139	135	134	114	114	114	114	100	100	100	100
F	143	136	132	130	149	149	149	149	100	100	100	100
M	142	135	131	129	149	142	138	136	100	100	100	100
A	135	128	124	122	149	142	138	136	100	100	100	100
M	132	125	121	120	146	138	134	133	100	100	100	100
J	116	110	107	106	144	136	132	130	100	100	100	100
J	107	101	98	97	132	125	121	120	149	146	145	145
A	108	102	99	98	135	128	125	123	114	114	114	114
S	113	107	104	103	143	136	132	130	100	100	100	100
O	138	131	127	125	149	141	137	135	100	100	100	100
N	143	136	132	130	147	147	147	147	100	100	100	100
D	147	140	136	134	106	106	106	106	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.8. Shortfin eel > 300 mm: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	141	145	149	148	123	123	123	123	100	100	100	100
F	132	136	140	139	142	142	142	143	100	100	100	100
M	127	131	134	133	142	146	150	149	100	100	100	100
A	117	120	123	122	142	146	150	149	100	100	100	100
M	114	117	121	120	141	145	149	148	100	100	100	100
J	108	111	114	113	130	134	138	137	100	100	100	100
J	103	106	109	108	114	117	121	120	141	144	144	144
A	104	107	110	109	117	120	124	123	123	123	123	123
S	106	109	112	111	130	134	137	136	100	100	100	100
O	120	123	126	125	142	146	150	149	100	100	100	100
N	132	136	140	139	140	140	140	140	100	100	100	100
D	142	146	150	148	114	114	114	114	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.9. Shortfin eel < 300 mm: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	162	170	175	186	100	100	100	100	100	100	100	100
F	171	181	186	197	157	159	159	160	100	100	100	100
M	172	181	186	198	157	165	170	180	100	100	100	100
A	161	169	174	185	157	165	170	180	100	100	100	100
M	158	167	172	182	163	171	176	187	100	100	100	100
J	135	142	146	155	172	182	187	198	100	100	100	100
J	117	124	127	135	158	167	172	182	153	161	161	161
A	119	126	129	137	161	170	175	186	100	100	100	100
S	128	135	139	148	172	182	187	199	100	100	100	100
O	165	173	179	190	157	165	170	181	100	100	100	100
N	171	181	186	197	146	147	147	147	100	100	100	100
D	159	168	173	183	93	93	93	93	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.10. Torrentfish: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	189	193	202	176	241	241	241	241	100	100	100	100
F	126	129	135	117	227	227	227	228	100	100	100	100
M	109	112	117	102	227	232	243	211	100	100	100	100
A	95	98	102	89	227	232	243	211	100	100	100	100
M	95	97	101	88	180	184	192	167	100	100	100	100
J	94	96	101	88	118	121	126	110	100	100	100	100
J	97	99	104	90	95	97	101	88	226	224	225	225
A	97	99	104	90	96	98	103	89	241	241	241	241
S	95	97	102	89	117	120	125	109	100	100	100	100
O	98	100	105	91	224	230	240	209	100	100	100	100
N	126	129	135	117	228	227	227	227	100	100	100	100
D	205	210	220	191	217	217	217	217	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.11. Lamprey: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m^3/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				Typical months				Wet months			
Month	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
J	107	118	116	101	94	94	94	94	100	100	100	100
F	112	124	122	106	112	114	114	115	100	100	100	100
M	117	130	128	111	112	124	122	106	100	100	100	100
A	119	132	130	113	112	124	122	106	100	100	100	100
M	115	127	125	108	107	118	116	101	100	100	100	100
J	117	129	127	110	114	127	124	108	100	100	100	100
J	113	125	123	107	115	127	125	108	109	118	119	119
A	114	126	124	108	119	132	130	113	94	94	94	94
S	117	129	127	110	115	127	125	108	100	100	100	100
O	119	132	130	113	112	124	122	106	100	100	100	100
N	112	124	122	106	104	105	105	105	100	100	100	100
D	110	122	120	104	95	95	95	95	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.12. Common bully: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	153	156	160	172	101	101	101	101	100	100	100	100
F	160	164	168	181	151	152	152	153	100	100	100	100
M	161	165	169	182	151	154	158	170	100	100	100	100
A	154	158	161	174	151	154	158	170	100	100	100	100
M	148	152	155	168	153	156	160	172	100	100	100	100
J	131	134	137	148	161	165	168	182	100	100	100	100
J	116	118	121	130	148	152	155	168	148	154	154	154
A	117	120	123	133	155	159	162	175	101	101	101	101
S	126	128	131	142	161	165	168	182	100	100	100	100
O	159	162	166	179	151	154	158	171	100	100	100	100
N	160	164	168	181	142	143	143	143	100	100	100	100
D	151	155	158	171	94	94	94	94	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.13. Redfin bully: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	140	140	144	162	84	84	84	84	100	100	100	100
F	148	148	152	171	136	137	137	137	100	100	100	100
M	160	161	165	186	136	136	140	158	100	100	100	100
A	164	165	169	190	136	136	140	158	100	100	100	100
M	165	165	170	191	140	141	145	163	100	100	100	100
J	138	138	142	160	152	153	157	177	100	100	100	100
J	117	117	120	136	165	165	170	191	133	136	136	136
A	119	120	123	139	164	165	169	191	84	84	84	84
S	130	130	134	151	153	154	158	178	100	100	100	100
O	165	165	170	191	136	136	140	158	100	100	100	100
N	148	148	152	171	128	129	129	129	100	100	100	100
D	136	137	140	158	84	84	84	84	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.14. Banded kokopu adult: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	67	73	80	75	52	52	52	52	100	100	100	100
F	85	93	102	96	64	64	64	65	100	100	100	100
M	99	108	119	111	64	70	76	71	100	100	100	100
A	119	131	143	134	64	70	76	71	100	100	100	100
M	115	126	138	129	68	75	82	77	100	100	100	100
J	118	129	141	132	90	99	108	101	100	100	100	100
J	112	123	135	126	115	126	138	129	62	67	67	67
A	112	123	135	126	118	130	142	133	52	52	52	52
S	116	127	140	130	91	100	109	102	100	100	100	100
O	114	125	137	128	64	70	77	72	100	100	100	100
N	85	93	102	96	60	61	61	61	100	100	100	100
D	66	72	79	74	61	61	61	61	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.15. Shortjawed kokopu: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m^3/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				Typical months				Wet months			
Month	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
J	112	114	108	101	73	73	73	73	100	100	100	100
F	135	137	130	122	102	103	103	103	100	100	100	100
M	142	145	137	129	102	104	99	93	100	100	100	100
A	142	145	137	129	102	104	99	93	100	100	100	100
M	135	137	130	122	115	117	111	104	100	100	100	100
J	122	124	118	111	138	141	133	125	100	100	100	100
J	110	112	106	99	135	137	130	122	102	105	105	105
A	111	113	107	101	142	145	137	129	73	73	73	73
S	117	119	113	106	139	141	134	126	100	100	100	100
O	144	147	139	131	103	105	99	93	100	100	100	100
N	135	137	130	122	100	100	100	100	100	100	100	100
D	107	109	103	97	71	71	71	71	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 6. *continued*

Table A6.16. Giant kokopu: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	92	95	93	92	77	77	77	77	100	100	100	100
F	103	107	104	103	90	90	90	90	100	100	100	100
M	110	114	111	110	90	93	91	90	100	100	100	100
A	117	121	118	117	90	93	91	90	100	100	100	100
M	114	118	116	115	93	96	94	93	100	100	100	100
J	108	112	109	108	106	109	107	106	100	100	100	100
J	103	106	104	103	114	118	116	115	90	92	92	92
A	103	107	104	103	117	121	118	117	77	77	77	77
S	106	110	107	106	106	110	107	106	100	100	100	100
O	116	120	117	116	90	93	91	90	100	100	100	100
N	103	107	104	103	89	89	89	89	100	100	100	100
D	91	94	92	91	80	80	80	80	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. Results for seasonal fish habitat retention analysis: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime.

Table A7.1. Brown trout adult (Hayes & Jowett 1994): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	88	81	68	49	96	96	96	96	100	100	100	100
F	86	79	66	47	89	82	68	49	100	100	100	100
M	85	78	65	47	89	82	68	49	100	100	100	100
A	85	78	65	47	89	82	68	49	100	100	100	100
M	85	78	65	47	88	81	67	48	100	100	100	100
J	88	80	67	48	86	79	66	47	100	100	100	100
J	92	84	70	50	85	78	65	47	89	82	68	49
A	91	83	70	50	85	78	65	47	96	96	96	96
S	89	81	68	49	86	79	66	47	101	101	101	101
O	85	78	65	47	89	82	68	49	100	100	100	100
N	86	79	66	47	89	82	68	49	100	100	100	100
D	89	81	68	49	103	103	103	103	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.2. Brown trout adult (Bovee 1995) no substrate: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	70	61	49	34	80	80	80	80	100	100	100	100
F	70	61	49	34	70	61	49	34	100	100	100	100
M	71	61	49	34	70	61	49	34	100	100	100	100
A	73	63	51	35	70	61	49	34	100	100	100	100
M	74	64	52	36	70	61	49	34	100	100	100	100
J	79	68	55	38	70	61	49	34	100	100	100	100
J	85	74	60	41	74	64	52	36	70	61	49	34
A	84	73	59	41	73	63	51	35	80	80	80	80
S	80	70	56	39	70	61	49	34	100	100	100	100
O	72	63	51	35	70	61	49	34	100	100	100	100
N	70	61	49	34	70	61	49	34	100	100	100	100
D	70	61	49	34	90	90	90	90	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.3. Brown trout juvenile (Bovee 1995) no substrate: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	143	141	134	117	148	148	148	148	100	100	100	100
F	128	126	120	105	149	147	140	122	100	100	100	100
M	122	120	114	100	149	147	140	122	100	100	100	100
A	113	111	106	92	149	147	140	122	100	100	100	100
M	111	109	104	90	141	139	132	115	100	100	100	100
J	105	104	99	86	125	124	118	103	101	101	101	101
J	102	101	96	83	111	109	104	90	149	147	140	122
A	102	101	96	84	113	112	106	93	147	147	148	148
S	104	103	98	85	125	123	117	102	105	105	105	105
O	115	114	108	94	149	147	140	122	100	100	100	100
N	128	126	120	105	149	147	140	122	100	100	100	100
D	146	144	137	119	140	140	140	140	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.4. Brown trout 15–25cm (Raleigh *et al.* 1986): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	115	112	107	98	117	117	117	117	100	100	100	100
F	113	109	105	96	115	112	107	98	100	100	100	100
M	111	107	103	94	115	112	107	98	100	100	100	100
A	106	102	98	90	115	112	107	98	100	100	100	100
M	104	101	97	88	115	111	107	97	100	100	100	100
J	100	97	93	85	112	109	104	95	100	100	100	100
J	98	95	91	83	104	101	97	88	115	112	107	98
A	98	95	91	83	106	103	99	90	117	117	117	117
S	99	96	92	84	112	108	104	95	100	100	100	100
O	107	104	100	91	115	112	107	98	100	100	100	100
N	113	109	105	96	115	112	107	98	100	100	100	100
D	115	112	107	98	114	114	114	114	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.5. Koaro: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	175	167	186	221	175	175	175	175	100	100	100	100
F	145	139	155	184	173	165	184	219	100	100	100	100
M	127	121	135	160	173	165	184	219	100	100	100	100
A	101	96	107	127	173	165	184	219	100	100	100	100
M	99	95	106	126	173	165	184	219	100	100	100	100
J	92	88	97	116	138	132	146	174	100	100	100	100
J	98	93	104	123	99	95	106	126	173	165	184	219
A	97	93	104	123	101	97	108	128	176	176	175	175
S	94	89	100	118	137	131	145	173	99	99	99	99
O	107	102	114	135	173	165	184	219	100	100	100	100
N	145	139	155	184	173	165	184	219	100	100	100	100
D	172	164	183	217	187	187	187	187	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.6. Longfin eel > 300mm: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	111	109	105	96	112	112	112	112	100	100	100	100
F	108	107	103	94	110	108	105	95	100	100	100	100
M	106	104	101	91	110	108	105	95	100	100	100	100
A	101	100	96	87	110	108	105	95	100	100	100	100
M	100	98	95	86	111	109	105	96	100	100	100	100
J	98	96	93	84	107	106	102	93	100	100	100	100
J	98	96	93	84	100	98	95	86	110	108	105	95
A	98	96	93	84	101	100	96	88	112	112	112	112
S	97	96	93	84	107	106	102	93	99	99	99	99
O	102	101	97	89	110	108	105	95	100	100	100	100
N	108	107	103	94	110	108	105	95	100	100	100	100
D	111	109	105	96	112	112	112	112	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.7. Longfin eel < 300 mm: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				Typical months				Wet months			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	147	139	135	134	143	143	143	143	100	100	100	100
F	143	136	132	130	149	142	138	136	100	100	100	100
M	142	135	131	129	149	142	138	136	100	100	100	100
A	135	128	124	122	149	142	138	136	100	100	100	100
M	132	125	121	120	146	138	134	133	100	100	100	100
J	116	110	107	106	144	136	132	130	101	101	101	101
J	107	101	98	97	132	125	121	120	149	142	138	136
A	108	102	99	98	135	128	125	123	142	142	143	143
S	113	107	104	103	143	136	132	130	102	102	102	102
O	138	131	127	125	149	141	137	135	100	100	100	100
N	143	136	132	130	149	142	138	136	100	100	100	100
D	147	140	136	134	125	125	125	125	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.8. Shortfin eel > 300 mm: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	141	145	149	148	139	139	139	139	100	100	100	100
F	132	136	140	139	142	146	150	149	100	100	100	100
M	127	131	134	133	142	146	150	149	100	100	100	100
A	117	120	123	122	142	146	150	149	100	100	100	100
M	114	117	121	120	141	145	149	148	100	100	100	100
J	108	111	114	113	130	134	138	137	100	100	100	100
J	103	106	109	108	114	117	121	120	142	146	150	149
A	104	107	110	109	117	120	124	123	138	138	139	139
S	106	109	112	111	130	134	137	136	100	100	100	100
O	120	123	126	125	142	146	150	149	100	100	100	100
N	132	136	140	139	142	146	150	149	100	100	100	100
D	142	146	150	148	130	130	130	130	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.9. Shortfin eel < 300 mm: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	162	170	175	186	140	140	140	140	100	100	100	100
F	171	181	186	197	157	165	170	180	100	100	100	100
M	172	181	186	198	157	165	170	180	100	100	100	100
A	161	169	174	185	157	165	170	180	100	100	100	100
M	158	167	172	182	163	171	176	187	100	100	100	100
J	135	142	146	155	172	182	187	198	99	99	99	99
J	117	124	127	135	158	167	172	182	157	165	170	180
A	119	126	129	137	161	170	175	186	138	138	140	140
S	128	135	139	148	172	182	187	199	97	97	97	97
O	165	173	179	190	157	165	170	181	100	100	100	100
N	171	181	186	197	157	165	170	180	100	100	100	100
D	159	168	173	183	112	112	112	112	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.10. Torrentfish: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	189	193	202	176	231	231	231	231	100	100	100	100
F	126	129	135	117	227	232	243	211	100	100	100	100
M	109	112	117	102	227	232	243	211	100	100	100	100
A	95	98	102	89	227	232	243	211	100	100	100	100
M	95	97	101	88	180	184	192	167	100	100	100	100
J	94	96	101	88	118	121	126	110	106	106	106	106
J	97	99	104	90	95	97	101	88	227	232	243	211
A	97	99	104	90	96	98	103	89	232	232	231	231
S	95	97	102	89	117	120	125	109	120	120	120	120
O	98	100	105	91	224	230	240	209	100	100	100	100
N	126	129	135	117	227	232	243	211	100	100	100	100
D	205	210	220	191	241	241	241	241	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.11. Lamprey: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m^3/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				Typical months				Wet months			
Month	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
J	107	118	116	101	101	101	101	101	100	100	100	100
F	112	124	122	106	112	124	122	106	100	100	100	100
M	117	130	128	111	112	124	122	106	100	100	100	100
A	119	132	130	113	112	124	122	106	100	100	100	100
M	115	127	125	108	107	118	116	101	100	100	100	100
J	117	129	127	110	114	127	124	108	101	101	101	101
J	113	125	123	107	115	127	125	108	112	124	122	106
A	114	126	124	108	119	132	130	113	101	101	101	101
S	117	129	127	110	115	127	125	108	105	105	105	105
O	119	132	130	113	112	124	122	106	100	100	100	100
N	112	124	122	106	112	124	122	106	100	100	100	100
D	110	122	120	104	96	96	96	96	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)						
Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.12. Common bully: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	153	156	160	172	136	136	136	136	100	100	100	100
F	160	164	168	181	151	154	158	170	100	100	100	100
M	161	165	169	182	151	154	158	170	100	100	100	100
A	154	158	161	174	151	154	158	170	100	100	100	100
M	148	152	155	168	153	156	160	172	100	100	100	100
J	131	134	137	148	161	165	168	182	100	100	100	100
J	116	118	121	130	148	152	155	168	151	154	158	170
A	117	120	123	133	155	159	162	175	135	135	136	136
S	126	128	131	142	161	165	168	182	99	99	99	99
O	159	162	166	179	151	154	158	171	100	100	100	100
N	160	164	168	181	151	154	158	170	100	100	100	100
D	151	155	158	171	112	112	112	112	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.13. Redfin bully: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	140	140	144	162	122	122	122	122	100	100	100	100
F	148	148	152	171	136	136	140	158	100	100	100	100
M	160	161	165	186	136	136	140	158	100	100	100	100
A	164	165	169	190	136	136	140	158	100	100	100	100
M	165	165	170	191	140	141	145	163	100	100	100	100
J	138	138	142	160	152	153	157	177	100	100	100	100
J	117	117	120	136	165	165	170	191	136	136	140	158
A	119	120	123	139	164	165	169	191	121	121	122	122
S	130	130	134	151	153	154	158	178	97	97	97	97
O	165	165	170	191	136	136	140	158	100	100	100	100
N	148	148	152	171	136	136	140	158	100	100	100	100
D	136	137	140	158	94	94	94	94	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.14. Banded kokopu adult: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	67	73	80	75	60	60	60	60	100	100	100	100
F	85	93	102	96	64	70	76	71	100	100	100	100
M	99	108	119	111	64	70	76	71	100	100	100	100
A	119	131	143	134	64	70	76	71	100	100	100	100
M	115	126	138	129	68	75	82	77	100	100	100	100
J	118	129	141	132	90	99	108	101	98	98	98	98
J	112	123	135	126	115	126	138	129	64	70	76	71
A	112	123	135	126	118	130	142	133	59	59	60	60
S	116	127	140	130	91	100	109	102	95	95	95	95
O	114	125	137	128	64	70	77	72	100	100	100	100
N	85	93	102	96	64	70	76	71	100	100	100	100
D	66	72	79	74	54	54	54	54	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.15. Shortjawed kokopu: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	112	114	108	101	97	97	97	97	100	100	100	100
F	135	137	130	122	102	104	99	93	100	100	100	100
M	142	145	137	129	102	104	99	93	100	100	100	100
A	142	145	137	129	102	104	99	93	100	100	100	100
M	135	137	130	122	115	117	111	104	100	100	100	100
J	122	124	118	111	138	141	133	125	98	98	98	98
J	110	112	106	99	135	137	130	122	102	104	99	93
A	111	113	107	101	142	145	137	129	96	96	97	97
S	117	119	113	106	139	141	134	126	92	92	92	92
O	144	147	139	131	103	105	99	93	100	100	100	100
N	135	137	130	122	102	104	99	93	100	100	100	100
D	107	109	103	97	82	82	82	82	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 7. *continued*

Table A7.16. Giant kokopu: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m^3/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
J	92	95	93	92	88	88	88	88	100	100	100	100
F	103	107	104	103	90	93	91	90	100	100	100	100
M	110	114	111	110	90	93	91	90	100	100	100	100
A	117	121	118	117	90	93	91	90	100	100	100	100
M	114	118	116	115	93	96	94	93	100	100	100	100
J	108	112	109	108	106	109	107	106	99	99	99	99
J	103	106	104	103	114	118	116	115	90	93	91	90
A	103	107	104	103	117	121	118	117	88	88	88	88
S	106	110	107	106	106	110	107	106	98	98	98	98
O	116	120	117	116	90	93	91	90	100	100	100	100
N	103	107	104	103	90	93	91	90	100	100	100	100
D	91	94	92	91	82	82	82	82	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 8. Results for seasonal blue duck habitat retention analysis: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime.

Table A8.1. Waitaha blue duck (adult): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	147	152	152	160	94	94	94	94	100	100	100	100
F	155	161	161	170	144	145	145	146	100	100	100	100
M	159	165	165	174	144	149	149	157	100	100	100	100
A	157	163	163	172	144	149	149	157	100	100	100	100
M	156	162	162	171	147	153	153	161	100	100	100	100
J	135	140	140	148	157	162	163	172	100	100	100	100
J	117	121	121	128	156	162	162	171	141	147	147	147
A	119	124	124	130	157	163	163	172	94	94	94	94
S	129	133	133	141	157	163	163	172	100	100	100	100
O	160	165	165	175	144	149	149	157	100	100	100	100
N	155	161	161	170	134	136	136	136	100	100	100	100
D	145	150	150	158	90	90	90	90	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 8. *continued*

Table A8.2. Blue duck (adult) (Collier & Wakelin 1995): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 19 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	136	143	146	166	73	73	73	73	100	100	100	100
F	156	164	168	190	132	134	134	135	100	100	100	100
M	170	179	183	208	132	139	142	161	100	100	100	100
A	184	193	198	225	132	139	142	161	100	100	100	100
M	187	197	202	229	137	144	148	168	100	100	100	100
J	152	159	163	186	161	169	173	197	100	100	100	100
J	123	129	133	151	187	197	202	229	129	135	136	136
A	126	133	136	154	184	193	198	225	73	73	73	73
S	141	148	152	172	162	170	174	198	100	100	100	100
O	184	193	198	225	132	139	142	161	100	100	100	100
N	156	164	168	190	121	122	122	122	100	100	100	100
D	133	139	143	162	75	75	75	75	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 9. Results for seasonal blue duck habitat retention analysis: Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime.

Table A9.1. Waitaha blue duck (adult): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m³/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**	**5 m³/s**	**4 m³/s**	**3 m³/s**	**2 m³/s**
J	147	152	152	160	129	129	129	129	100	100	100	100
F	155	161	161	170	144	149	149	157	100	100	100	100
M	159	165	165	174	144	149	149	157	100	100	100	100
A	157	163	163	172	144	149	149	157	100	100	100	100
M	156	162	162	171	147	153	153	161	100	100	100	100
J	135	140	140	148	157	162	163	172	100	100	100	100
J	117	121	121	128	156	162	162	171	144	149	149	157
A	119	124	124	130	157	163	163	172	127	127	129	129
S	129	133	133	141	157	163	163	172	98	98	98	98
O	160	165	165	175	144	149	149	157	100	100	100	100
N	155	161	161	170	144	149	149	157	100	100	100	100
D	145	150	150	158	103	103	103	103	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%

Appendix 9. *continued*

Table A9.2. Blue duck (adult) (Collier & Wakelin 1995): Percentage of modelled habitat availability (WUA) at the natural dry, typical and wet month flows predicted to be retained by four residual flow options under a 23 m^3/s abstraction regime (WUA at proposed flow / WUA at natural flow * 100).

	Dry months				**Typical months**				**Wet months**			
Month	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**	**5 m^3/s**	**4 m^3/s**	**3 m^3/s**	**2 m^3/s**
J	136	143	146	166	114	114	114	114	100	100	100	100
F	156	164	168	190	132	139	142	161	100	100	100	100
M	170	179	183	208	132	139	142	161	100	100	100	100
A	184	193	198	225	132	139	142	161	100	100	100	100
M	187	197	202	229	137	144	148	168	100	100	100	100
J	152	159	163	186	161	169	173	197	100	100	100	100
J	123	129	133	151	187	197	202	229	132	139	142	161
A	126	133	136	154	184	193	198	225	113	113	114	114
S	141	148	152	172	162	170	174	198	97	97	97	97
O	184	193	198	225	132	139	142	161	100	100	100	100
N	156	164	168	190	132	139	142	161	100	100	100	100
D	133	139	143	162	82	82	82	82	100	100	100	100

Key: Habitat quality retention levels (as % of habitat at the natural seasonal flow statistic)

Habitat gain	100-110%	110-120%	120-130%	130-140%	>140%	
Habitat loss	90-100%	80-90%	70-80%	60-70%	50-60%	<50%