Ian Jowett Consulting

Minimum flow requirements for the Waiaua, Haparapara, and Kereu rivers

Client Report: IJ0909

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Ian Jowett

Prepared for

Environment Bay of Plenty

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Pukekohe 2120, New Zealand

Phone +64-9-239 1837, Mob 021 944 447

ian.jowett@ihug.co.nz

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Executive summary

The Waiaua, Haparapara, and Kereu rivers all flow directly to the sea on the north eastern side of the East Cape. All rivers have some potential to supply water to nearby agricultural land.

The Waiaua River is about 9 km east of Opotiki. The river is about 20 km long with the lower 10 km of river in farmland and the upper part in unmodified native forest. There are some existing takes for agricultural purposes.

The Haparapara River is about 43 km NE of Opotiki. The river is about 34 km long and has its headwaters at about 1000 m near the Raukumara Ranges. The river flows through native forest for almost its entire length. The Kereu River is about 52 km NE of Opotiki and is similar to the Haparapara River.

Environment Bay of Plenty commissioned instream habitat surveys to assess minimum flow requirements in these three rivers.

The Waiaua River is the smallest river of the three with an estimated median flow of 3.16 m^3/s, a natural 7-day mean annual low flow (MALF) 0.539 m^3/s and an estimated natural 5 year low flow of 0.373 m^3/s just above the State Highway 35 Bridge. An instream habitat survey was carried out in two reaches of this section of river. The lower survey reach was 1 km above the SH 35 bridge and just above the tidally affected part of the river. The upstream reach was at Gaskill Road, where the river is less confined by willows with more exposed gravel banks.

The Haparapara and Kereu rivers are similar in size and character. The Haparapara at SH35 has an estimated median flow of 5.9 m^3/s, with a MALF and 5 year low flow of 1.91 m^3/s and 1.58 m^3/s, respectively. The Kereu at SH35 has an estimated median flow of 4.2 m^3/s, with a MALF and 5 year low flow of 1.26 m^3/s and 1.02 m^3/s, respectively. Instream habitat surveys of these two rivers were carried out about 1 km above the SH 35 bridges.

The Waiaua, Haparapara and Kereu rivers all contain diverse native fish communities because they are close to the sea and their catchments are not extensively developed. Because of the diverse fish communities, a habitat retention standard of 90% of habitat at MALF, as specified in the RWLP, is an appropriate standard.

The instream minimum flow requirement (IMFR) for all three rivers was evaluated according to methods described in the Environment BOP Regional Water and Land Plan. For all rivers, the IMFR was greater than the MALF and there was no water available for allocation under the policy of allocating the difference between the IMFR and the 5 year low flow.

The instream minimum flow requirement for the Waiaua River was 0.658 m^3/s to maintain 90% of maximum habitat for large eels. This flow is about 20% higher than MALF and is almost double the 5 year low flow.

The instream minimum flow requirement for the Haparapara River was 3.805 m^3/s to maintain 90% of maximum habitat for torrentfish. This flow is 200% higher than MALF and is more than double the 5 year low flow.

The instream minimum flow requirement for the Kereu River was 2.154 m^3/s to maintain 90% of maximum habitat for bluegill bullies. This flow is 70% higher than MALF and is about double the 5 year low flow.

In my opinion, the fact that instream minimum flow requirements (IMFR) are greater than MALF for these rivers indicates a problem with the methods specified in the EBOP RWLP. The methods were largely developed and tested for streams and rivers with stable flow regimes, typical of pumice catchments. There are also more habitat suitability curves available for native fish than were available when the EBOP method was developed and tested. In rivers with less stable flow regimes, the ratio of median flow to MALF is high, and flows that provide maximum habitat can be just under median flow, resulting in an IMFR that can be considerably greater than MALF. There appear to be two problems with the method. The first is that the minimum flow requirement for a species is taken as the flow that provides a percentage of maximum habitat when the flow that provides maximum habitat is less than the median flow. The other is that the IMFR is set for the fish species with the highest minimum flow requirement.

An alternative method as used by the Southland Regional Council (Jowett & Hayes 2004) is to select a target fish species and set the minimum flow requirement so that the minimum flow provides a percentage of habitat at MALF or as a percentage of maximum habitat if the flow that provides maximum habitat is less than MALF.

The proposed National Environmental Standard on ecological flows suggests a default minimum flow of 90% of MALF and a default maximum allocation of 30% of MALF for small streams where the degree of hydrologic alteration by abstraction or other forms of flow regulation is low. For the Waiaua River, this would be a minimum flow of 0.485 m^3/s and a maximum allocatable flow of 0.162 m^3/s. For the Haparapara River, this method would give a minimum flow of 1.715 m^3/s and a maximum allocatable flow of 0.573 m^3/s, and for the Kereu, a minimum flow of 1.134 m^3/s and a maximum allocatable flow of 0.378 m^3/s.

1 Introduction

The Waiaua, Haparapara, and Kereu rivers all flow directly to the sea on the north eastern side of the East Cape. All rivers have some potential to supply water to nearby agricultural land.

The Waiaua River is about 9 km east of Opotiki. The river is about 20 km long with the lower 10 km of river in farmland and the upper part in unmodified native forest. The river has some existing takes for agricultural purposes.

The Haparapara River is about 43 km NE of Opotiki. The river is about 34 km long and has its headwaters at about 1000 m near the Raukumara Ranges. The river flows through native forest for almost its entire length.

The Kereu River is about 52 km NE of Opotiki and is similar to the Haparapara River.

Environment Bay of Plenty (EBOP) commissioned an instream habitat survey to assess minimum flow requirements (IMFR) in these three rivers.

This report evaluates minimum flow requirements for the rivers using information on the fish community obtained from the freshwater fish database (NZFFD) and instream habitat data collected in April 2010.

2 Description of rivers and instream habitat survey reaches

The headwaters of the Waiaua River are in native forest and the Motu Road follows the river to its head. The river flats are farmed in the lower 10 km of river and the instream habitat survey was carried out in two reaches of this section of river (Fig. 2.1) on 27 April 2010. The cross-section calibration measurements were made on 15 and 19 April, before the main survey.

The lower survey reach was 1 km above the SH 35 bridge and just above the tidally affected part of the river. This part of the river is confined by willows and its substrate is small gravel. The river is a series of long runs and short riffles, with few pools mainly on bends.

The upper reach was at Gaskill Road, where the river is less confined by willows and there are more exposed gravel banks. The substrate is gravel with large gravels in the riffles. Like the downstream reach, the river is mostly runs with short riffles and occasional pools mostly at bends.

The Haparapara River flows through native forest except for the last 1 km before the sea, where there is farmland. The only road access is where the State Highway 35 crosses the river 1.3 km from the sea. The river is has a gravel bed that covers most of the valley floor, and it is possible to drive up the river in a 4WD vehicle.

The survey reach was about 1.3 km long and began about 0.2 km upstream of the SH 35 bridge (Fig. 2.2). The full survey of this reach was made on 3 May 2010, with calibration measurements carried out in the previous month.

The Kereu River is about 3 km NE of Te Kaha and is similar to the Haparapara, with native forest over most of the catchment and farmland on the narrow coastal strip. The river is accessible from SH 35 using 4WD vehicles.

The survey reach was selected between the Kaumero Stream and the State Highway 35 Bridge. The survey reach was about 1 km long and began about 0.3 km upstream of the SH 35 bridge (Fig. 2.3). The full survey of this reach was made on 4 May 2010, with calibration measurements carried out in the previous month.

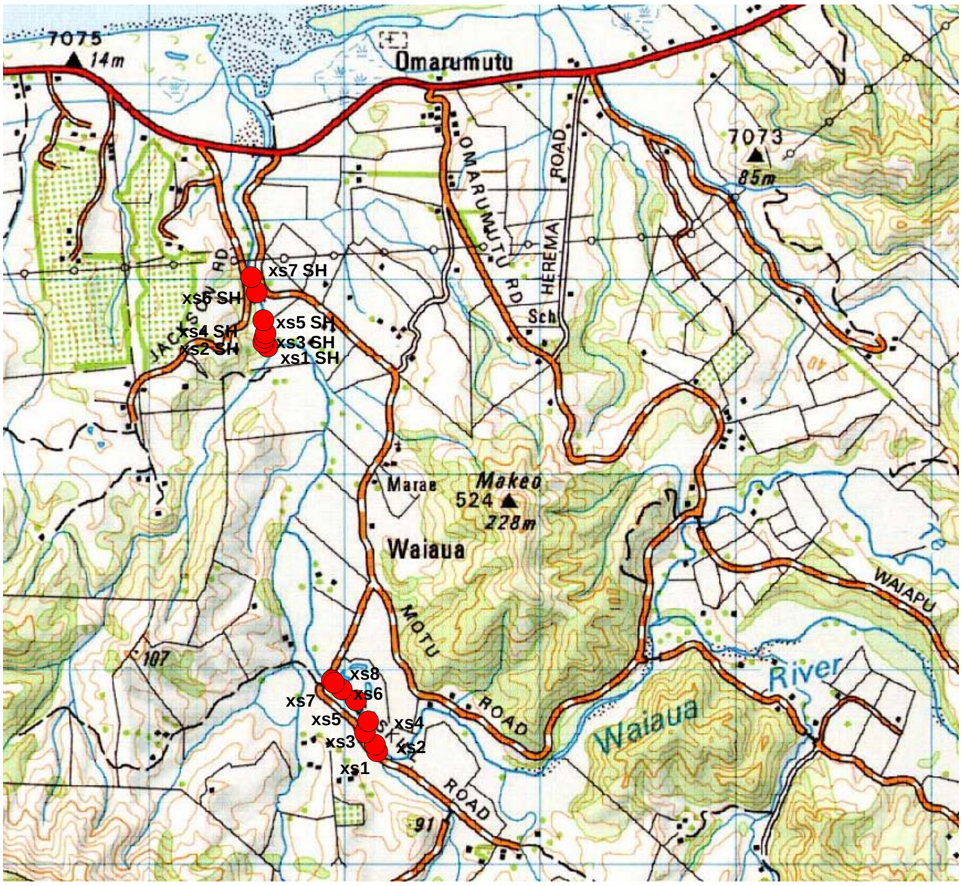

Figure 2.1 The Waiaua River with red circles showing the location of two survey reaches. The blue grid scale is at 1 km spacing.

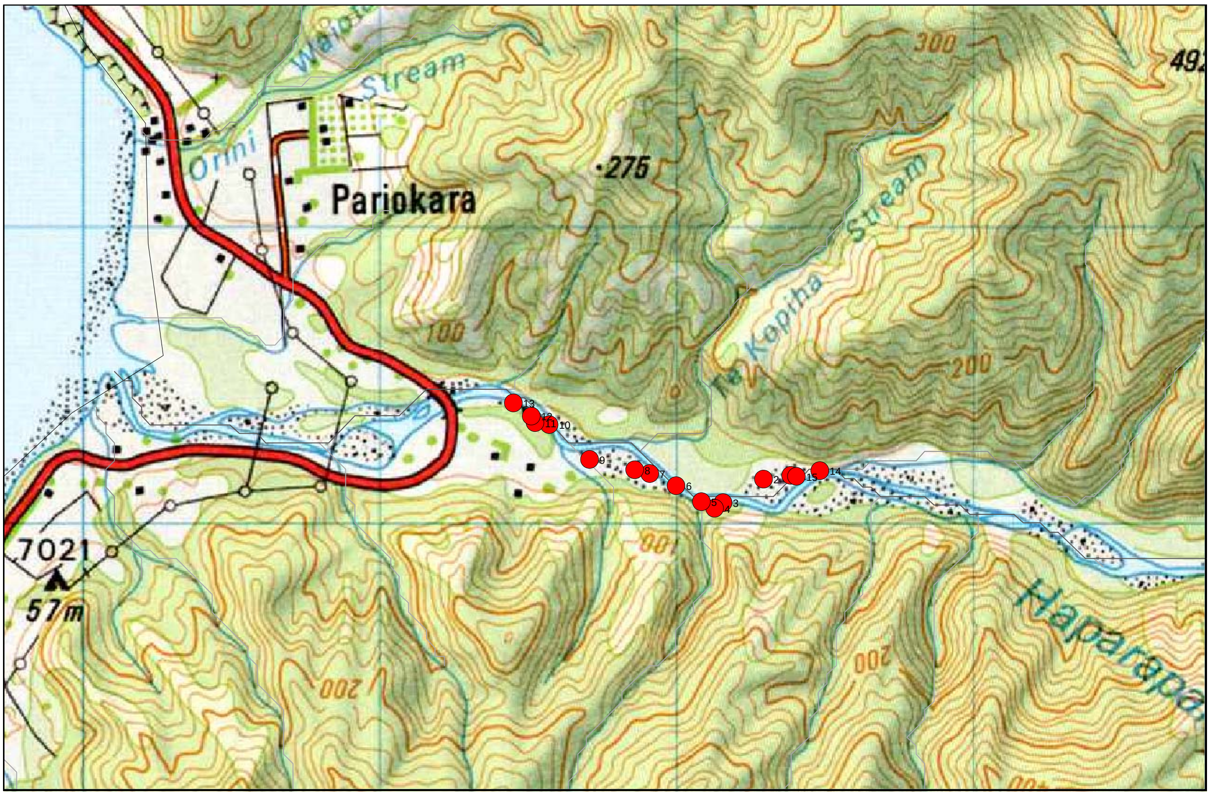

Figure 2.2 The Haparapara River with red circles showing the location of survey reach. The blue grid scale is at 1 km spacing.

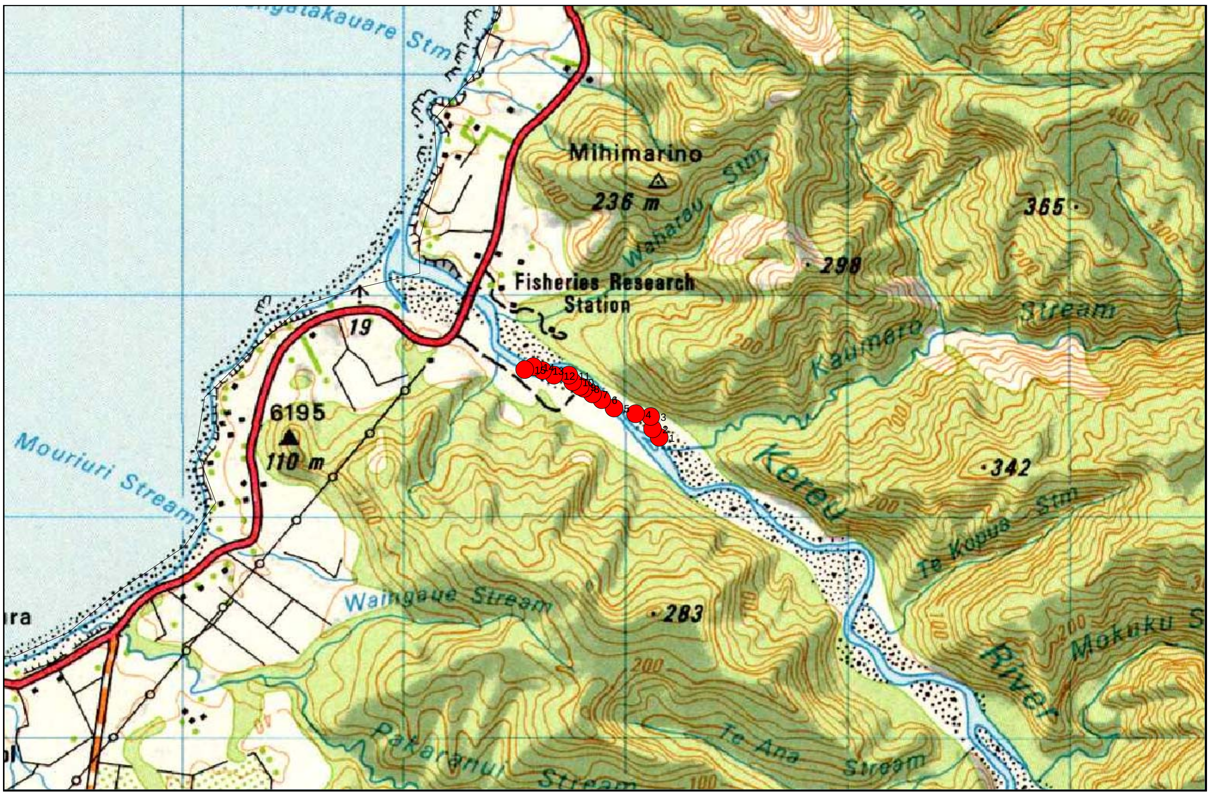

Figure 2.3 The Kereu River with red circles showing the location of survey reach. The blue grid scale is at 1 km spacing.

2.1 Hydrology

There are no water level recorders on the Waiaua, Haparapara, or Kereu rivers. The catchment area of the Waiaua River is 97 km^2 at the SH 35 bridge and 84.3 km^2 at Gaskill Road bridge. The catchment area of the Haparapara and Kereu rivers at their SH 35 bridges is 167 and 141 km^2, respectively.

EBOP have carried out flow gaugings at low flow at these sites and these low flow gaugings can be correlated with nearby water level recorders with long-term records.

The long-term (31 year) site Otara River at Browns Bridge is near the Waiaua River and was used to estimate its median flow, 7-day mean annual low flow (MALF) and the 7-day 5 year low flow. EBOP staff established a relationship between low flows at the Waiaua SH 35 bridge and the flow in the Otara River at Browns Bridge (SH35 = Otara*0.3759-96.15, r^2 =0.920, N = 7).

Low flow statistics were calculated for the Otara River at Browns Bridge using the 31 years of record. This gave estimates of 1689 L/s for the 7-day MALF and 1248 L/s for the 7-day 5 year low flow using calendar years including the first incomplete year (1979). The median flow for the Otara River was 5994 L/s.

The relationship between flows in the Waiaua at the SH 35 bridge and Otara River at Browns Bridge was then used to calculate flow statistics for the Waiaua River (Table 2.1). Flow statistics at Gaskill Road were calculated using a relationship between the flows at the SH 35 and Gaskill Road bridges (Gaskill = SH35 *1.0024-77.409, r^2 =0.995, N=4).

Flow statistics for the Kereu and Haparapara rivers were derived by correlation with the Raukokore River. The Raukokore River is a national network site operated by NIWA between 1979 and 2000. Its catchment area is 351 km^2; almost double that of the Haparapara and Kereu rivers. It has a recorded mean flow of 31 m^3/s and median flow of 13.55 m^3/s. Flow statistics were based on a July-June water year. The MALF (average of 19 years of minima and excluding years with substantial missing record during summer) was 3520 L/s and the 5 year 7-day low flow was 2705 L/s.

EBOP derived the correlation between low flow in the Haparapara and low flow in the Raukorore based on 8 concurrent low flow gaugings (Haparapara = 0.3989*Raukokore+500.6, r^2 = 0.591). This correlation, when applied to the Raukokore flow statistics to give estimates for the mean, median, MALF, and 5 year 7-day low flows of the Haparapara as 12.82, 5.91, 1.91, and 1.58 m^3/s, respectively (Table 2.1).

EBOP derived the correlation between low flow in the Kereu and low flow in the Raukorore based on 8 concurrent low flow gaugings (Kereu = 0.2956*Raukokore+218.04, r^2 = 0.885). This correlation, when applied to the Raukokore flow statistics give estimates for the mean, median, MALF, and 5 year 7-day low flows of the Kereu as 9.35, 4.22, 1.26, and 1.02 m^3/s, respectively (Table 2.1).

Table 2.1: Estimated hydrological statistics (L/s) for Waiaua River at SH 35 bridge and Gaskill Road, Haparapara River and Kereu River.

	Waiaua at Gaskill Rd	Waiaua at SH 35	Haparapara River at SH 35	Kereu at SH 35
Median	2085	2157	5910	4220
MALF	463	539	1910	1260
5 year 7 day low flow	296	373	1580	1020

2.2 Fish species

The New Zealand Freshwater Fish Database (NZFFD), administered by the National Institute of Water and Atmosphere (NIWA), contains 6 records from the Waiaua River collected between the estuary and a point 11 km upstream. These surveys were carried out between 1977 and 2003 and show that common bullies and eels are the most commonly occurring species (Table 2.1). An examination of the occurrence of fish species in a larger area (Ohiwa to Motu) showed a similar pattern of occurrence (Fig. 2.3). The few records of Crans bully in this region were collected in 1977 and are probably misidentified common bullies. The upper reaches of the Waiaua River have not been sampled extensively and probably contain galaxiid species, such as koaro, banded kokopu and possibly shortjaw kokopu. Bluegill bullies may be present in the Waiaua River, although none have been reported.

There are 5 NZFFD records for the Haparapara River, one at the SH 35 bridge and 4 in the headwaters. These records show that the river contains a diverse range of native fish species, with shortjaw kokopu and koaro at the inland sites, as well as common bullies, longfin eels, bluegill bullies, redfin bullies, torrentfish, and shortfin eels. Although only longfin eel and common bullies were reported from the SH bridge, the mainstem of river near the coast will contain the same species as reported from further upstream, except for koaro and shortjaw kokopu, which are unlikely to be found in open gravel bed rivers.

There are 10 NZFFD records for the Kereu River, 2 near the coast and the rest inland. The records near the coast report inanga, lamprey, common bullies, longfin eels, bluegill bullies, redfin bullies, and shortfin eels. The same set of species (except inanga) plus banded kokopu, shortjaw kokopu, and Crans bully (1977) are reported from the inland locations. Although torrentfish have not been reported from this river, they are present in nearby rivers and will be present in the Kereu River.

Trout are not believed to be present in the Haparapara River (EBOP) and may not be present in the Kereu.

Table 2.1: Summary of NZFFD records.

Species	Scientific name	Number of Waiaua records with species present (max. 6)	Number of Haparapara records with species present (max. 5)	Number of Kereu records with species present (max. 10)
Longfin eel	*Anguilla dieffenbachii*	4	2	8
Shortfin eel	*Anguilla australis*	2	3	4
Torrentfish	*Cheimarrichthys fosteri*	3	2	
Common bully	*Gobiomorphus cotidianus*	6	2	4
Redfin bully	*Gobiomorphus huttoni*	2	2	4
Bluegill bully	*Gobiomorphus hubbsi*		4	5
Crans bully	*Gobiomorphus basalis*	1		1
Inanga	*Galaxias maculatus*	1		1
Common smelt	*Retropinna retropinna*	3		
Rainbow trout	*Oncorhynchus mykiss*	2		
Lamprey	*Geotria australis*			2
Estuarine triplefin	*Grahamina sp.*	1		
Banded kokopu	*Galaxias fasciatus*			3
Koaro			1	
Shortjaw kokopu	*Galaxias postvectis*		2	1
Gambusia	*Gambusia affinis*	1		

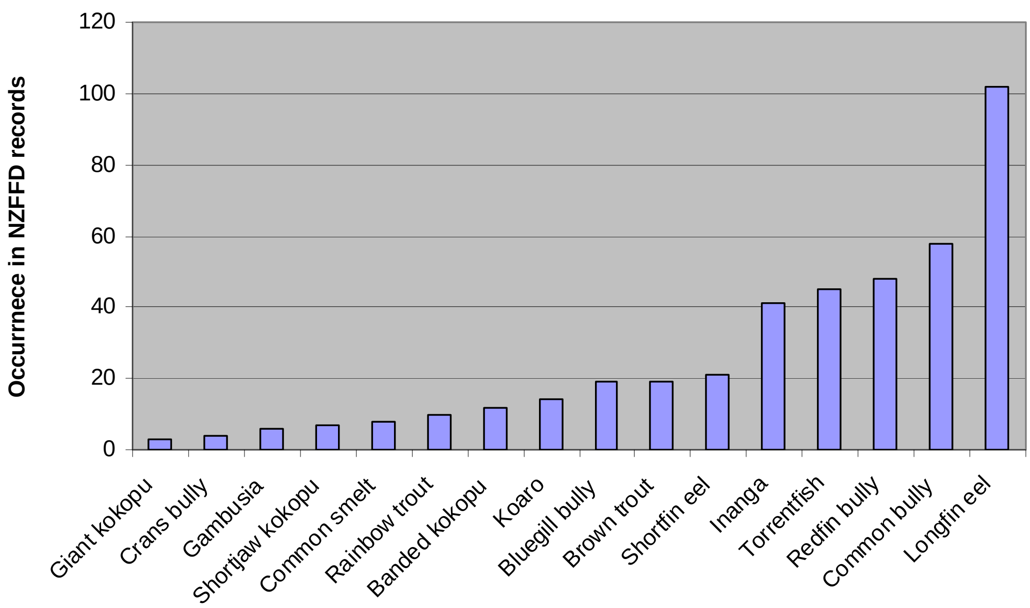

Figure 2.3: Number of times that fish species occur in NZFFD records between Ohiwa Harbour and Motu River.

2.3 Habitat suitability curves

The fish habitat suitability curves used in this study are from Jowett & Richardson (2008). These habitat suitability curves were based on data from 124 different rivers with 5000 sampling locations and 21,000 fish. The fish species likely to be present in the lower parts of the rivers, where they affected by abstraction, are longfin eel, shortfin eel, torrentfish, common bully, redfin bully, bluegill bully, inanga, common smelt, and rainbow trout. Inanga habitat was not considered because they have low velocity and flow preferences, and flow requirements will be dictated by other species.

3 Instream habitat survey

The instream habitat survey of the Waiaua River was carried out by NIWA and EBOP staff on 27 April 2010 in the two reaches above the SH35 bridge and at Gaskill Road described in Section 2. A total of 15 cross-sections were measured, 7 in the reach above the SH 35 bridge and 8 at Gaskill Road. These measurements showed that there was an increase in flow of about 10% from the additional 13 km^2 (13%) of catchment between the two reaches. Cross-sections were selected in runs, riffles and pools, in the proportion that they occurred in the reaches. Habitat mapping was carried out over the reaches to determine the weightings for each of the habitat types. In the SH 35 reach, weights of 14.8, 13.1, and 14.5% were applied to cross-sections in runs, rifles and pools, respectively. At Gaskill Road, the corresponding weights were 14.5, 10.6 and 10.1%. In total, there were 8 cross-sections in runs, 5 in riffles and 2 in pools.

The instream habitat survey of the Haparapara River was carried out by NIWA and EBOP staff on 3 May 2010 in a 1.3 km reach above the SH35 bridge. A total of 15 cross-sections were measured. Habitat mapping was carried out over a longer section of river to determine the weightings for each of the habitat types and cross-sections were selected in runs (7), riffles (5) and pools (3), in the proportion that they occurred in the reaches. Weights of 7.67, 6.85, and 4.03% were applied to cross-sections in runs, rifles and pools, respectively. A flood occurred between the two calibration measurements (15/4/10 and 19/4/10) and the main survey on 3 May and the temporary staff gauges were also removed by local people and GPS measurements were used to relocate the cross-section. Measurements in the nearby and similar Kereu River showed that the flood caused only minor changes to the ratings. The cross-section levels measured on 3 May were adjusted so that they fell on ratings based on the two calibration measurements.

The instream habitat survey of the Kereu River was carried out by NIWA and EBOP staff on 4 May 2010 in a 1 km reach above the SH35 bridge. A total of 15 cross-sections were measured. Habitat mapping was carried out over a longer section of river to determine the weightings for each of the habitat types and cross-sections were selected in slow runs (5), runs (5), riffles (4) and pools (1), in the proportion that they occurred in the reaches. Weights of 9.19, 5.21, 4.03, and 11.85% were applied to cross-sections in runs, rifles and pools, respectively. A flood occurred between the two calibration measurements (14/4/10 and 19/4/10) and the main survey on 4 May. The cross-section levels measured on 4 May were adjusted so that they fell on ratings based on the two calibration measurements and this showed that the flood had caused only minor changes to the ratings (average 35 mm, range 0-70 mm).

Water velocities, depths, and substrate composition were recorded at 0.1-0.3 m intervals depending on the uniformity and width of the cross-section. At each cross-section, water level was measured and referenced against a temporary staff gauge. This was done so that the water level could be measured at different flows on return visits.

The habitat analysis for each river proceeded as follows:

1. Flows were computed from depth and velocity measurements for each cross-section.

2. A stage-discharge relationship was developed for each cross-section fitted through the surveyed flow and stage (water level) and two calibration measurements at different stages and flows.

3. Water depths and velocities were computed at each measurement point across each cross-section for a range of simulated flows, and the habitat suitability index (HSI) was evaluated (see Figure A1.2 in Appendix I) at each measurement point from habitat suitability curves for each fish species.

4. The weighted usable area (WUA) for each simulated flow was calculated as the sum of the habitat suitability indices across each cross-section, weighted by the proportion of the habitat type which each cross-section represented in the river.

5. Weighted usable area was plotted against flow and the resulting curves examined to determine the flow that provided maximum habitat and the flow required to maintain 90% of habitat (WUA) available at MALF and to retain 90% of maximum habitat.

Flows of up to the median flow were modelled to show the overall effect of flow changes on instream habitat.

4 Results

4.1 Physical characteristics

Waiaua River

The instream habitat survey was carried out at a flow of 0.6 m^3/s. Calibration measurements were carried out at flows of about 0.5 and 0.9 m^3/s. The average physical characteristics of the two reaches were similar (Table 4.1) with an average stream width of 8.5 m and depth of 0.26 m.

Table 4.1: Average water surface width, depth and velocity measured in the two survey reaches from the survey and calibration measurements carried out in April 2010.

Reach	Survey flow (m^3/s)	Width (m)	Depth (m)	Velocity (m/s)	Calibration flow 15/4/2010	Calibration flow 19/4/2010
SH bridge	0.61	8.4	0.28	0.34	0.95	0.54

Gaskill Road	0.59	8.5	0.25	0.33	0.88	0.45

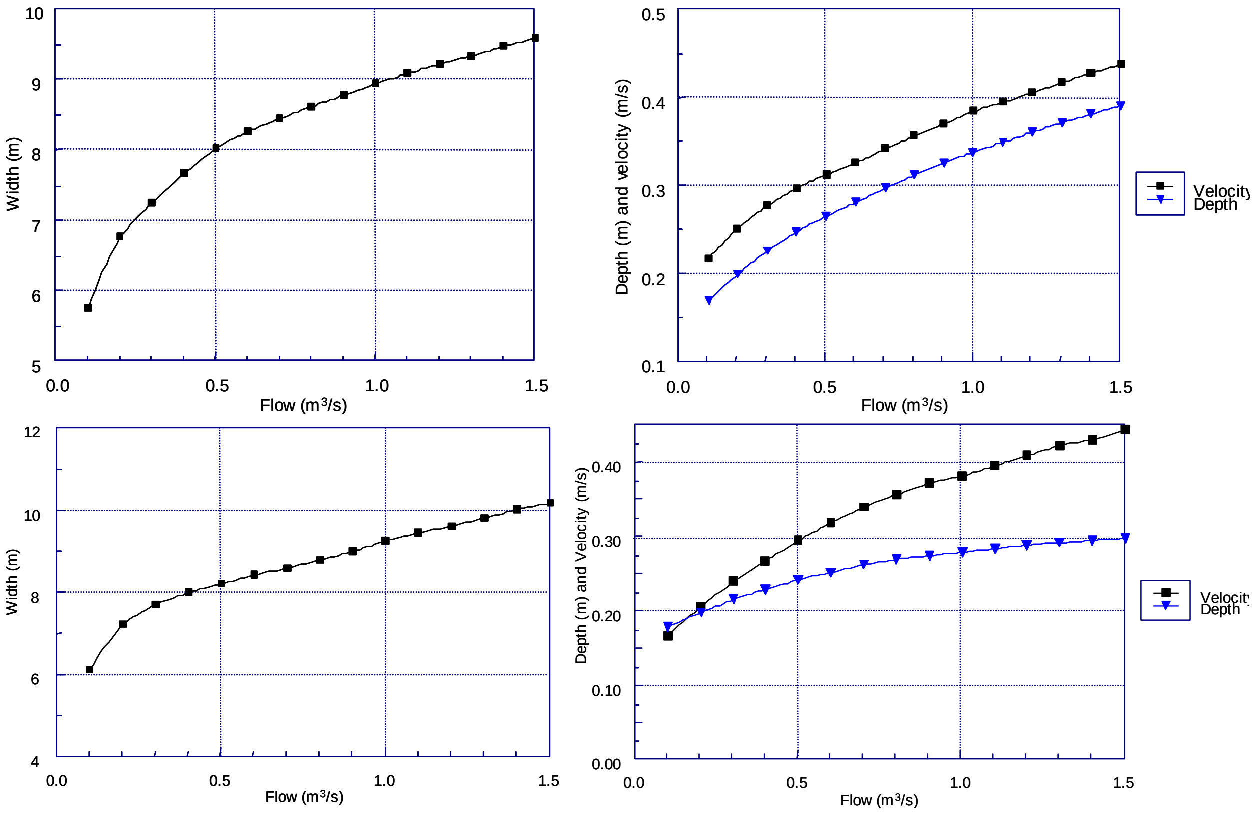

Figure 4.1: Variation of average width (left), depth (right blue line), and velocity (right black line) with flow in the Waiaua River 1 km above the SH 35 bridge (upper) and at Gaskill Road (lower).

The stream width begins to decrease more sharply when flows fall below about 0.25 m^3/s in both reaches (Fig. 4.1). The variation of depth and velocity with flow showed no distinct break points, but in the SH 35 reach the average depth doubled when the flow increased from 0.1 to 1.5 m^3/s, whereas in the Gaskill Road the depth increased by 50%. This is probably because the Gaskill Road reach is less confined and slightly steeper than the SH 35 reach.

Haparapara River

The instream habitat survey of the Haparapara River was carried out at a flow of 3.51 m^3/s. Calibration measurements were carried out at flows of 1.67 and 4.13 m^3/s. At a flow of 3 m^3/s, the average water surface width was 22.2 m, depth 0.3 m, and velocity 0.43 m/s (Fig. 4.2). At 1.5 m^3/s, the average water surface width was 18.6 m, depth 0.27 m, and velocity 0.36 m/s.

The Haparapara River is almost 3 times as wide as the Waiaua River, although the average depth and velocity are similar. The flat portions of the curves in Fig. 4.2 are caused by the flow spreading out at two cross-sections when flows exceed about 2.5 m^3/s.

Kereu River

The instream habitat survey was carried out at a flow of 2.60 m^3/s. Calibration measurements were carried out at flows of 1.29 and 3.36 m^3/s. At a flow of 3 m^3/s, the average water surface width was

21.7 m, depth 0.34 m, and velocity 0.41 m/s (Fig. 4.3). At 1.5 m^3/s, the average water surface width was 18.8 m, depth 0.30 m, and velocity 0.33 m/s.

The physical characteristics of the Kereu River are similar to those of the Haparapara.

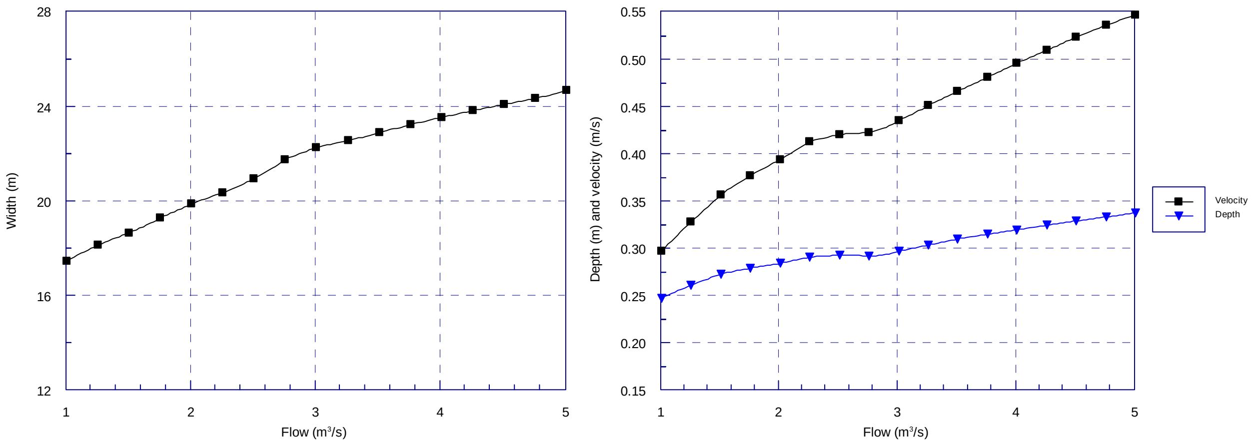

Figure 4.2: Variation of average width (left), depth (right blue line), and velocity (right black line) with flow in the Haparapara River above the SH 35 bridge.

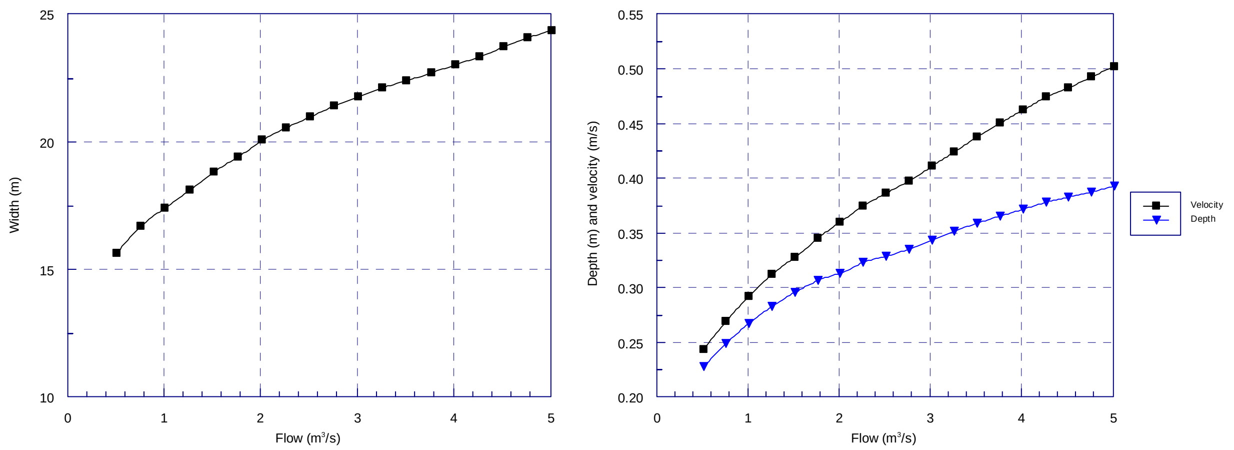

Figure 4.3: Variation of average width (left), depth (right blue line), and velocity (right black line) with flow in the Kereu River above the SH 35 bridge.

4.2 Instream habitat

Waiaua River

Both WUA (m^2/m) and HSI can be used to assess minimum flow requirements. HSI can be regarded as a measure of the “quality” of the habitat provided by the flow, whereas WUA (m^2/m) is a measure of the “quantity” of available habitat. In streams and rivers where the flow is confined between defined banks, relationships between flow and WUA (m^2/m) are usually similar to those between flow and HSI, so only the WUA curves are shown here.

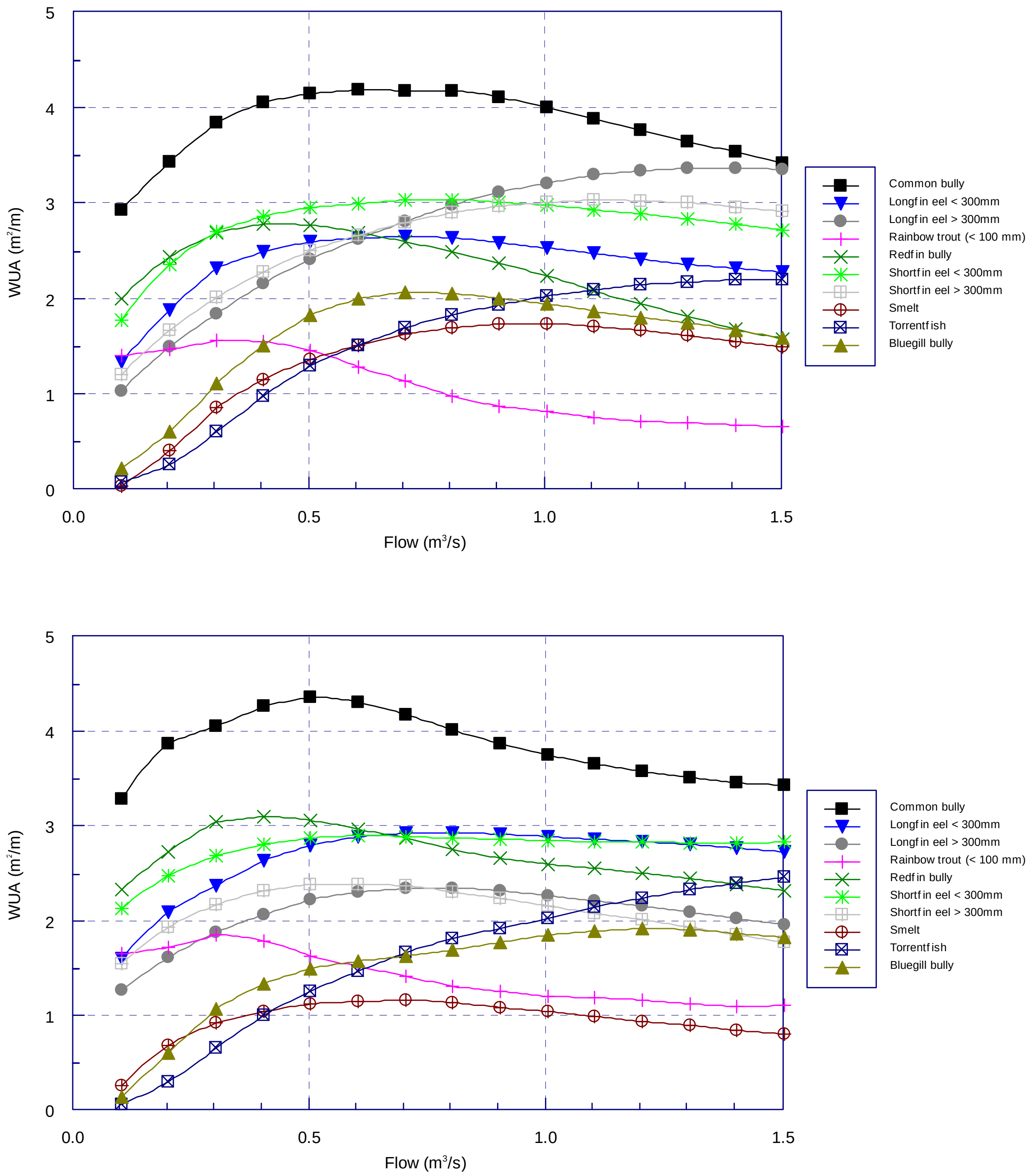

Figure 4.4: Variation of weighted usable area (WUA m^2/m) with flow for fish habitat in the Waiaua River. The SH 35 bridge reach is the upper graph and Gaskill Road reach is the lower graph.

The flows of 0.4- 0.8 m^3/s in the Gaskill Road reach provided maximum habitat for all fish species except torrentfish and bluegill bullies (Fig. 4.4). Flows that provided maximum habitat for fish in the SH 35 reach were slightly higher and were between 0.4 and 1.1 m^3/s for most fish species (Table 4.2). Flows providing maximum habitat were less than median flow (2.16 m^3/s) for all species except torrentfish.

To simplify the flow assessment, data from the two reaches were combined assuming equal weights to each reach and an increase in flow between the two sites of 0.1 m^3/s, with flows expressed in terms of the flow in the SH 35 reach (Fig. 4.5). This showed that maximum habitat for adult longfin eels was provided by a flow of 1.10 m^3/s (Table 4.2). Habitat maxima for other species were less, with 1.05 m^3/s, 0.75 m^3/s, 0.85 m^3/s, 0.70 m^3/s and 0.60 m^3/s providing maximum habitat for bluegill bullies, juvenile longfin, adult shortfin, juvenile shortfin, and common bully, respectively (Table 4.2).

Table 4.2: Flows that provide maximum habitat for fish in reaches at SH 35 bridge and Gaskill Road and both reaches together with flow in terms of SH 35 bridge and a flow increase of 0.1 m^3/s between Gaskill Road and SH 35 bridge.

Species	SH reach	Gaskill reach	Both reaches
Longfin eel < 300 mm	0.7	0.7	0.75
Longfin eel > 300 mm	1.3	0.8	1.10
Shortfin eel < 300 mm	0.7	0.6	0.70
Shortfin eel > 300 mm	1.1	0.6	0.85
Torrentfish	>1.5	>1.5	>1.5
Common bully	0.6	0.5	0.60
Redfin bully	0.4	0.4	0.45
Bluegill bully	0.75	1.2	1.05

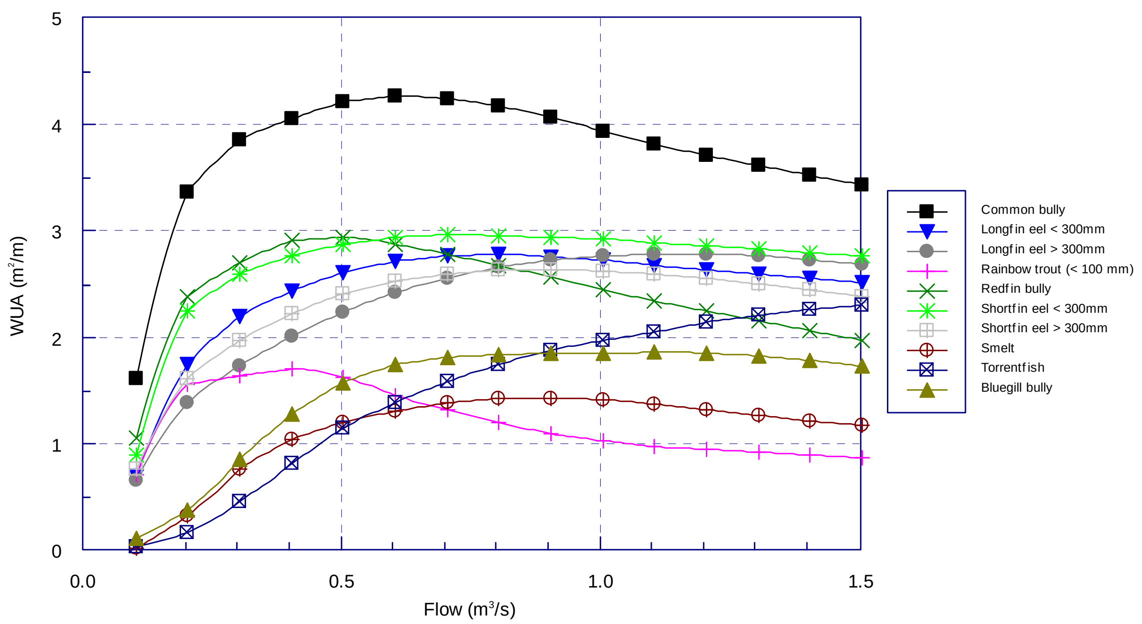

Figure 4.5: Variation of weighted usable area (WUA m^2/m) with flow (in terms of flow at SH 35 bridge) for fish habitat in the Waiaua River allowing for an increase in flow of 0.1 m^3/s between Gaskill Road and SH 35 bridge reaches.

Haparapara and Kereu rivers

Habitat/flow relationships in the Haparapara River were similar to those in the Kereu River (Figs 4.6 & 4.7). Flows of about 1-3 m^3/s provided maximum habitat in both the Haparapara and Kereu rivers for all fish species except torrentfish (Fig. 4.6). Flows providing maximum habitat were less than median flow for all species except torrentfish, for which flows close to the median flows (5.91 m^3/s in Haparapara and 4.22 m^3/s in the Kereu) provided maximum habitat (Table 4.3).

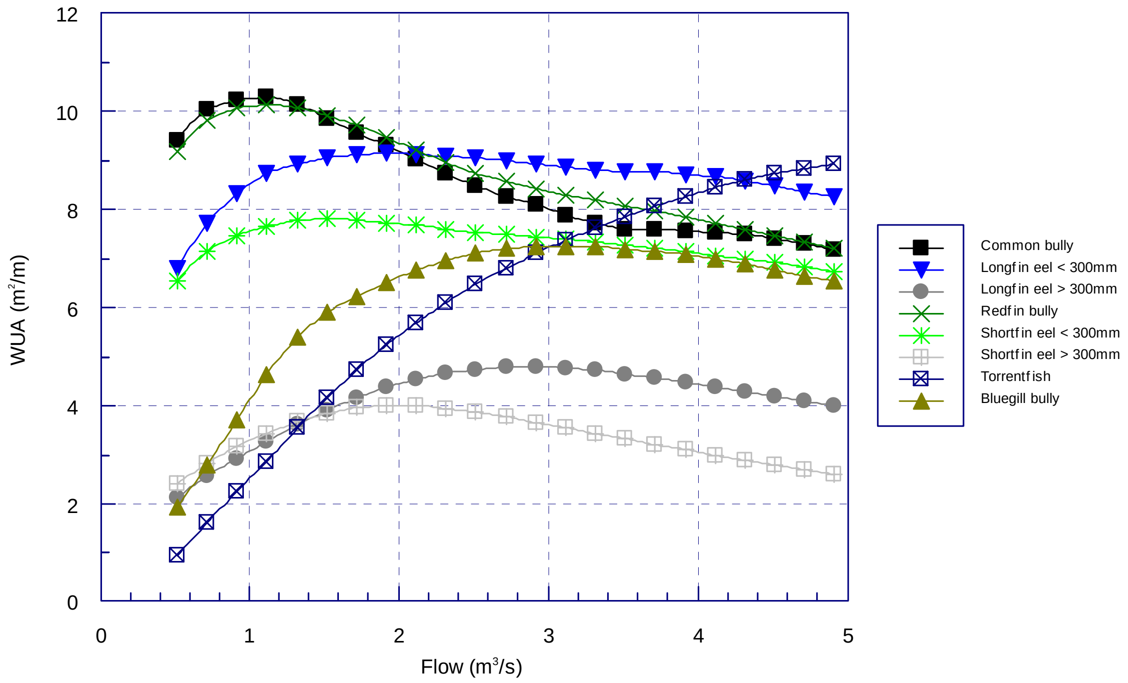

Figure 4.6: Variation of weighted usable area (WUA m^2/m) with flow for fish habitat in the Haparapara River.

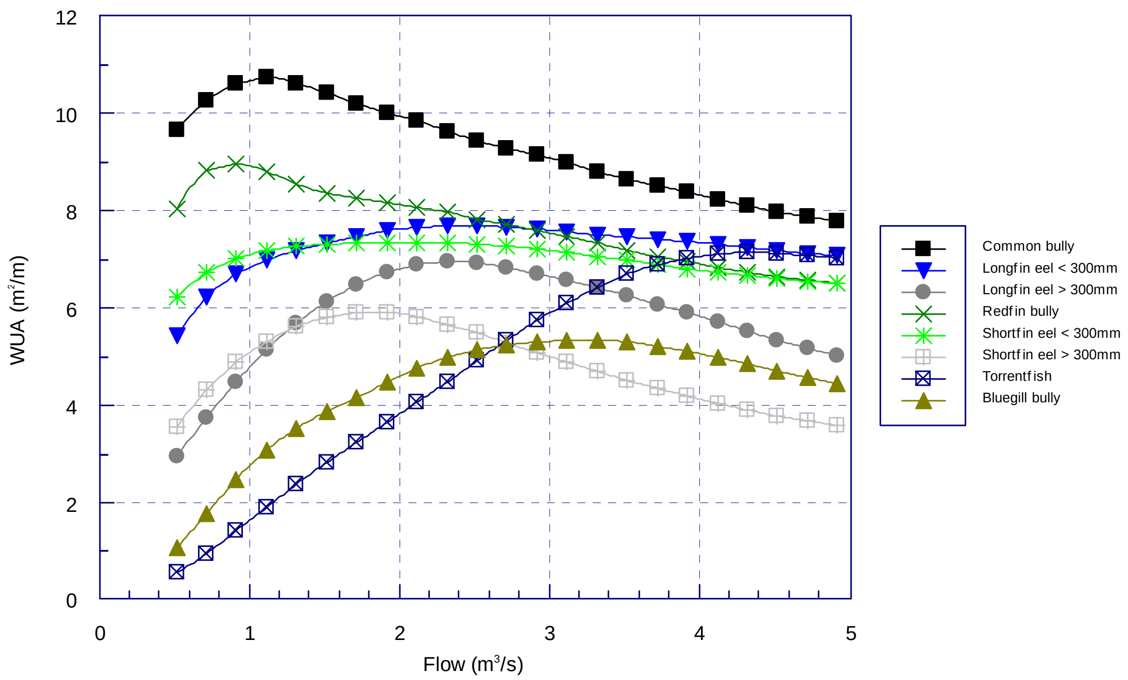

Figure 4.7: Variation of weighted usable area (WUA m^2/m) with flow for fish habitat in the Kereu River.

Table 4.3: Flows that provide maximum habitat for fish in the Haparapara and Kereu rivers.

Species	Haparapara	Kereu
Longfin eel < 300 mm	1.8	2.4
Longfin eel > 300 mm	2.8	2.3
Shortfin eel < 300 mm	1.5	2.1
Shortfin eel > 300 mm	2.0	1.8
Torrentfish	5.7	4.3
Common bully	1.1	1.1
Redfin bully	1.1	0.9
Bluegill bully	3.0	3.2

5 Minimum flow requirements

5.1 Rationale for assessment of minimum flow requirements

Natural low flows limit the amount of available habitat and it is often assumed that frequently occurring low flows will limit fish populations. Fish can respond to low flows by moving to different habitats or adopting different behavioural patterns. If the low flow persists for long enough, there may be mortality or emigration. The mean annual low flow has been used as a measure of frequently occurring low flows for long-lived fish species (e.g., Jowett 1992). However, studies have also shown that flood flows can limit trout populations, with minor floods during incubation or rearing causing high mortality (Hayes 1995; Nehring & Miller 1987) and large floods can be devastating (Jowett & Richardson 1989).

The minimum flow is the primary protection mechanism for aquatic ecosystems. The minimum flow can be selected to maintain instream conditions to a required standard. That standard can be varied depending upon the value of the instream resource and the potential benefits of water uses. Thus, minimum flow requirements are specific to each stream and river depending upon instream values, water uses, and stream type. A basic principle established in the Flow Guidelines (Ministry for the Environment 1998) is that instream values and their requirements must be identified and appraised within the context of definite instream management objectives. Case studies have shown that minimum flows selected to prevent a sharp decline in habitat have maintained instream management objectives for native fish, trout and benthic invertebrate communities to the desired standards (Jowett & Biggs 2006; Jowett et al. 2008).

In most small streams, taking water will reduce available habitat for fish and benthic invertebrates, and will reduce fish populations if the periods of low flow are sufficiently long. Reduction in habitat may cause some mortality, either during movement to better habitat or by increasing densities above holding capacity. The fast-water fish species (bluegill bullies, torrentfish and koaro) will be the first species affected, but eels, other bully species and (probably) galaxiids will be more tolerant. This opinion is based on studies of low flows in the Waipara and Onekaka rivers (Jowett et al 2005; Jowett et al. 2008).

The detrimental effect of low flows increases with the duration of low flow. In years where flows are relatively high, native fish populations will be maintained at good levels. In years when flows are low for 30-60 days the fast-water species and diadromous bullies will be affected, but will recover the following years if flows are higher.

The effect of abstraction will be greater on small streams than large streams and rivers and will be greater on gravel-bed streams than spring-fed streams that are relatively deep with steep banks.

The selection of appropriate minimum flow is a matter of judgement and objectives, where the habitat requirements and perceived values of the different species must be considered. Minimum flows are often selected so that they prevent a serious decline in habitat, the breakpoint or flow below which habitat declines sharply, but this depends to some extent on the amount of time that the flow is likely to be at that minimum.

5.2 Minimum flow requirements under the EBOP Regional Water & Land Plan

The Environment BOP Regional Water and Land Plan (RWLP) sets out a process and methodology to determine an instream minimum flow requirement. Method 177 defines a procedure to be followed and Method 178 sets out the protection levels according to fish species in the stream.

Method 177 requires an instream habitat analysis to determine the minimum flow. Essentially, the minimum flow is 85-100% (set by Method 178) of maximum habitat or 85-100% of the habitat at the mean annual low flow, if the flow that provides maximum habitat is greater than the median flow.

Method 172 requires management of consumptive use when flows are within 10% of the minimum flow.

Policy 66 sets out the allocation policy. With respect to low flows, the maximum allocatable flow in a stream is the five year 7-day low flow minus the instream minimum flow requirement.

Rule 43 in RWLP allows for the discretionary take and use of water on a case by case basis where the total volume of water exceeds that specified in the low flow allocation Policy 66.

5.3 Minimum flow in the Waiaua, Haparapara and Kereu rivers

As described in Section 5.1, a reduction in the amount of habitat for native fish can reduce fish populations, especially for those species with high velocity preferences. However, the flow must be low for a month or more for there to be an effect and fish densities need to be relatively high so that habitat becomes a limiting factor.

A wide variety of native fish are found in the Waiaua, Haparapara, and Kereu rivers because they are close to the coast. The lower part of the rivers will also provide passage for juvenile galaxiids that will be migrating from the sea to headwater streams in spring.

Under Method 130, the diverse native fish community in these rivers would classify for a 90% habitat protection level. This means that the minimum flow should retain at least 90% of the habitat at MALF for all fish species. If the flow that provides maximum habitat is less than the median flow, the minimum flow requirement is the flow that retains 90% of maximum habitat.

The flows that provide maximum habitat in the Waiaua River are close to MALF for many fish species (Table 5.1). Using the EBOP method, the flow that provides maximum habitat is less than the median flow (2.16 m^3/s) for all fish species, and therefore the minimum flow for all species is the flow that provides 90% of maximum habitat (i.e., the greatest flow in the right hand column in Table 5.1). Torrentfish have the highest flow requirement and a flow of 1.181 m^3/s will maintain 90% of maximum torrentfish habitat.

Under the EBOP method, there would be no allocable water in this river, as a minimum flow of 1.181 m^3/s is greater than the 5 year low flow of 0.373 m^3/s.

However, the Department of Conservation and most other regional councils accept MALF or a percentage of it as a reasonable minimum flow. The proposed National Environmental Standard on ecological flows suggests a default minimum flow of 90% of MALF for small streams (MfE 2008). If the minimum instream flow requirement were taken as 90% of habitat at MALF, the highest flow in column 4 of Table 5.1 is the minimum flow requirement for torrentfish of 0.491 m^3/s. This flow is higher than the 5 year low flow, and under EBOP methods, there would be no allocable water in the river. The proposed National Environmental Standard on ecological flows suggests a default maximum allocation of 30% of MALF for small streams (MfE 2008).

Table 5.1: Estimation of minimum flow requirements (m^3/s) in the Waiaua River for fish habitat. MALF is 0.539 m^3/s and the median flow is 2.16 m^3/s.

Species	Maximum habitat (m^3/s)	% of maximum habitat at MALF	Retention of 90% of habitat at MALF (m^3/s)	Retention of 90% of maximum habitat (m^3/s)
Longfin eel < 300 mm	0.75	96	0.382	0.437
Longfin eel > 300 mm	1.10	83	0.400	0.658
Shortfin eel < 300 mm	0.70	98	0.313	0.337
Shortfin eel > 300 mm	0.85	93	0.389	0.478
Torrentfish	1.8	53	0.491	1.181
Common bully	0.60	99	0.292	0.297
Redfin bully	0.45	99	0.272	0.281
Bluegill bully	1.05	90	0.475	0.550
Common smelt	0.85	87	0.449	0.577
Rainbow trout (juvenile)	0.40	91	0.174	0.196

The flows that provide maximum habitat in the Haparapara River are between median flow and MALF for all fish species (Table 5.2). Using the EBOP method, the minimum flow requirement for all species is the flow that provides 90% of maximum habitat. This is the right hand column of Table 5.2

and the fish species with the highest minimum flow requirement is torrentfish with a minimum flow requirement of 3.805 m^3/s.

This flow is 200% higher than MALF. Under the EBOP method, there would be no allocable water in this river, as a minimum flow of 3.805 m^3/s is greater than the 5 year low flow of 1.58 m^3/s.

If the minimum instream flow requirement were taken as 90% of habitat at MALF for all fish species, the highest flow in column 4 of Table 5.2 is the minimum flow requirement for torrentfish of 1.69 m^3/s. This flow is higher than the 5 year low flow, and under EBOP methods, there would be no allocable water in the river.

Table 5.2: Estimation of minimum flow requirements in the Haparapara River for fish habitat. MALF is 1.91 m^3/s and the median flow is 5.91 m^3/s.

Species	Maximum habitat (m^3/s)	% of maximum habitat at MALF	Retention of 90% of habitat at MALF (m^3/s)	Retention of 90% of maximum habitat (m^3/s)
Longfin eel < 300 mm	1.8	100	0.871	0.872
Longfin eel > 300 mm	2.8	91	1.516	1.831
Shortfin eel < 300 mm	1.5	99	0.622	0.647
Shortfin eel > 300 mm	2.0	100	1.237	1.238
Torrentfish	5.7	57	1.690	3.805
Common bully	1.1	90	0.261	0.468
Redfin bully	1.1	94	0.344	0.491
Bluegill bully	3.0	90	1.481	1.906

The flows that provide maximum habitat in the Kereu River are between median flow and MALF for all fish species, except torrentfish for which the flow that provides maximum habitat is slightly greater than the median flow (Table 5.3). Using the EBOP method, the minimum flow requirement for all species except torrent fish is the flow that provides 90% of maximum habitat. This is the right hand column of Table 5.3 and the fish species with the highest minimum flow requirement is bluegill bully with a minimum flow requirement of 2.154 m^3/s. For torrentfish, the minimum flow requirement is the flow that provides 90% of habitat at MALF (i.e., 1.163 m^3/s in Table 5.3). Thus, the minimum flow for the river is 2.154 m^3/s.

This flow is 70% higher than MALF. Under the EBOP method, there would be no allocable water in this river, as a minimum flow of 2.154 m^3/s is greater than the 5 year low flow of 1.02 m^3/s.

If the minimum instream flow requirement were taken as 90% of habitat at MALF for all fish species, the highest flow in column 4 of Table 5.3 is the minimum flow requirement for torrentfish of 1.163 m^3/s. This flow is higher than the 5 year low flow, and under EBOP methods, there would be no allocable water in the river.

Table 5.3: Estimation of minimum flow requirements in the Kereu River for fish habitat. MALF is 1.26 m^3/s and the median flow is 4.22 m^3/s.

Species	Maximum habitat (m^3/s)	% of maximum habitat at MALF	Retention of 90% of habitat at MALF (m^3/s)	Retention of 90% of maximum habitat (m^3/s)
Longfin eel < 300 mm	2.4	93	0.778	1.046
Longfin eel > 300 mm	2.3	80	1.063	1.566
Shortfin eel < 300 mm	2.1	99	0.612	0.651
Shortfin eel > 300 mm	1.8	94	0.959	1.110
Torrentfish	4.3	32	1.163	3.296
Common bully	1.1	99	0.472	0.494
Redfin bully	0.9	96	0.442	0.504
Bluegill bully	3.2	64	1.109	2.154

6 Conclusion

The Waiaua, Haparapara and Kereu rivers all contain diverse native fish communities because they are close to the sea and their catchments are not extensively developed. Because of the diverse fish communities, a habitat retention standard of 90% of habitat at MALF, as specified in the RWLP, is an appropriate standard. Instream minimum flow requirements (IMFR) were derived according to methods described in the Environment BOP Regional Water and Land Plan in all three rivers.

The instream minimum flow requirement for the Waiaua River was 0.658 m^3/s to maintain 90% of maximum habitat for large eels. This flow is about 20% higher than MALF and is almost double the 5 year low flow. Under the EBOP method, there would be no water available for allocation in this river.

The instream minimum flow requirement for the Haparapara River was 3.805 m^3/s to maintain 90% of maximum habitat for torrentfish. This flow is 200% higher than MALF and is more than double the 5 year low flow. Under the EBOP method, there would be no water available for allocation in this river.

The instream minimum flow requirement for the Kereu River was 2.154 m^3/s to maintain 90% of maximum habitat for bluegill bullies. This flow is 70% higher than MALF and is about double the 5 year low flow. Under the EBOP method, there would be no water available for allocation in this river.

In my opinion, the fact that instream minimum flow requirements (IMFR) are greater than MALF for these rivers indicates a problem with the methods specified in the EBOP RWLP. The methods were largely developed and tested for streams and rivers with stable flow regimes, typical of pumice catchments. There are also more habitat suitability curves available for native fish than were available when the EBOP method was developed and tested. In rivers with less stable flow regimes, the ratio of median flow to MALF is high, and flows that provide maximum habitat can be just under median flow, resulting in an IMFR that can be considerably greater than MALF. There appear to be two problems with the method. The first is that the minimum flow requirement for a species is taken as the flow that provides a percentage of maximum habitat when the flow that provides maximum habitat is less than the median flow. The other is that the IMFR is set for the fish species with the highest minimum flow requirement.

An alternative method as used by the Southland Regional Council (Jowett & Hayes 2004) is to select a target fish species and set the minimum flow requirement so that the minimum flow provides a percentage of habitat at MALF or as a percentage of maximum habitat, if the flow that provides maximum habitat is less than MALF.

The proposed National Environmental Standard on ecological flows suggests a default minimum flow of 90% of MALF and a default maximum allocation of 30% of MALF for small streams where the degree of hydrologic alteration by abstraction or other forms of flow regulation is low. For the Waiaua River, this would be a minimum flow of 0.485 m^3/s and a maximum allocatable flow of 0.162 m^3/s. For the Haparapara River, this method would give a minimum flow of 1.715 m^3/s and a maximum allocatable flow of 0.573 m^3/s, and for the Kereu, a minimum flow of 1.134 m^3/s and a maximum allocatable flow of 0.378 m^3/s.

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Appendix 1: Flow regime assessment methodology

Long-term solutions to river flow management need to take a holistic view of the river system, including geology, fluvial morphology, sediment transport, riparian conditions, biological habitat and interactions, and water quality, both in a temporal and spatial sense.

The instream flow incremental methodology (IFIM; Bovee 1982) is an example of an interdisciplinary framework that can be used in a holistic way to determine an appropriate flow regime by considering the effects of flow changes on instream values, such as river morphology, physical habitat, water temperature, water quality, and sediment processes (Figure A1.1). Its use requires a high degree of knowledge about seasonal and life-stage requirements of species and inter-relationships of the various instream values or uses.

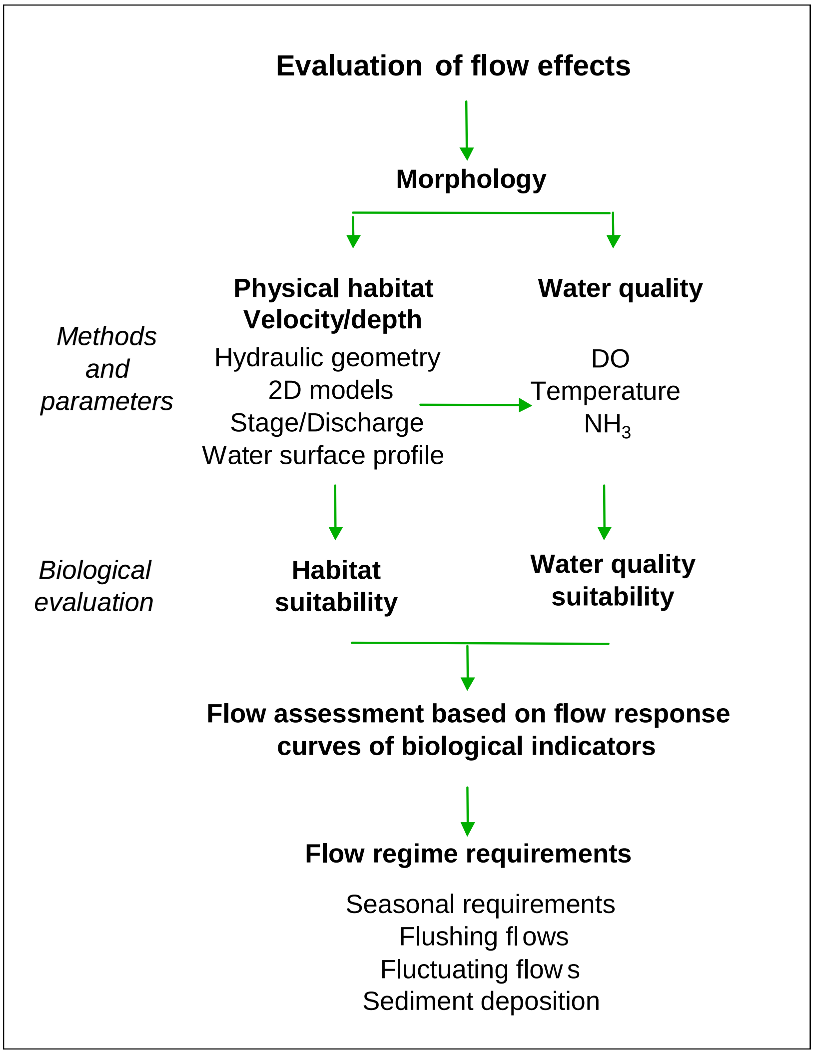

Figure A1.1: A framework for the consideration of flow requirements.

Other flow assessment frameworks are more closely aligned with the "natural flow paradigm" (Poff et al. 1997). The range of variability approach (RVA) and the associated indicators of hydrologic alteration (IHA) allow an appropriate range of variation, usually one standard deviation, in a set of 32 hydrologic parameters derived from the ‘natural’ flow record (Richter et al. 1997). The implicit assumption in this method is that the natural flow regime has intrinsic values or important ecological functions that will be maintained by retaining the key elements of the natural flow regime. Arthington et al. (1992) described a holistic method that considers not only the magnitude of low flows, but also the timing, duration and frequency of high flows. This concept was extended to the building block methodology (BBM), which “is essentially a prescriptive approach, designed to construct a flow regime for maintaining a river in a predetermined condition” (King et al. 2000). It is based on the concept that some flows within the complete hydrological regime are more important than others for the maintenance of the river ecosystem, and that these flows can be identified and described in terms of their magnitude, duration, timing, and frequency.

A holistic consideration of every aspect of flow and sediment regime, river and riparian morphology, and their associations with the life cycles of the aquatic biota requires a degree of knowledge about individual rivers that is rarely available. Fortunately, the large proportion of consents considered by regional councils in New Zealand involves changes to the low flows rather than the high flows, and thus there is no significant effect on the sediment transport regime and river morphology. The aim of the minimum flow is to retain adequate water depths and velocities in the stream or river for the maintenance of the critical values. The flow assessment considers physical habitat at a meso- to macro-habitat level rather than microhabitat. In this way, suitable average depths and velocities can be maintained in the main habitats, with a degree of habitat diversity that is generated by the morphology of the river, and is largely independent of flow. Although the geomorphological and flow related ecological processes that are associated with low to median flows are generally taken into consideration in instream flow methods, special issues, such as fish passage or seasonal flow requirements, may need to be investigated in some situations. Consideration should also be given to downstream effects. The effect of an abstraction is usually greatest immediately below the abstraction site, but diminishes as the river flow is supplemented by contributions from tributaries and the proportional change in flow reduces. However, there may be situations where the critical effect is well downstream. This is most likely where the cumulative effect of abstractions from tributaries may result in unacceptably low flows in downstream reaches.

Instream flow methods can be classified into three basic types; historic flow, hydraulic and habitat based methods. Historic flow methods are coarse and largely arbitrary. An ecological justification can be argued for the mean annual low flow (MALF) and retention of the natural flow regime, and the concept of a low flow habitat bottleneck for large brown trout has been partly justified by research (e.g., Jowett 1992), but setting flows at lower levels (e.g., the 5 year 7 day low flow — $Q_{7,5}$ etc.) is rather arbitrary. Hydraulic methods do not have a direct link with instream habitat and interpretation of ecological thresholds based on breakpoints or other characteristics of hydraulic parameters, such as wetted perimeter and mean velocity, are arbitrary and depend on rules of thumb and expert experience. On the other hand, habitat-based methods have a direct link to habitat use by aquatic species. They predict how physical habitat (as defined by various habitat suitability models) varies with flow and the shapes of these characteristic curves provide the information that is used to assess flow requirements. Habitat based methods allow more flexibility than historic flow methods, offering the possibility of allocating more flow to out-of-stream uses while still maintaining instream habitat at levels acceptable to other stakeholders (i.e., the method provides the necessary information for instream flow analysis and negotiation).

The ecological goal of habitat methods is to provide or retain a suitable physical environment for aquatic organisms that live in a river. The consequences of loss of physical habitat are well known; the environmental bottom line is that if there is no suitable habitat for a species it will cease to exist. Habitat methods tailor the flow assessment to the resource needs and can potentially result in improved allocation of resources. Although it is essential to consider all aspects such as food, shelter, and living space (Orth 1987; Jowett 1995), appropriate habitat suitability curves are the key to the successful application of habitat based methods.

The procedure in an instream habitat analysis is to select appropriate habitat suitability curves or criteria (e.g., Figure A1.2), and then to model the effects of a range of flows on the selected habitat variables in relation to these criteria. The habitat suitability index (HSI) at each point was calculated as a joint function of depth, velocity and substrate type using the method shown in Figure A2. The area of suitable physical habitat, or weighted usable area (WUA), was calculated by multiplying the area represented by each point by its joint habitat suitability. So, for example in Figure A2, at a given point in the river (it is really an area of reasonably uniform depth and velocity) where the depth is 0.1 m, depth suitability is only 65% optimal, according to knowledge of the depth requirements of the fish. Similarly, the velocity recorded at the point is 0.25 m/s, which is optimal (suitability weighting of 1), and the substrate is fine gravel (sub-optimal with a weighting of 0.4) and cobbles (optimal with a weighting of 1). Multiplying these weighting factors together we get a joint habitat suitability weighting of 0.455 for that point in the river for the selected fish species. If the depth had been 0.2 m and there had been no fine gravel, then that point in the river would have been optimal (i.e., 1 for depth × 1 for velocity × 1 for substrates = 1). This exercise was repeated within the habitat assessment model for the depth/velocity/substrate types in every grid square across the river and the area covered by each square was multiplied by the point suitability. These areas which have been weighted by their respective point suitability values were then summed to get a measure of total area of suitable physical habitat for the given species at the given flow. This process was then repeated for a series of other flows with the depths, velocities, and habitat suitability being modelled for the new flows as described above. The total area of suitable physical habitat was then plotted as a function of flow to show how the area of suitable physical habitat for a given species changes with flow. Variations in the amount of suitable habitat with flow are then used to assess the effect of different flows for target organisms. Flows can then be set so that they achieve a particular management goal.

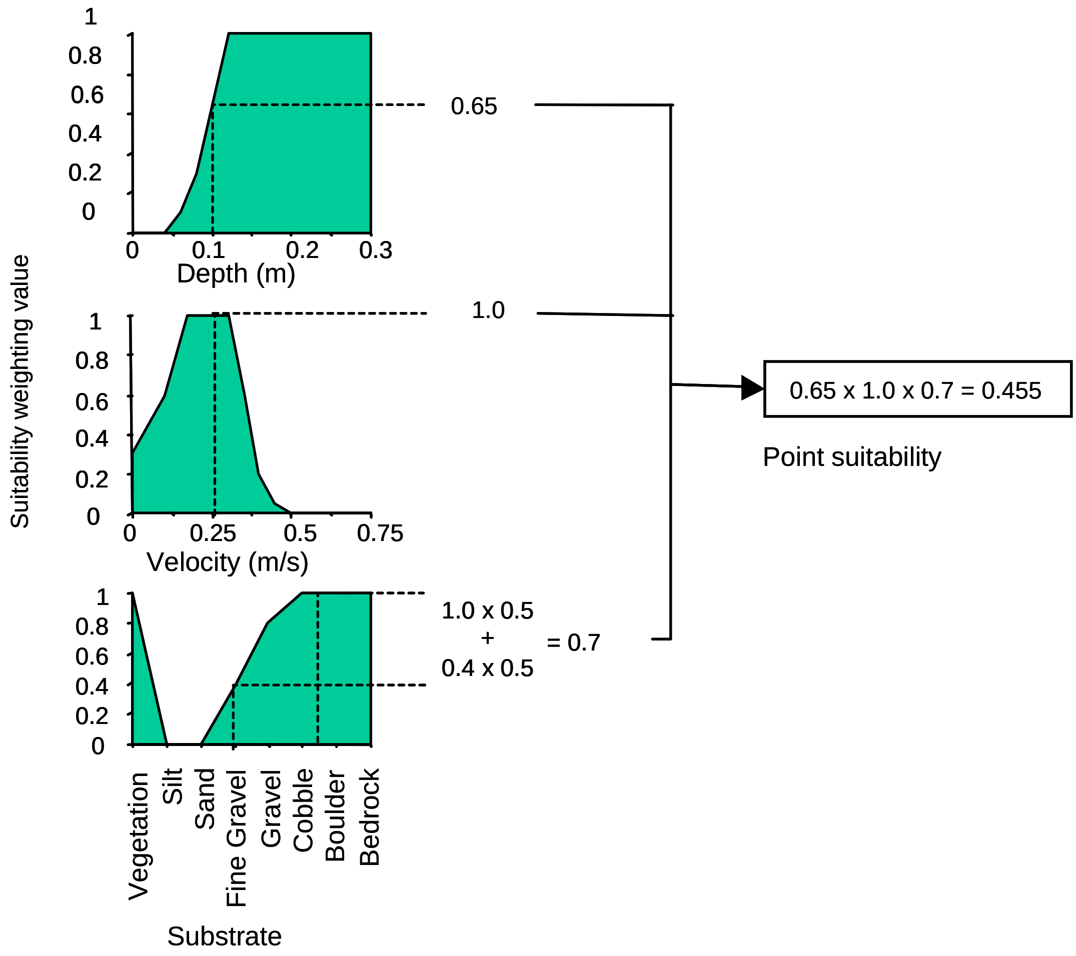

Figure A1.2: Calculation of habitat suitability for a fish species at a point with a depth of 0.1 m, velocity of 0.25 m/s, and substrate comprising 50% fine gravel and 50% cobble. The individual suitability weighting values for depth (0.65), velocity (1.0), and substrate (0.7) are multiplied together to give a combined point suitability of 0.455.

The flow related habitat metrics used to quantify instream habitat are weighted useable area (WUA m^2/m) and the average habitat suitability index (HSI) (Bovee 1982; Stalnaker et al. 1995). HSI is numerically equivalent to WUA divided by the wetted river width.

Various approaches to setting levels of protection have been used, from maintaining a maximum amount of habitat, a percentage of habitat at median flow, or using an "inflection point" of the habitat/flow relationship (Jowett 1997). The latter is possibly the most common procedure used for assessing minimum flow requirements using habitat methods. While there is no percentage or absolute value associated with an inflection point, it is a point of diminishing return, where proportionately more habitat is lost with decreasing the flow than is gained by increasing the flow.

Habitat methods can also incorporate flow regime requirements, in terms of both seasonal variation and flow fluctuations. Flow fluctuations are an important component of the habitat of most naturally flowing streams. Such fluctuations remove excess accumulations of silt and accumulated organic matter (e.g., from algal slimes) and rejuvenate stream habitats. Extended periods without a flow disturbance usually result in a shift in benthic community composition such as a reduction in diversity, and an increase in biomass of a few species within plant and animal communities.

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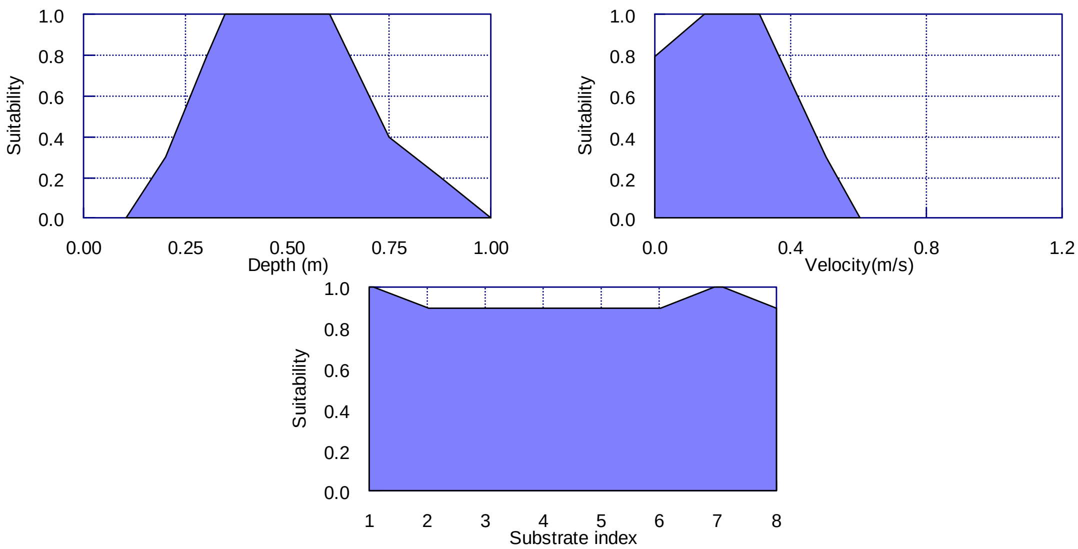
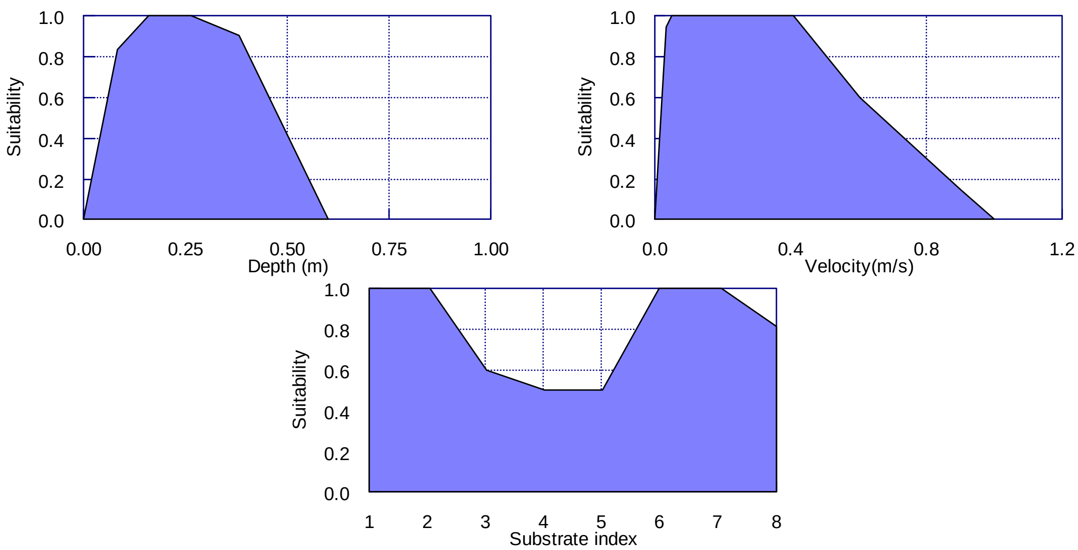
Appendix 2: Habitat suitability curves used in this study

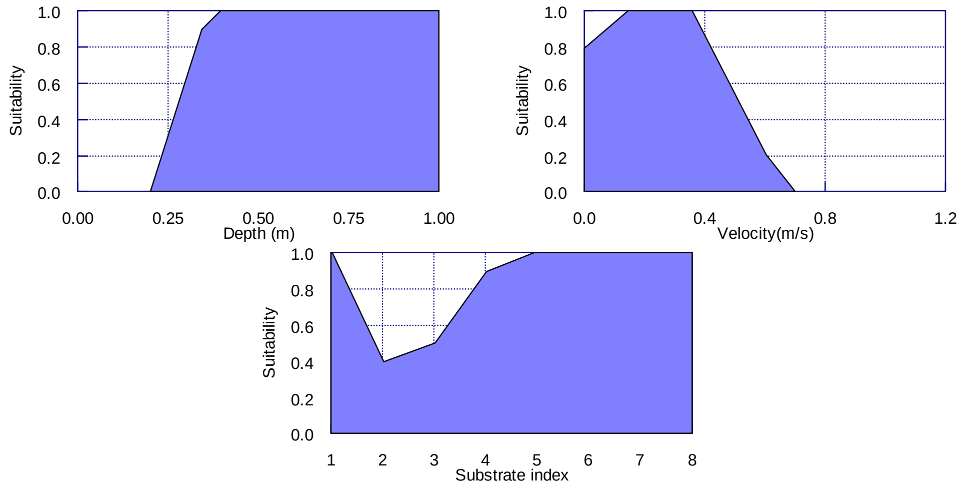
Shortfin eel > 300mm (Jowett & Richardson 2008)



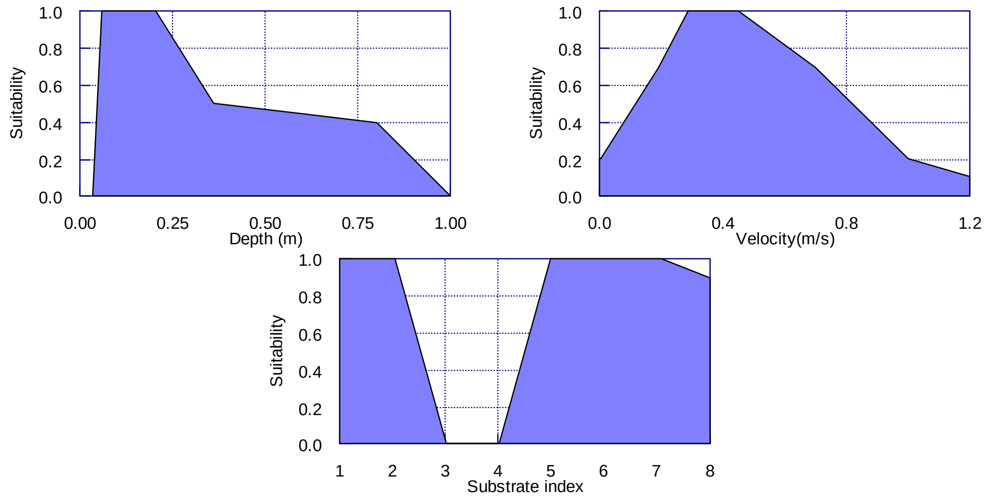
Shortfin eel < 300mm (Jowett & Richardson 2008)



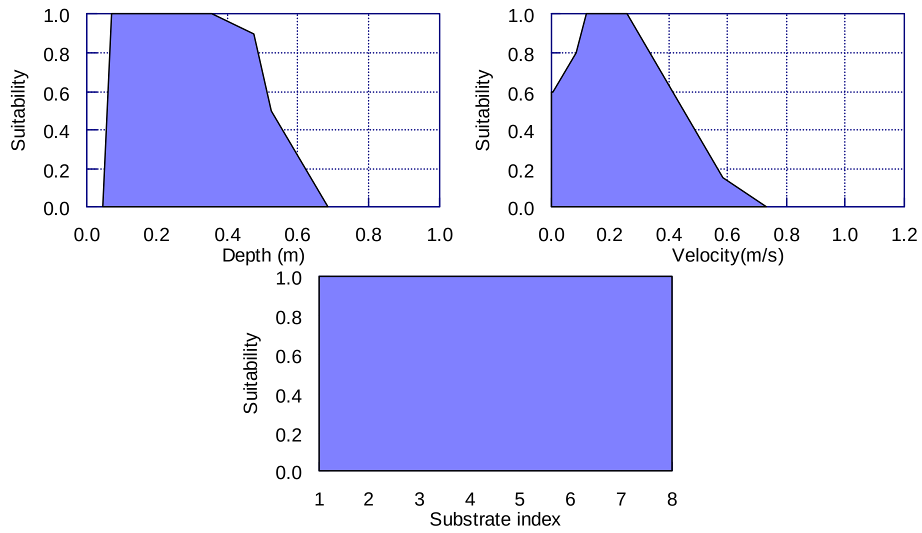
Longfin eel > 300mm (Jowett & Richardson 2008)



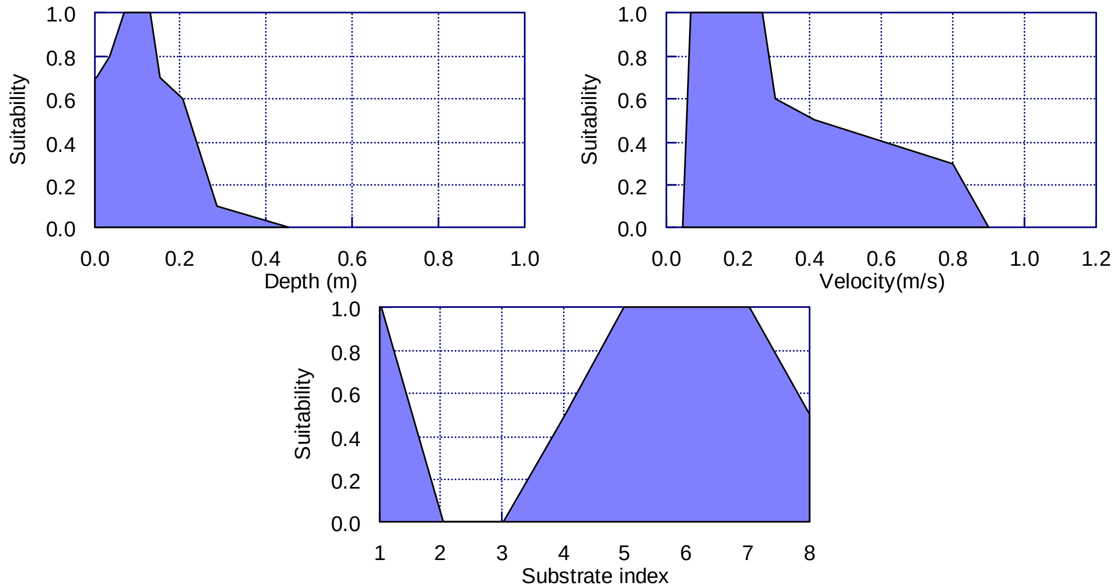
Longfin eel < 300mm (Jowett & Richardson 2008)



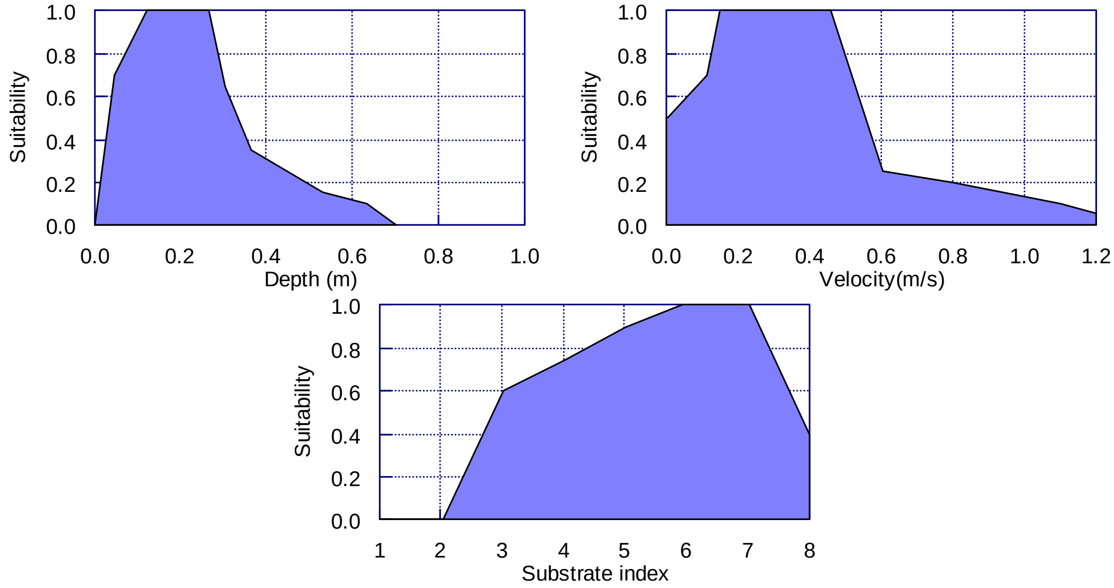
Common bully (Jowett & Richardson 2008)



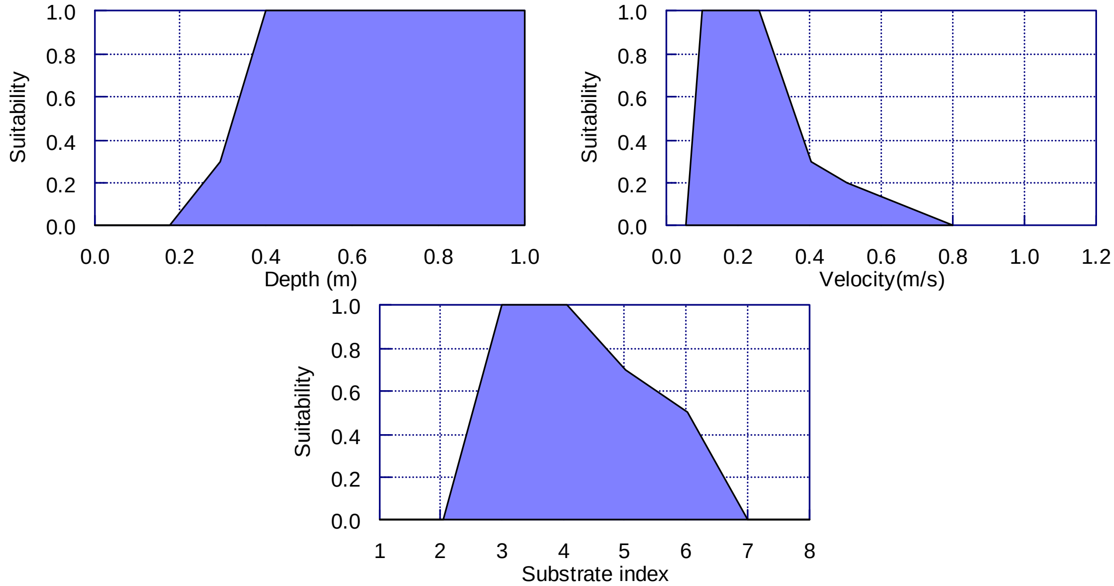
Rainbow trout (< 100 mm) (Jowett & Richardson 2008)



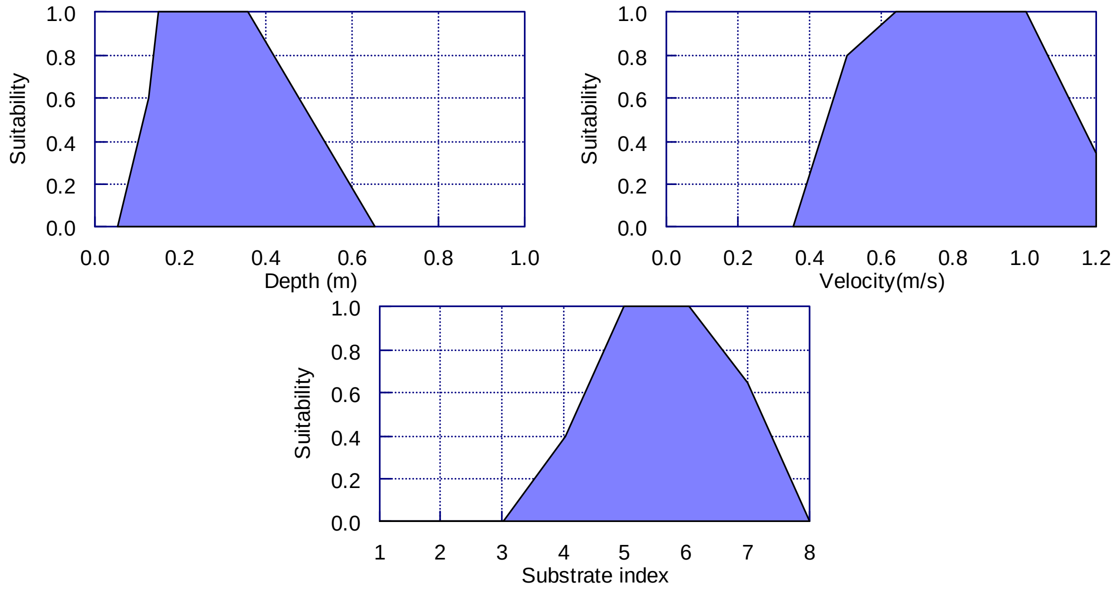
Redfin bully (Jowett & Richardson 2008)



Smelt (Jowett & Richardson 2008)



Torrentfish (Jowett & Richardson 2008)



Bluegill bully (Jowett & Richardson 2008)