Minimum Flows for the Whirinaki River and upper-Rangitaiki River

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Prepared for

Environment Bay of Plenty

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Executive Summary

Irrigation demand on the Galatea Plains is increasing with intensification of dairy farming. Surface and groundwater resources on the plains are approaching or exceeding default limits set by Environment Bay of Plenty and farmers are now looking to the Rangitaiki and Whirinaki Rivers for water supply. Environment Bay of Plenty has undertaken habitat surveys of the Rangitaiki and Whirinaki Rivers to support the setting of an Instream Minimum Flow Requirement (IMFR) on these rivers. Environment Bay of Plenty commissioned NIWA to report on the results of habitat surveys for determining flow requirements for the upper-Rangitaiki River and the Whirinaki River.

Instream habitat modelling (RHYHABSIM) was used to model change in fish habitat with flow for the Rangitaiki and Whirinaki Rivers. This method meets requirements to use objective scientific methods set out in the Proposed Regional Water and Land Plan (Bay of Plenty). Deriving an IMFR (instream minimum flow requirement) from the modelling output followed a standard method. The method, in short, allows a percent reduction in habitat dependent on the significance of each fish species.

Flow requirements for fish habitat in the Rangitaiki River at Galatea are relatively low (IMFR 8.7 m^3/s, compared to a 5-year low flow (Q_5) of 19.4 m^3/s at Galatea). The Rangitaiki River trout fishery is regionally significant and consequently the recommended IMFR for this reach provides a high level of protection for habitat of large rainbow trout. Fish habitat requirements further downstream at Te Teko were reviewed, but the available data proved unsuitable for determining approximate flow requirements. A habitat survey would be required in the lower Rangitaiki River before additional allocations were made from the River. Water temperature modelling is also recommended in determining the flow requirements of the lower-river.

Flow requirements of the Whirinaki River were also assessed. The Whirinaki is another regionally significant trout fishery, and habitat is the critical issue here requiring flows in excess of the Q_5 to provide adequate habitat protection (IMFR 6.5 m^3/s; Q_5 4.3 m^3/s). With a forested catchment and no major point discharges, it is considered unlikely that water quality issues would require higher flows.

1. Introduction

1.1 Study Brief

Irrigation demand on the Galatea Plains is increasing with intensification of dairy farming. The Galatea Plains provide well-drained alluvial soils that dry out quickly in summer. Surface and groundwater resources on the plains are approaching or exceeding default limits set by Environment Bay of Plenty, and farmers are now looking to the Rangitaiki and Whirinaki Rivers, which border the Galatea Plains, for water supply. Environment Bay of Plenty have undertaken habitat surveys of the Whirinaki and upper-Rangitaiki Rivers to support the setting of minimum flows on these rivers (Figure 1.1). Bente Clausen was contracted to analyse this data using the habitat-modelling programme RHYHABSIM. NIWA was then contracted to report this information and raise any other issues that are potentially critical in setting minimum flows for the two rivers. Environment Bay of Plenty decided this report should focus on habitat issues, with major discharges and associated water quality issues dealt with on an individual consent basis. This report presents the results of the habitat surveys, for the purpose of identifying critical issues that will determine the minimum flows for the Rangitaiki and Whirinaki Rivers.

1.2 Background

Water from streams in the Bay of Plenty region is used by irrigators, industry and municipal schemes. The Proposed Regional Water and Land Plan has stipulated that minimum flows be set using objective scientific methods, such as the Instream Flow Incremental Methodology (IFIM). Environment Bay of Plenty reviewed the ecological effects of water abstraction and methods for setting minimum flows (Wilding 1999), and then applied these methods in a series of studies (Wilding 2000, 2002a, 2002b, 2003).

Central to these studies was the development of instream management objectives. These were developed to allow consistent interpretation of the habitat modelling results across the Bay of Plenty. The approach follows concepts advocated by the Ministry for the Environment (MfE 1998) to implement regional plan objectives, and is explained in Appendix I. The objective is to provide adequate protection for aquatic ecosystems and this is achieved by identifying a primary flow for each species and then scaling this by an appropriate protection level. That level is determined by the significance of the given fish population. The recommended minimum flow, termed the IMFR (instream minimum flow requirement), is based on the species with the highest flow requirement.

The past reports included a regionalisation analysis in order to generalise the results from the selected sites to other streams. To achieve this, the Bay of Plenty Region was divided into areas supporting similar stream types. Regionalisation analysis has already been undertaken for the Kaimai area and Tauranga area (Wilding 2002b, 2003). However, this approach is not applied to the Rangitaiki and Whirinaki Rivers because of the lack of other rivers in the region this size to justify generalisation analysis.

1.3 IMFR and Water Allocation

As set out in the Proposed Regional Water and Land Plan, the IMFR (instream minimum flow requirement) is used to set surface water allocation limits. The IMFR sets the flow below which the stream shall not be taken by abstraction. It also determines the allocatable flow (the sum of consented takes) for two abstraction scenarios – termed low-flow allocation and high-flow allocation. The low flow allocation is calculated by subtracting the IMFR from the Q_5 (one in 5-year 7-day low flow). The Q_5 is the management level established in the Proposed Regional Water and Land Plan. Using the Q_5 figure provides water to abstractors, on average four years out of five before natural drought conditions would require them to stop taking water (to prevent the stream flow dropping below the IMFR). This provides some degree of certainty for water abstractors. The high flow allocation (water harvesting) is available when stream flow is above the Q_5, where the take is of short duration and does not compromise the IMFR. A Resource Consent is required for both high and low-flow allocation takes.

These methods of restricting takes are termed the allocation method. The intention of the allocation method is to set an environmental standard which allows for reliable surface water abstraction, while ensuring that adverse effects on aquatic habitats (and other values) are avoided, remedied or mitigated. (See the Proposed Regional Water and Land Plan for an explanation).

1.4 Scope

The scope of this report is to determine minimum flow requirements for the Whirinaki and upper-Rangitaiki Rivers based on fish habitat modelling. This report does not provide an exhaustive review of issues related to flow in the Rangitaiki and Whirinaki catchments, instead it provides focussed assessment of in-river ecological issues for setting minimum flows. The Ministry for the Environment's flow guidelines (MfE 1998) present a range of other ecological, community and cultural values potentially affected by river flows that are outside the scope of this report.

Figure 1.1: The Rangitaiki and Whirinaki Rivers are the focus of this report. Locations of habitat surveys are indicated for both rivers, as well as hydro-electric dams and the Fonterra milk processing plant in Edgecumbe. The Wheao power scheme includes small impoundments on the Rangitaiki and Wheao Rivers just to the south of this map. The headwaters of the Rangitaiki River border the Lake Taupo catchment. Figure 2.1 offers a closer look at the habitat survey reaches. The blue lines are rivers and the red lines are roads.

2. Methods

2.1 Sites and Catchment Information

Habitat surveys were undertaken on the Rangitaiki and Whirinaki Rivers. Sites were chosen to investigate the flow requirements of reaches potentially affected by irrigation abstraction on the Galatea Plains (Figure 2.1). Generally speaking, the reach most affected by a water take is that with the smallest flow – typically the reach just downstream of a take. So for the Rangitaiki River a reach was chosen adjacent to the Galatea Plains, between the Whirinaki River confluence and Lake Aniwhenua (Figure 2.1). There are several streams flowing into the river over this reach, of which the Horomanga River is the largest. For the Whirinaki River, a reach was chosen upstream of the Whirinaki Road bridge (Figure 2.1).

Both the Rangitaiki and Whirinaki Rivers are large by Bay of Plenty standards. The Whirinaki is a tributary of the Rangitaiki, but the two rivers are quite different in character. The Rangitaiki drains a large area of the Central Volcanic Plateau and the catchment is mostly forested (52% exotic production forest, 25% native forest). Flows are relatively stable because the pumice soils and ignimbrite geology (ignimbrite plus Taupo and Kaharoa breccia and ashes) allow rapid infiltration of rainfall, increasing groundwater flow and reducing the occurrence of flood events. This geology produces streams with mostly sandy runs plus occasional bedrock and cobble.

The Rangitaiki supports a regionally-significant recreational trout fishery, particularly Lake Aniwhenua which is a hydroelectric impoundment located just downstream of the habitat study reach (Proposed Regional Water and Land Plan, Schedule 1D). The long distance inland, and the presence of natural and artificial barriers, limits the abundance and diversity of native fish in the upper Rangitaiki River (above Matahina Dam). Recently, significant numbers of small eels were reported in Galatea streams (Wilding 2002), because the Kokopu Trust have been manually transferring eels above Matahina and Aniwhenua Dam since 1989. There are several hydroelectric dams on the Rangitaiki River (Figure 1.1). The Wheao Power Scheme is inland from Murupara, and with relatively little storage capacity operates mostly on run of river flow. Aniwhenua and Matahina are the two larger dams located between Galatea and Te Teko (Figure 1.1). The resource consents for Matahina Dam have an existing minimum flow requirement of 40 m^3/s and allow daily twin-peaking of flows for peak-demand generation (Consent number 02 2195/1, condition 5.1).

Downstream of the dams, the Rangitaiki River flows across the Rangitaiki Plains, and the land use changes to dairy pasture and horticulture, though pasture remains a small proportion of the total catchment area (17% at the river mouth). The main point discharge to the river is effluent from the milk processing site in Edgecumbe, operated by Fonterra Limited (Figure 1.1). The township of Murupara discharges treated sewage to the river above the Galatea Plains.

Returning to the Whirinaki, this river emerges from the Ikawhenua Ranges and flows 6 km across the Galatea Plains before joining the Rangitaiki River (Figure 2.1). The substrate is mainly cobble and boulder with frequent riffles. The catchment geology includes large areas of pumice and ignimbrite, but a lot of the baserock is greywacke (63% crushed argillite), which is why the Whirinaki River is more similar in character to the cobble streams of the Ikawhenua Ranges than to the Rangitaiki River. This river is a regionally significant trout fishery (Proposed Regional Water and Land Plan, Schedule 1D). Most of the catchment is native forest (part of the Whirinaki Forest Park), with smaller areas of plantation pine forest (82% native forest and scrub, 11% exotic production forest).

Flow statistics for both rivers are summarised in Table 2.1.

Table 2.1: Flow statistics for the Whirinaki River, and for various locations along the Rangitaiki River (units m^3/s). Q_5 is the 1 in 5-year, 7-day low flow. MALF is the 7-day mean annual low flow. Estimates for the Galatea survey reach are the sum of flows for the Rangitaiki River at Murupara and the Whirinaki River. Thornton is at the river mouth of the Rangitaiki River, and estimates for this site were calculated using mean flow estimates produced for the River Environment Classification scaled in proportion to measured flow statistics for Rangitaiki at Te Teko (the REC uses catchment area, rainfall and evaporation rates to calculate flow).

	Median flow	MALF	Q_5	flow record
Rangitaiki at Murupara (site 15408)	20.8	15.4	13.5	1949-2000
Rangitaiki at Galatea	32.5	20.6	17.8	estimate
Rangitaiki at Te Teko (site 15412)	62	44	40	1948-2004
Rangitaiki at Thornton	63	44.5	40.5	estimate
Whirinaki at Galatea (site 15410)	11.7	5.2	4.3	1953-2000

2.2 Trout surveys

Because trout are expected to have the highest flow requirements, fishing methods were chosen that would identify the species and size range of trout present. Drift diving was undertaken following methods of Hicks & Watson (1985) and Kusabs (2000). A 1500 m long section of the Rangitaiki River was drift-dived by 6 people on 12 May 2003. Water clarity was 2.3 m (horizontal black disc). This was insufficient for accurate fish counts in a river of this depth and velocity, but still provided useful information on the species and size range present. The Rangitaiki River was surveyed by NIWA above Murupara in January 1988 with better visibility of 4.7 m (Tierney & Jowett 1990). A 1500 m section of the Whirinaki River was dived on 12 May 2003, again by 6 people, with 2.3 m clarity (adequate in this smaller river). Both the Rangitaiki and Whirinaki drift-dive sections overlap with the surveyed habitat sections (Figure 2.1). Drift dive records for the Whirinaki were also supplied by Fish & Game New Zealand, Eastern Region ('Fish & Game') who monitor the river annually just upstream at Mangamate Falls.

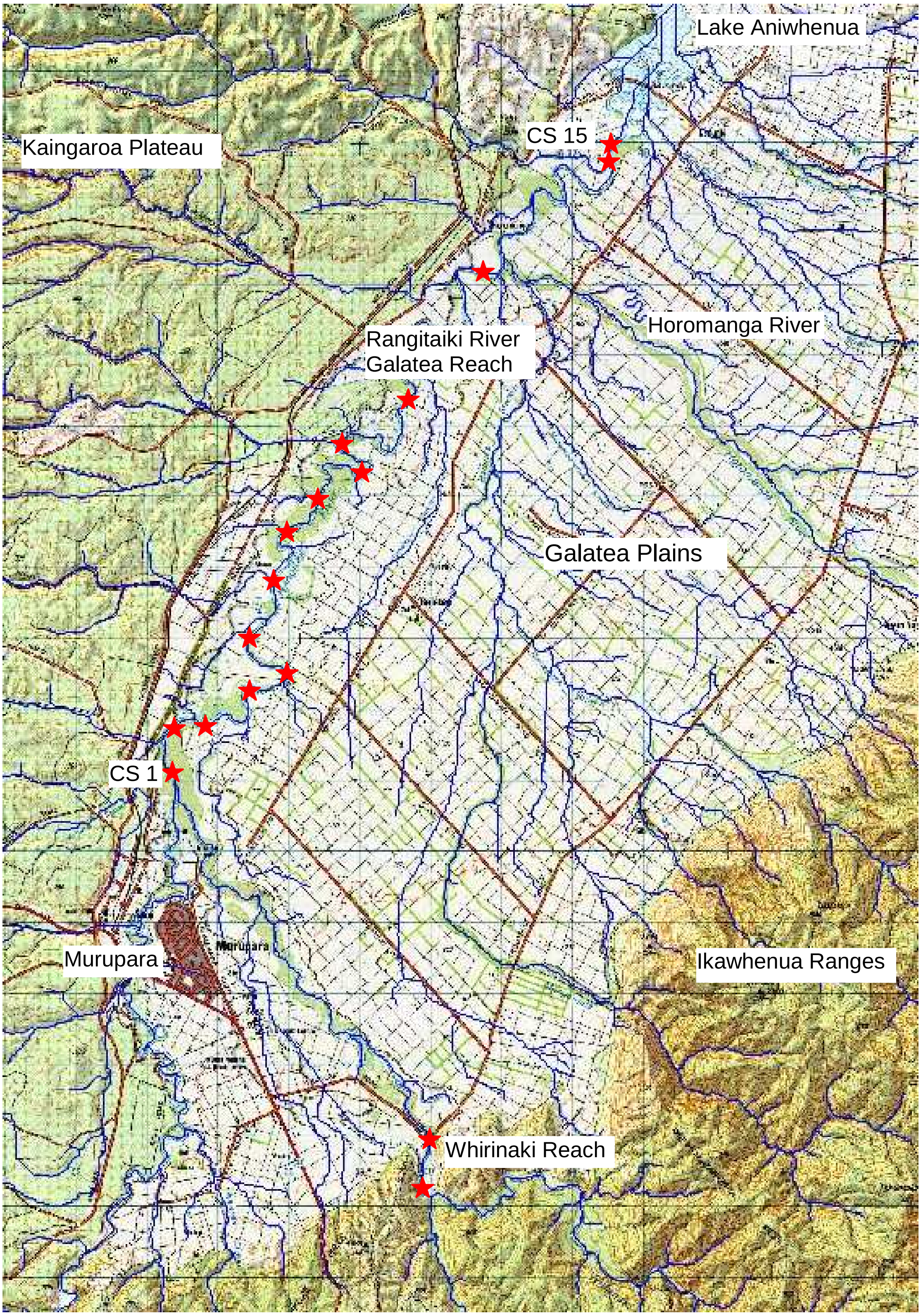

Figure 2.1: Galatea Plains and the location of habitat survey cross-sections on the Whirinaki and Rangitaiki Rivers. Fifteen cross-sections ("CS") were chosen to represent habitat for each reach and are represented by red stars. (NZMS 260 V17 © Sourced from Land Information New Zealand data. Crown copyright reserved).

2.3 Habitat Survey

The physical habitat component of IFIM (instream flow incremental methodology) was used to evaluate change in fish habitat with flow. This method focuses on depth, velocity and substrate as determinants of habitat suitability. Survey dates and measured flows are summarised in Appendix 2.

Data were collected from the Whirinaki River following the habitat mapping method described by Jowett (1996). This involves measuring the length of run, riffle and pool habitat over a reach so that the survey cross-sections chosen to represent each of these habitat types can then be weighted according to proportion of river habitat each represents. Of the fifteen cross-sections originally surveyed, five water level markers were lost or tampered with before sufficient data could be collected. Pools were infrequent in this reach, and the only pool cross-section surveyed was omitted because the water level marker was lost.

The Rangitaiki River has more uniform channel than the Whirinaki and comprises mainly of run habitat. Fifteen cross-sections were placed randomly along the river (c. 1 km) and all given equal weighting in the analysis. The data from some of these cross-sections (sections 11 to 14) was omitted from the analysis because of inconsistent water level readings. Eleven cross-sections were used in the analysis.

Flow requirements of the lower Rangitaiki River are outside the scope of this report. However, some preliminary analysis was undertaken to determine whether a habitat survey is required in the lower-river. Only if flow-requirements in the lower-river are greater than the Galatea reach would this limit water allocation at Galatea. In the absence of habitat survey data, alternative cross-sectional data was obtained in the hope of providing some understanding of flow requirements for fish habitat in the lower-river. Standard flow measurements record width, depth, velocity and water level, which provide most of the cross-sectional data requirements of the habitat modelling procedure (substrate composition and above-water measurements are not included in flow gaugings). Only one cross-section is measured however, compared to 15 for a normal habitat survey. NIWA operates a continuous flow recorder at Te Teko, and flow measurements are undertaken routinely to recalibrate stage-discharge calculations. Five flow measurements were chosen from different years in the hope that the shape of the channel would have changed enough to provide some representation of channel heterogeneity.

2.4 Data Analysis

The data were analysed using RHYHABSIM (version 3.0, Jowett 2001). RHYHABSIM stands for River Hydraulics and Habitat Simulation. The habitat analysis proceeded as follows:

1. Flows were computed from depth and velocity measurements for each cross-section.
2. A relationship between water level (stage) and flow (or rating curve) was developed for each cross-section using a least-squares fit to the logarithms of the measured flows and water levels, including an estimated stage at zero flow.
3. Water depths and velocities were computed at individual measurement points for a range of simulated flows. Then habitat suitability was evaluated from habitat suitability curves for each fish species (Appendix 3).
4. The weighted usable area (WUA) for each simulated flow was calculated as the sum of the habitat suitability scores across each cross-section, weighted by the proportion of the habitat type that each cross-section represents in the river.
5. WUA was plotted against flow and the resulting curves examined to determine flow requirements.

In order to derive more sensible rating curves, some changes were made to the Rangitaiki data (Galatea reach). The calibration gauging from 4 February 2003 was deleted because it was an outlier in all rating-curves. A stage at zero flow was nominated for cross-section 15, as the calibration gaugings indicated water level was being controlled downstream - possibly by Lake Aniwhenua (SZF set at 1.4 m below peg height). The survey flow was calculated as the average of what were considered the best cross-section gaugings (cross-sections 3, 5, 6 & 8). This gave a flow of 15.2 m^3/s, compared to the reach average of 13.6 m^3/s, and in doing so produced more sensible ratings. The analysis allowed for the inflow from the Horomanga River below cross-section 13. There were no such problems with the data from the Whirinaki River.

Deriving minimum flows from habitat-flow response curves followed specific instream management objectives, which were developed for application to the wider Bay of Plenty region. There are three steps to the method:

1. Identify the primary flow for each species. This is the flow where habitat is optimal, unless the optimum exceeds the streams natural flow (median flow) and is therefore unreasonable. In the latter case use the MALF as the primary flow.

2. Multiply habitat at the primary flow by the appropriate protection level to obtain a minimum flow for each species. Protection levels are scaled according to population/ecosystem significance (given in Appendix 1).

3. The species with the highest minimum flow determines the IMFR.

This approach is explained in greater detail in Appendix 1.

A range of different habitat criteria have been developed for rainbow and brown trout, both in New Zealand and North America. The criteria chosen will affect the minimum flow value because, generally speaking, larger trout have higher flow requirements. After recommendations by Hayes (2000) and Ian Jowett (NIWA pers. comm.), the favoured criteria are presented in Table 2.2, with trout size determining which criteria are appropriate in each case. A significant proportion of rainbow trout observed in the Rangitaiki and Whirinaki exceeded the size range recommended for the Cheeseman-Bovee habitat criteria. In the absence of more appropriate criteria, habitat was also modelled using habitat criteria developed for large trout in the Tongariro River (Appendix 3). The velocity criteria from the Tongariro may have been influenced by anglers, causing the fish to seek out higher than preferred water velocity (Jowett et al. 1996).

Table 2.2: Trout habitat criteria for use with RHYHABSIM based on size range of fish present in the study reach.

Species	Size	Habitat Criteria
Brown Trout	Adult (>40cm)	"Brown trout adult (Hayes & Jowett 1994)"
	Yearling (15-25cm)	"Brown trout yearling (Raleigh 1986)"
	Fry (<15cm)	"Brown trout fry to 15cm (Raleigh 1986)"
Rainbow Trout	Medium adults (30-45cm)	"Rainbow trout feeding (30-40cm Cheeseman Bovee)"
	Juvenile (<20cm)	"Juvenile rainbow trout feeding (Cheeseman Bovee)"

3. Results

3.1 Rangitaiki River

3.1.1 Fish Habitat Modelling

A habitat survey was undertaken on the Galatea reach between the Whirinaki confluence and Lake Aniwhenua. This section of the Rangitaiki River is some 50 km inland and flows alongside the Galatea Plains, where irrigation abstractions are proposed.

Existing records from the New Zealand Freshwater Fish Database (September 2004) reveal shortfin and longfin eels plus some dwarf galaxias are present in tributaries of the Rangitaiki River around Galatea. Young eels are now present in the Galatea area as a result of the elver transfer programme past Matahina and Aniwhenua dams. Dwarf galaxias are unlikely to be found in the Rangitaiki River (preferring shallow cobble habitat), but their habitat criteria were included in the modelling for reference (Figure 3.1). The native fish species have lower flow requirements than trout (Table 3.2).

The Proposed Regional Water and Land Plan (Schedule 1D) lists the Rangitaiki River as a significant trout fishery and drift diving revealed plenty of large rainbow trout, plus some large brown trout (Table 3.1). Additionally, Teirney & Jowett (1990) classified the Rangitaiki as a high abundance trout river. Therefore a habitat protection level of 95% was chosen for application to the modelling results for trout habitat (Figures 3.2 & 3.3) using the method described in Section 2.4 and Appendix 1.

Minimum flows were calculated for each species and life stage (Table 3.2). The highest flow requirement is for adult rainbow trout, using the Tongariro habitat criteria (10.5 m^3/s). As mentioned in the methods, the Tongariro adult trout criteria are believed to overestimate flow requirements for large rainbow trout except where angler pressure is high. Therefore, the average of the large trout Tongariro flow and the medium trout flow is recommended to provide adequate protection for the large trout found in the Galatea reach (8.7 m^3/s). This IMFR is considerably less than the natural low flows, so it is important to investigate whether other river values have higher flow requirements.

Table 3.1 Drift-diving results from the Rangitaiki and Whirinaki Rivers presented as fish observed per kilometre. Drift-diving of the Whirinaki River was undertaken by Environment Bay of Plenty and Eastern Region Fish & Game (Fish & Game results are averages from 6 years of annual monitoring). Abundances observed by Environment Bay of Plenty for the Rangitaiki River are questionable because of poor water clarity. NIWA results are from Tierney & Jowett (1990). Small fish are < 230 mm; large fish are > 380 mm.

	Rangitaiki		Whirinaki	
fish/km	**Env. BOP**	**NIWA**	**Env. BOP**	**Fish &Game**
Rainbow trout small		42		15
Rainbow med.	51	75	16	13
Rainbow large	14	25	2	5
Brown trout small		4		6
Brown med.		7		11
Brown large	3	2		6
Unident. trout small	39		27	6
Unident. med.				7
Unident. large				2
Total	107	155	45	70

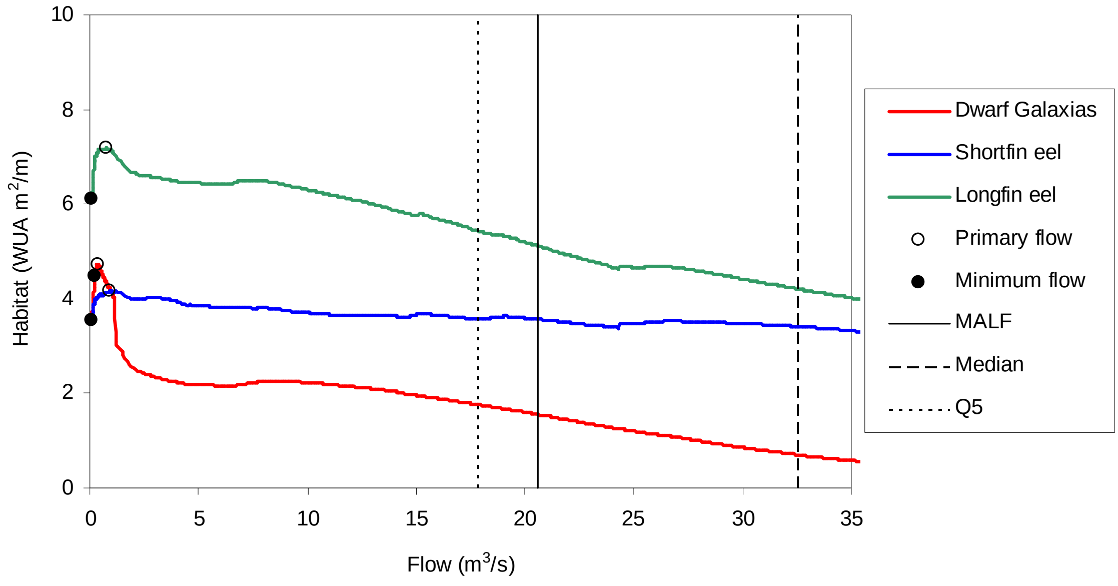

Figure 3.1 Change in native fish habitat with flow for the Rangitaiki River at Galatea. The primary flow is the point to which the protection level is applied (see Worked Example, Appendix 1). MALF is the mean annual low flow, Q_5 is the 1 in 5-year 7-day low flow.

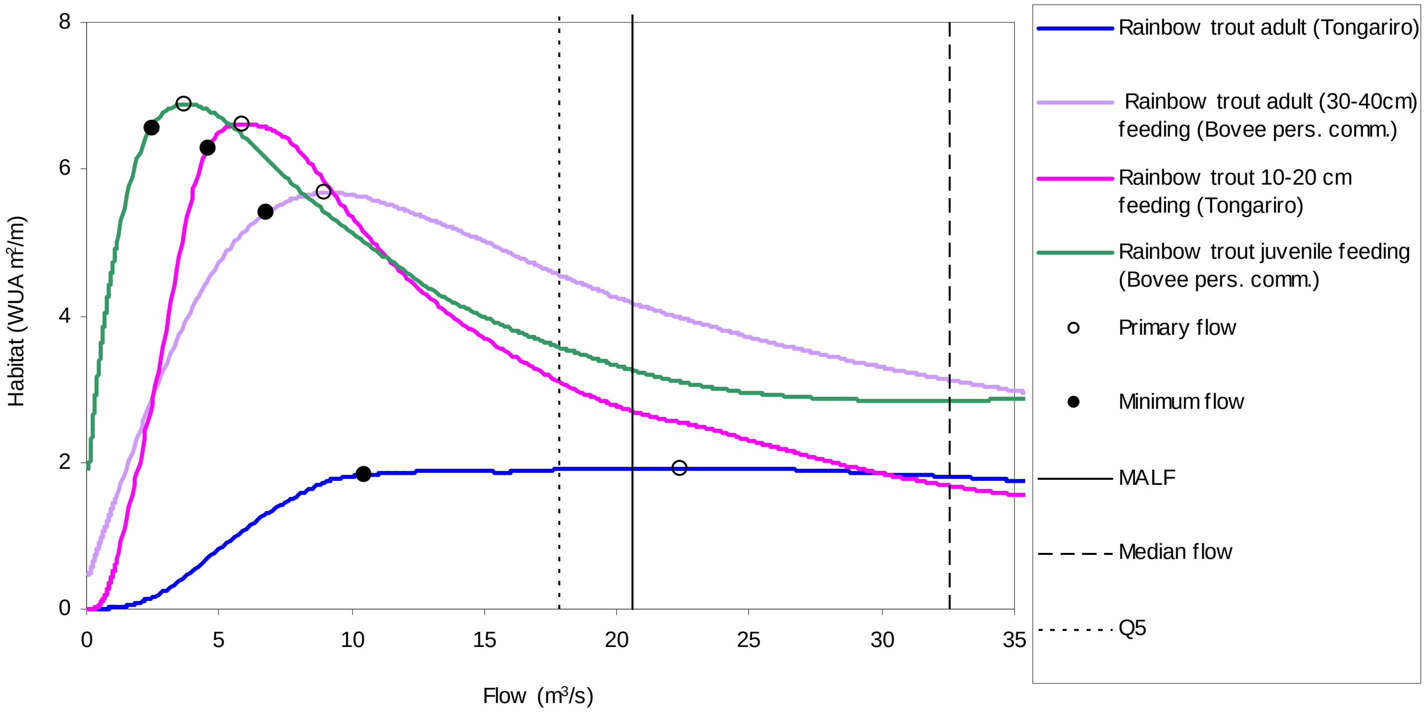

Figure 3.2: Change in rainbow trout habitat with flow for the Rangitaiki River at Galatea. The primary flow is the point to which the protection level is applied (see Worked Example, Appendix 1). MALF is the mean annual low flow, Q_5 is the 1 in 5-year 7-day low flow.

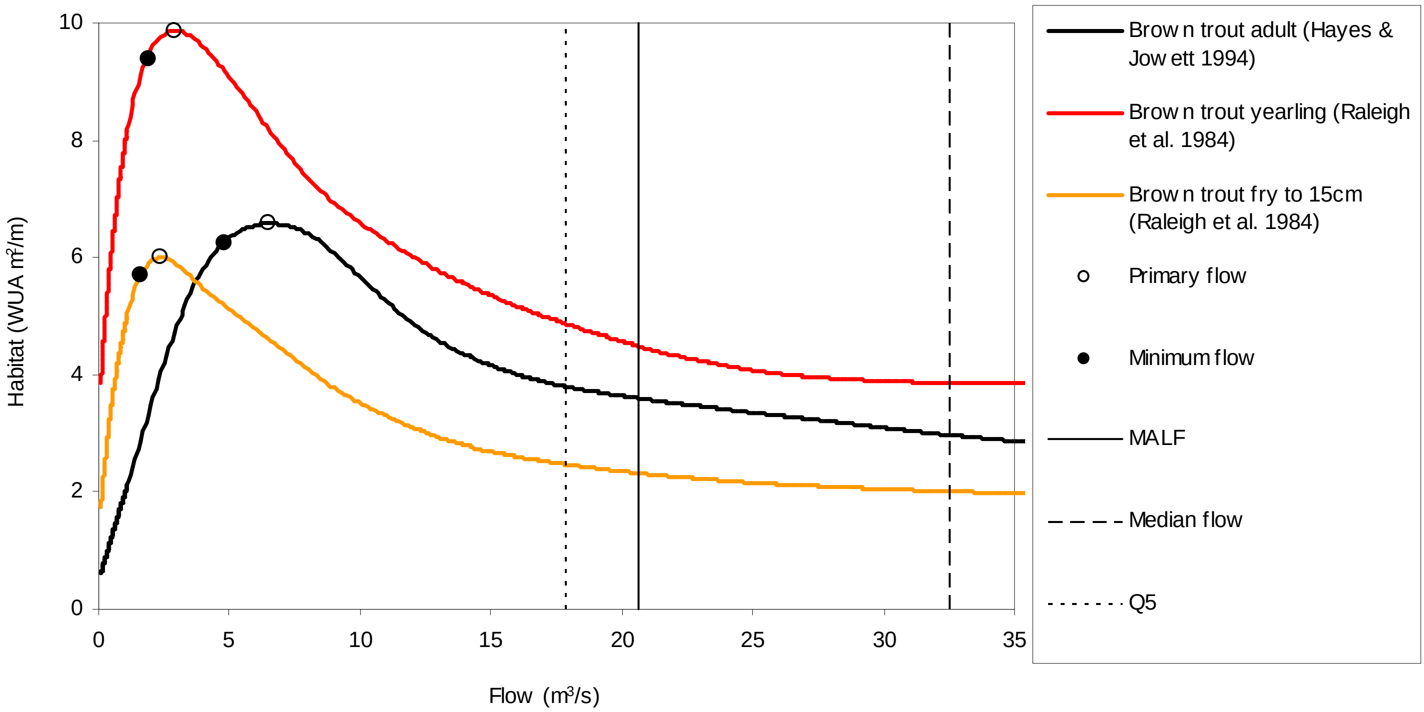

Figure 3.3: Change in brown trout habitat with flow for the Rangitaiki River at Galatea. The primary flow is the point to which the protection level is applied (see Worked Example, Appendix 1). MALF is the mean annual low flow, Q_5 is the 1 in 5-year 7-day low flow.

Table 3.2: Minimum flows (m^3/s) calculated for fish in the Rangitaiki River at Galatea and the Whirinaki River. The protection level for trout and dwarf galaxias was set at 95%, and for eels 85%. The IMFR is calculated as the average of the minimum flow for medium and large adult rainbow trout (see section 3.1.1).

	Minimum Flow (m^3/s)	
Species / life stage	**Rangitaiki at Galatea**	**Whirinaki River**
Brown trout adult	4.8	3.1
Brown trout yearling	1.9	1.3
Brown trout fry	1.6	1.3
Brown trout spawning (Shirvell & Dungey 1983)		1.8
Rainbow trout large adult (Tongariro)	10.5	8.5
Rainbow trout medium adult	6.8	4.4
Rainbow trout juvenile	2.5	1.6
Rainbow trout spawning (Tongariro)		2.4
Dwarf galaxias	0.2	0.3
Longfin eel	0.09	0.8
Shortfin eel	0.08	1.9
IMFR	**8.7**	**6.5**
Q_5 flow	19.4	4.3

Flow requirements for trout habitat were estimated for the lower-Rangitaiki River at Te Teko, using cross-sectional data originally collected for flow gaugings at the NIWA flow recorder. However, the results were not considered reliable enough to include in this report. Velocities in the Rangitaiki River at the Te Teko flow recorder are high (cross-section average close to 1 m/s), and are not predicted to drop significantly till flows fall below 30 m^3/s (Figure 3.4). Although unusual, the relationship between flow and velocity is correct, as confirmed by the gauging data at Te Teko. This situation produced a habitat peak for adult trout at about 10 m^3/s, when flows were sufficiently low for velocities to drop to about 0.5 m/s; and a second peak at much higher flows (>30 m^3/s) when slower flowing margins became deep enough for adult trout. Subtle changes to the ratings produced significant jumps in minimum flows, depending on the magnitude of the first peak. More cross-sections would need to be surveyed to obtain a reliable estimate of flow requirements for fish habitat in the lower Rangitaiki River.

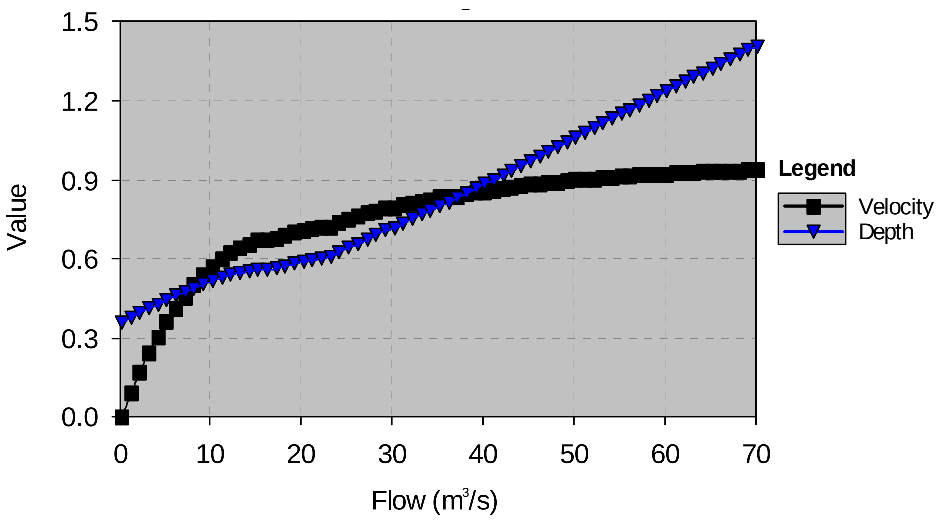

Figure 3.4: Predicted change in velocity (m/s) and depth (m) with flow at the Te Teko flow monitoring site on the Rangitaiki River (site 15412).

3.1.2 Water Quality

Discharges upstream of the Galatea reach were not assessed because water abstraction is proposed on the Galatea Plains (Figure 2.1). Therefore contaminants would be abstracted in proportion to the irrigation take, and so concentrations would not increase. This applies to the treated sewage discharge from Murupara township, and any groundwater derived run-off from the log-yard in Murupara (stormwater from the log-yard, containing resin-acids, is discharged to groundwater).

Water quality issues in the lower-Rangitaiki River could potentially have higher flow requirements than the upper-river. However, the lower-river is not the focus of this report, so water quality issues are mentioned here for the sole purpose of guiding future work on the lower-river. There are major discharges from the Rangitaiki Plains to the lower-river, including from the Fonterra Limited milk processing site at Edgecumbe (Figure 1.1). Lactose is discharged here and is an issue because it promotes the growth of sewage fungus in the river (McIntosh & Bruere 2004, Scholes & McIntosh 2004). The growth of sewage fungus will be affected by the quantity of lactose discharged as well as the flow available in the river for dilution. Fonterra's consent for the lactose discharge includes limits based on in-river concentrations (consent number 02 4211, condition 7.2.3), which means the amount that Fonterra can discharge is controlled by river flows.

With increased organic loading in the lower river from pasture and major discharges, dissolved oxygen is worthy of consideration for determining flow requirements. Environment Bay of Plenty monitoring data show that oxygen concentrations approach saturation most of the time (average 96% saturation, with a 5 percentile value of 83%). This is based on spot measurements, so do not provide an understanding of diurnal fluctuations, which can be significant. Deployment of data loggers would provide a better picture of oxygen issues in the river.

Average monthly temperatures of the lower Rangitaiki River remain below 20°C through summer, which is within the preference range of most species (based on Environment Bay of Plenty monitoring data). However, the 95-percentile temperatures are approaching the limits for some species, reaching 23°C in January. As with oxygen, data loggers provide better information on diurnal fluctuations in temperature, and would also provide useful validation data for temperature modelling, which is recommended as part of the IMFR investigation for the lower-Rangitaiki River.

Temperature and oxygen conditions are expected to be at their worst in the lower river, where total organic loading is higher and thermal equilibrium more likely to be reached. For this reason the two parameters were not evaluated for the upper-river.

3.2 Whirinaki River

A habitat survey was undertaken on the Whirinaki River, upstream of the Whirinaki Road Bridge (Figure 2.1). Drift diving results from Fish & Game is based on multiple surveys and reveal similar numbers of brown and rainbow trout, many of which were large fish (Table 3.1). The Whirinaki is a regionally significant trout fishery, as classified in the Proposed Regional Water and Land Plan (Schedule 1D). Minimum flows were calculated from the modelling results using the method specified in Section 2.4 and Appendix 1 with the protection level for trout set at 95%, in recognition of the significance of the fishery.

Maximum habitat for juvenile trout and native species occurs at flows less than 2 m^3/s (Figures 3.4 to 3.6), while adult trout prefer higher flows that are between Q_5 and median flow (Figures 3.4 & 3.5). Minimum flows calculated for each species and life stage are presented in Table 3.2. As for the Rangitaiki River, we again encounter the problem of lack of suitable habitat criteria for large rainbow trout. The Bovee criteria are for medium adults (< 450 mm) and the Tongariro criteria may overestimate flow requirements for larger fish (see section 2.3 & 3.1.1). I therefore recommend the IMFR be based on the average of the two criteria to provide a high level of protection for large rainbow trout (6.5 m^3/s). An IMFR greater than the allocation limit of the Q_5 flow means no water is available for allocation from the Whirinaki River (see section 1.3).

Because the IMFR based on fish habitat prevents water allocation, examining other potentially critical issues becomes less important. The Whirinaki River drains a largely forested catchment and there does not appear to be any significant point discharges, so it is unlikely that there would be any water quality issues that would require higher minimum flows in the Whirinaki catchment. The Whirinaki flows into the Rangitaiki River, at which point abstractions may also be limited by flow requirements of the Rangitaiki.

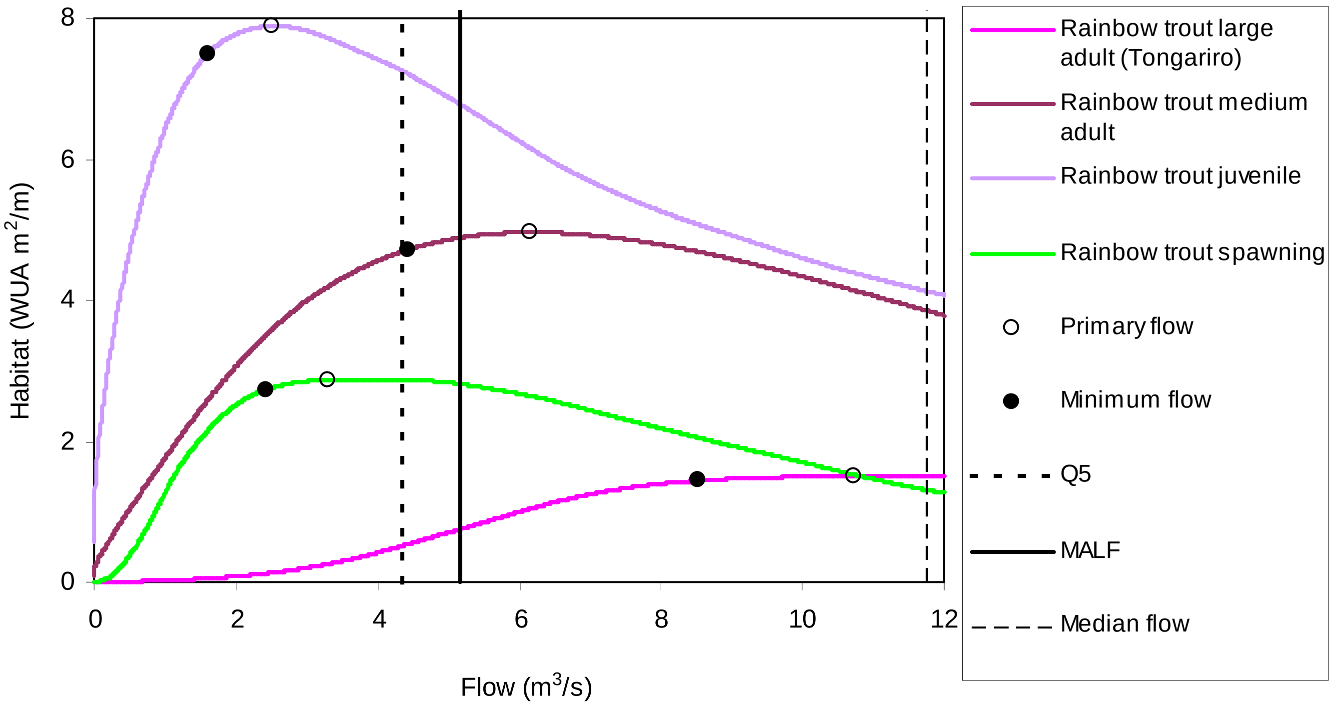

Figure 3.4: Change in habitat with flow for various life stages of rainbow trout in the Whirinaki River. Primary flow is the available habitat value to which the protection level (95%) is applied to produce the minimum flow for each species (see Worked Example, Appendix 1). Q_5 is the one in 5-year 7-day low flow; MALF is the mean annual 7-day low flow. Habitat preference curves are given in Appendix 3.

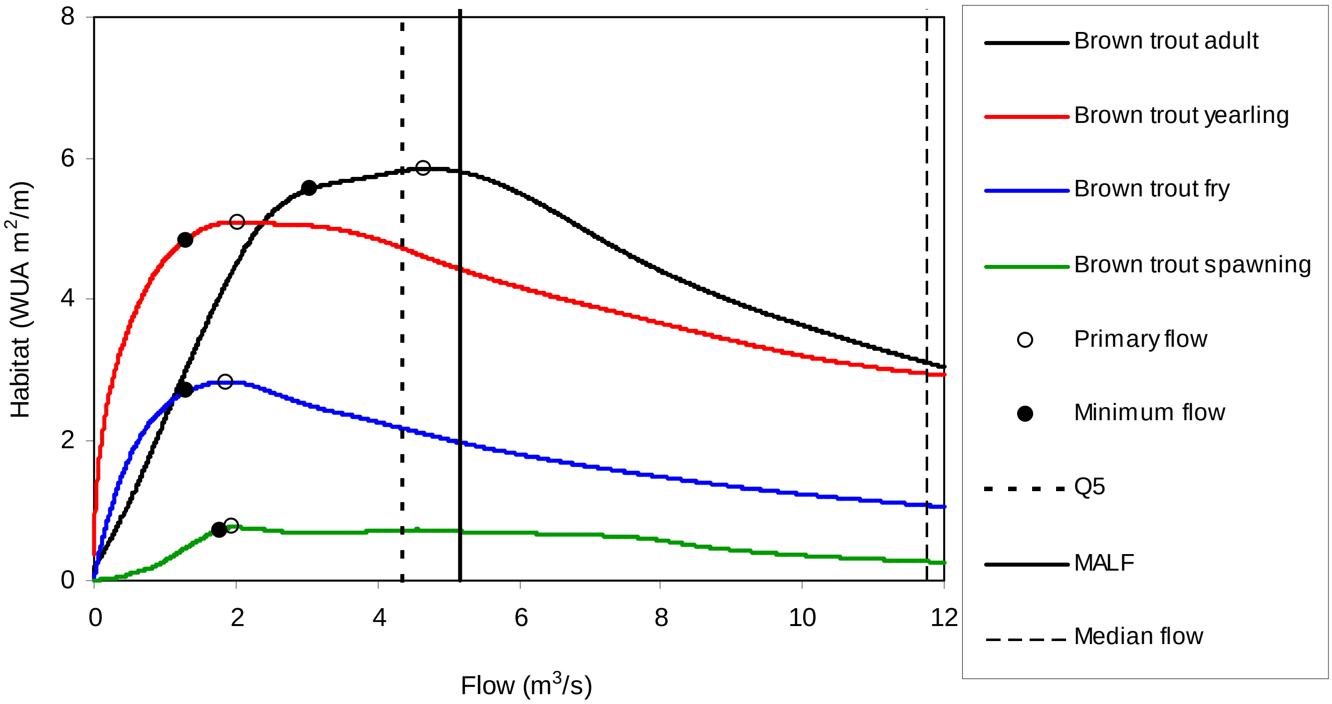

Figure 3.5: Change in habitat with flow for brown trout in the Whirinaki River. Primary flow is the available habitat value to which the protection level (95%) is applied to produce the minimum flow for each species (see Worked Example, Appendix 1). Q_5 is the one in 5-year 7-day low flow; MALF is the mean annual 7-day low flow. Habitat preference curves are given in Appendix 3.

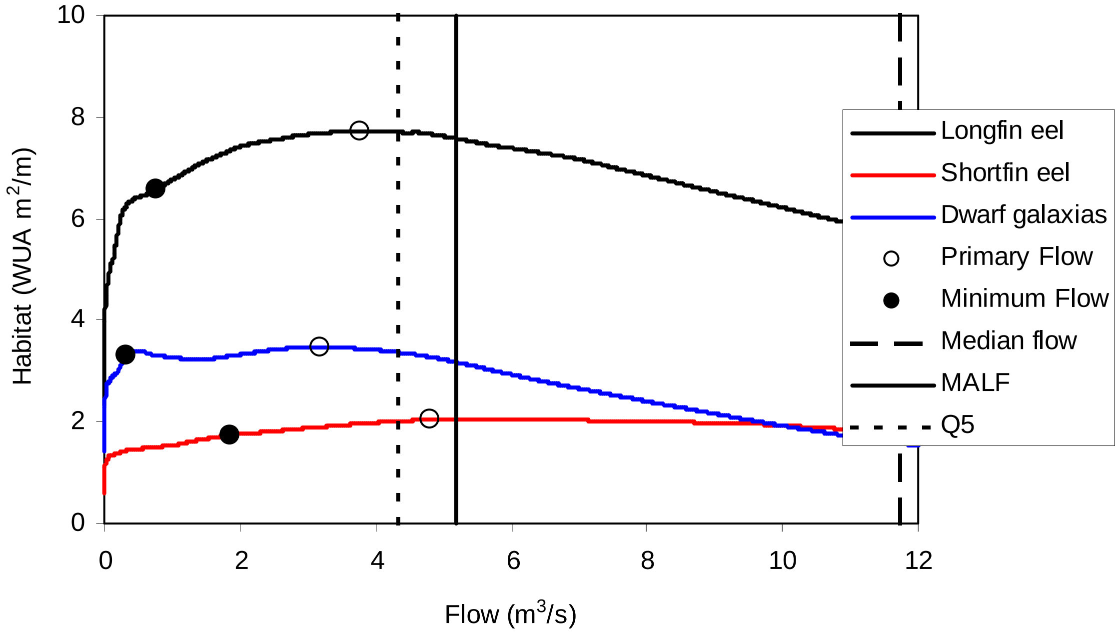

Figure 3.6: Change in habitat with flow for native fish in the Whirinaki River. Primary flow is the available habitat value to which the protection level is applied to produce the minimum flow for each species (see Worked Example, Appendix 1). The protection level for eels is 85% and for dwarf galaxias 95%. Q_5 is the one in 5-year 7-day low flow; MALF is the mean annual 7-day low flow. Habitat preference curves are given in Appendix 3.

4. Discussion

4.1 Flow requirements for the upper-Rangitaiki River

Flow requirements for fish habitat at Galatea are relatively low (IMFR 8.7 m^3/s), compared to the five-year low-flow (Q_5 19.4 m^3/s). The trout fishery in the Rangitaiki River is regionally significant and so the recommended IMFR for this reach is intended to provide a high level of protection. Fish habitat requirements further downstream at Te Teko were reviewed, but unfortunately the data available proved unsuitable for assessing the likelihood of fish habitat in this reach having higher flow requirements than Galatea. A habitat survey is therefore required in the lower Rangitaiki River to determine habitat requirements. This should also look at flow requirements to maintain water temperature (deployment of data loggers is recommended).

Habitat preferences curves for rainbow trout in New Zealand are lacking, particularly for the pumice geology streams of the Volcanic Plateau. There is a wide range of habitat criteria available from North America, but these are for fish smaller than can be found in top trout fishing rivers such as the Rangitaiki and Whirinaki. The habitat criteria that were developed in New Zealand for large trout reflect habitat use in the Tongariro River, which has cobble and boulder substrate (Jowett et al. 1996). In this type of river you are unlikely to find trout over sand substrates because these are associated with slow water areas that trout avoid. In contrast the Rangitaiki and other Volcanic Plateau streams often have fast-flowing areas with fine gravel and sand substrates, and this is where trout are often seen (pers. obs.). Therefore sandy areas may be incorrectly classed as unsuitable habitat. Reservations are also held over the transferability of Tongariro preference criteria because of the heavy fishing pressure on the river that may have pushed the trout into less preferred fast flowing water (Ian Jowett pers. comm.). Consequently there is uncertainty over their applicability to Bay of Plenty rivers. The most appropriate habitat criteria available were selected for this study, and by taking the average of the Bovee and Tongariro criteria the recommended flow requirements are expected to provide a high level of protection for large rainbow trout. More research on rainbow trout habitat preferences would provide more robust results however.

4.2 IMFR for the Whirinaki River

As well as investigating flow requirements of the Rangitaiki River, the Whirinaki River was also assessed. The Whirinaki is also a regionally significant trout fishery, and the river requires flows in excess of the Q_5 to achieve adequate protection of habitat. Habitat is the critical issue for the Whirinaki River, as it is considered unlikely that there would be any water quality issues requiring higher flows in this forested catchment. The Whirinaki River flows into the Rangitaiki River at Murupara, so any allocation from the Whirinaki is further constrained by the flow requirements of the Rangitaiki.

5. Acknowledgments

Matthew Bloxham (Environment Bay of Plenty) organised the habitat project and supplied results and details of methods used for this report. Environment Bay of Plenty staff undertook the habitat surveys, including Craig Putt, Wayne Secker, Mike Seabourne and Glenn Ellery. Janine Barber provided policy direction and Paul Scholes supplied the necessary water quality data. Bente Clausen (consultant) undertook the data checking and modelling of the habitat data. Rob Pitkethley from Fish & Game New Zealand, Eastern Region supplied fisheries data for the Whirinaki. At NIWA, Marie Townsend, Bob Murray and Kathy Walter supplied hydrological data. Ian Jowett provided advice and direction at various stages of the analysis and reporting.

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Appendix I: Instream Management Objectives for Bay of Plenty streams and methods for setting minimum flows

(Reprinted from Wilding 2002b)

Background

The environmental flows (or habitat) project was set up by Environment Bay of Plenty to provide a more defensible approach for water allocation. The project looks at the effects of abstraction on aquatic life both directly (reduced habitat) and indirectly (water quality, temperature). This appendix, reproduced from Environment Bay of Plenty reports, only deals with one aspect of minimum flow determination – interpreting habitat-flow response curves. Irrigation abstractions are the main focus, while issues associated with water impoundment are not addressed (flushing flows, etc.).

Modelling techniques are used to address the habitat issue. The RHYHABSIM programme models change in depth, velocity and substrate with flow and relates this to habitat preferences of native fish and trout. But it does not produce a minimum flow. As a result, deriving a minimum flow figure is subjective to the point were two people working with the same data can produce two different figures. The aim therefore is to establish an objective approach for deriving minimum flows from RHYHABSIM habitat modelling. Not only will this enable a consistent environmental outcome in setting minimum flows throughout the project but also provide external consultants with guidance for interpreting such data to the satisfaction of Environment B·O·P.

Objectives and Options

The first step was to review legal planning objectives. Relevant objectives in the Proposed Regional Water and Land Plan are:

33. Water flows in streams and rivers are maintained to:

    a. Provide adequate protection for existing aquatic life in the waterbody.

    b. Maintain identified significant values of rivers and streams.

    c. Maintain water quality relative to the assimilative capacity of the water body.

    d. Avoid or mitigate adverse effects on downstream environments.

Part a) is directly relevant here (background to this policy can be found in Appendix II of Wilding 2000). The MfE flow guidelines (1998) provide guidance on developing instream management objectives, pointing out the need to identify the values to be protected as well as the level of protection. From the above policy, values addressed by this project are existing aquatic life and in terms of level of protection we need to define what is adequate. This will vary depending on the significance of the aquatic ecosystem.

Features of a good instream management objective include:

- Retain adequate flow for ecosystem protection based on ecosystem significance.
- Provide an objective approach so 2 people can get the same answer.

Options for instream management objectives include:

1. Habitat remains unchanged.
2. Allow a percent reduction in habitat.
3. Allow change based on individual reach assessment, i.e., leaving it open to interpretation.

Allow change down to a region wide standard. For example, a NIWA study for Wellington and Taranaki Regional Councils suggested setting a minimum flow based on the 85%ile of percent brown trout habitat from the national "100 Rivers" study, (Jowett 1993a, 1993b).

Option 1 will often prevent water being made available and fails to recognise the potential for improved habitat at lower flows. Allowing an across-the-board reduction in habitat provides a consistent environmental outcome (Option 2), but it is somewhat clumsy because again it ignores the potential to optimise habitat at different flows. Option 3 doesn't provide the necessary objectivity, and achieving consistency in case by case negotiations may be difficult. Option 4 relies on a sentinel species that is likely to have the highest flow requirements. Brown trout are not present in all Bay of Plenty catchments and few native species with high flow requirements are sufficiently widespread. Also, standards based on the "100 rivers" study may set an unrealistic expectation for the small pressure catchments, (many pressure streams have flows <1 m^3/s, cf. only 2 of the "100 rivers" had flow < 2 m^3/s). It seems these more straightforward approaches won't produce the desired result in many instances so a more complex approach is recommended.

Recommended Approach

1. Using the habitat flow response curve, identify a primary flow for each species. This is the flow where habitat is optimal (greatest), unless the optimum exceeds the median flow (and is therefore unreasonable). In the latter case the MALF is used as the primary flow.

2. Multiply habitat at the primary flow by the protection level. Plot this point on the flow response curve and read the minimum flow for each species of the X-axis. The level of protection is scaled according to ecosystem significance. Significance criteria are given in the last section of this appendix. For example, habitat for Criteria 6 species can be reduced to 85% of that offered by the primary flow, while habitat for the most significant species cannot be reduced at all. (Note this percentage is a change in habitat, which may or may not equate to a similar drop in flow).

3. Having produced a minimum flow for each species present, the highest of these is chosen as the minimum flow for the stream reach. This is to ensure adequate protection for the existing stream community (i.e., all taxa).

Although relatively complex it is not a difficult process, and objectivity is achieved.

The minimum flow is based on the species with the highest flow requirements. An alternative approach offered by Jowett & Richardson (1994) for native fish communities, is to set minimum flows at that preferred by fish with intermediate flow requirements (redfin bully or common bully), rather than fast water species (torrentfish, bluegill bullies). While offering a compromise, Jowett & Richardson's approach will in some cases allow large reductions in habitat for fast water species, and this does not ensure adequate protection for the existing aquatic community. The tendency for fast water species to prefer the equivalent of flood flows is circumvented here by not allowing the primary flow to exceed the median flow.

The point of inflexion is sometimes advocated for setting minimum flows. The point of inflexion is the point above which there is little increase in habitat with flow – the graph levels off, (the longfin and shortfin eel curves in Figure 1 are good examples). A point of inflexion does not always exist and, where it does, can be influenced by the scale used for the axes. Where a point of inflexion exists, the recommended approach effectively recognises it because the flatter the curve the greater the flow reduction for a percentage reduction of habitat.

The basic principle of the recommended approach is to identify the optimum (or best available) flow and allow a reduction below this which recognises the significance of the stream community. It recognises that natural stream flows are not always ideal, and the risk associated with small reductions in habitat is acceptable for more common species. If one accepts this approach, the only room for debate is in the protection levels specified. One way to test the levels chosen is with follow up monitoring, the results of this feeding into consent reviews. Unfortunately conclusions can only really be certain if stream flows are drawn down to the minimum flow for an extended period. Baseline data would need to be collected before abstractions begin. This approach will tell us if too much water was allocated. However, determining if minimum flows are too conservative would rely on natural low flows falling below the set minimum for an extended period. Even then it is possible any effect would be a consequence of lack of floods rather than reduced flows *per se*.

Other Considerations

When estimating stream flows, this should be corrected for existing takes (municipal, industrial, irrigation). This necessitates measuring flows when water is not being abstracted or measuring the abstracted flow and correcting accordingly. There is some argument for not correcting for permitted domestic takes (< 15 m^3/day).

Significance criteria and allowable habitat reductions

Significance criteria were established to scale the level of protection (Table 1). The 100% protection level (Criteria 1) is only afforded to the most threatened species. Any reduction in habitat is unacceptable because the risk of irreversible population decline (i.e., extinction) is too high. The 85% level (Criteria 6) is intended to provide adequate protection for relatively widespread species. Intermediate criteria are protected accordingly.

Significant recreational trout fisheries are afforded a relatively high level because their value lies in the abundance of fish, a factor directly affected by habitat. While less fished trout populations are afforded the 85% protection level, populations that support negligible fishing are given the least protection (15%). This is because trout were introduced to New Zealand principally to provide a recreational fishery. The 15% level is specified to reduce the chance of fish kills.

The 90% level afforded to diverse communities reflects the non-threatened status of the taxa it applies to, (any threatened taxa are covered by the more protective criteria), and the desire to maintain an assemblage of species. The more species present the more likely one will have relatively high flow requirements. Although not presented in the table, appropriate food producing habitat for these species should be given the same level of protection.

No rules are set for deciding if the community represents a diverse assemblage (Criteria 4). Streams closer to the sea generally have higher diversity and so an inland stream with only a few taxa may still represent a relatively diverse community given the streams potential.

In some cases Crans bully should be given a Criteria 2 protection level. As a non-diadromous species, recruitment success is more dependent on a suitable instream environment. By contrast, local extinction of inanga from a stream would be more reversible with whitebait migrations from the sea. Likewise if a population of Crans bully was lost from a tributary, the species could eventually re-establish itself from the main river or lake. However, if abstraction affected the majority of the reproducing population in a catchment then Criteria 2 protection should be given. This is not stated as separate criteria because only one non-diadromous native species is present in the Bay of Plenty (that is not already given a higher protection level), and Crans bully is mostly confined to the East Cape streams where abstraction pressure is low.

Some may argue depauperate streams should be given a lower protection level. If a stream is proven to be depauperate it seems unlikely that in-depth RHYHABSIM assessments would be justified. Factors other than fish habitat may become the critical factor determining flow requirements (see MfE 1998).

Table 1: Significance criteria and protection levels.

Significance Criteria		Protection level (percentage of primary habitat)
1.	DoC priority A & B species[1]. Short-jawed kokopu; giant kokopu	100%
2.	DoC priority C species & regionally threatened species. Banded kokopu; koaro; black mudfish; dwarf galaxias[2]	95%
3.	Regionally significant trout fisheries plus habitat on which these fisheries depend for spawning and rearing. Brown trout; rainbow trout; etc.	95%
4.	Diverse native fish communities. Fish community featuring a significantly high number of native species. Constituent species are individually given this protection level, unless afforded higher protection by Crit. 1-3.	90%
5.	Unfished trout populations.	70%
6.	Other.	85%

Worked Example

A change in available habitat, be it up or down, is largely unavoidable if we want to make any water available for abstraction (see Figure 1). So where possible we want to optimise habitat available in the stream. For the Tahawai Stream, optimum habitat occurs at approximately 13 L/sec for banded kokopu (Figure 1). In some cases it is unreasonable to expect optimum conditions. For example, optimal habitat for longfin eel occurs at more than twice the median flow. In this case we set the primary flow at the MALF.

This provides a starting point for each species (Table 2). We then need to set a protection level that recognises ecosystem significance. Because the Tahawai Stream supports a high number of species we set the level of protection at 90% for all native species except banded kokopu, which fall into Criteria 2 (95%). A minimum flow is produced for each species and we adopt the highest figure to ensure the ecosystem is sustained. In this case inanga have the highest flow requirement, so the recommended

[1] Molloy & Davis, 1994.
[2] Dwarf galaxias is classed as regionally threatened. The only records of this species in the Bay of Plenty are from a few streams on the Galatea Plains (an area of high abstraction pressure). These records, until recently represented the northern limit of the species.

minimum flow for Tahawai would be set at 26 L/s. This is termed the IMFR, (instream minimum flow requirement). Allocable flow is based on Q_5 minus the IMFR, so with a Q_5 of 23 L/s no water is available for abstraction (23-26=-3 L/s). Note that reducing the minimum flow for shortfin eel from 14 L/s, down to the point of inflexion at 11 L/s, would make no difference to the IMFR, which is based on inanga for this stream.

Table 2: Tahawai Stream minimum flow evaluation. The primary wetted usable area (Primary WUA, m^2/m) is derived from Figure 1 using the recommended approach. This value is multiplied by the protection level (see last section) and a minimum flow is derived.

	Primary WUA	WUA x prot. level	Corresponding minimum flow (L/s)
Inanga	0.29	0.26	**26**
Torrentfish	0.11	0.095	24
Redfin bully	0.86	0.77	19
Longfin eel	1.04	0.93	14
Shortfin eel	0.73	0.66	13
Banded kokopu	0.18	0.17	8

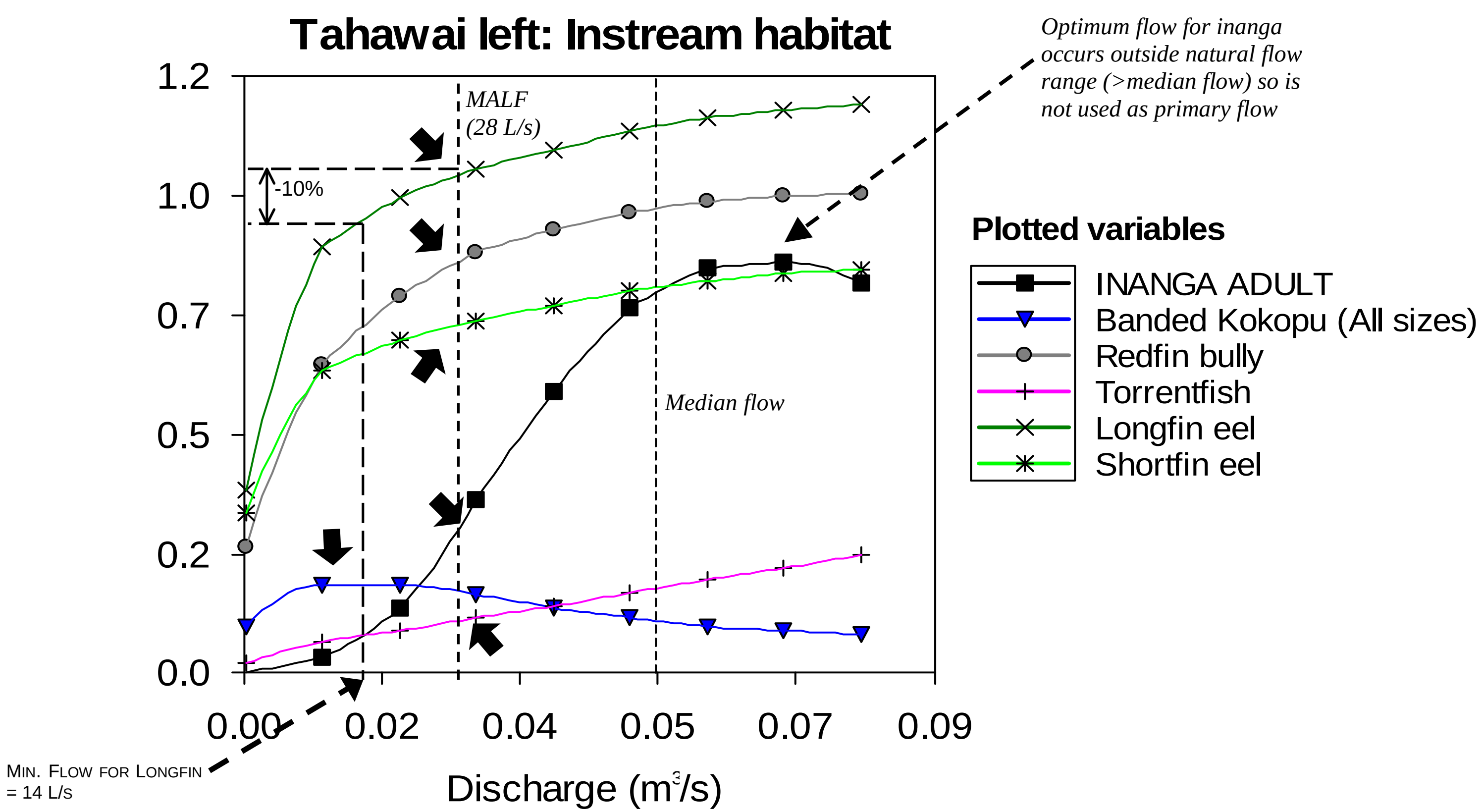


Figure 1: Modelled habitat for the Tahawai Stream (western BOP) expressed as habitat (WUA m^2/m) versus flow. Primary flows determined using established criteria are arrowed for each species. Minimum flow calculation for longfin eel illustrated. Note, this is presented as an example only, as taxa and baseflow estimates were altered to illustrate the method.

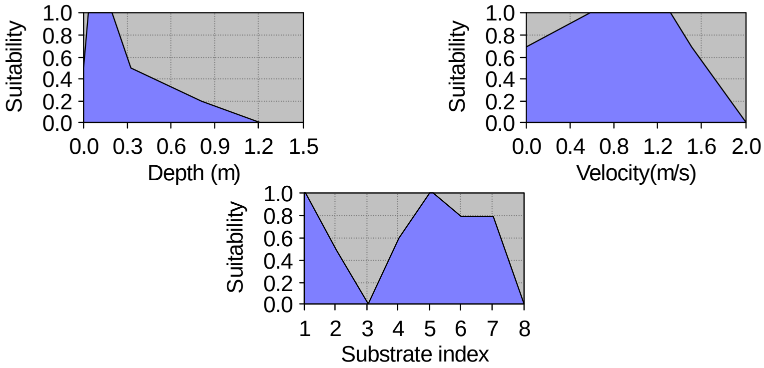
Appendix 2: Survey dates and recorded flows

Dates of habitat surveys and calibration gaugings at each site. Flows are given in m^3/s.

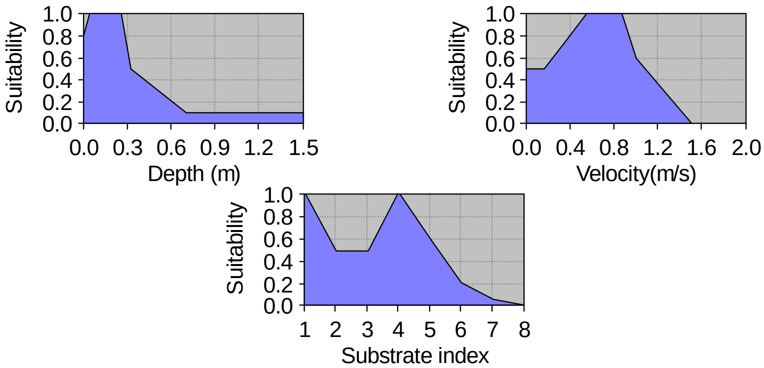
Date	Rangitaiki	Whirinaki
31-1-2003		5.895
4-2-2003	23.22 (omitted)	
11-2-2003		4.542 (survey)
8-4-2003	25.01	
13-5-2003		4.014
19-5-2003	15.16 (survey)	
6-8-2003		6.861
12-9-2003	34.91	

Appendix 3: Habitat preference curves

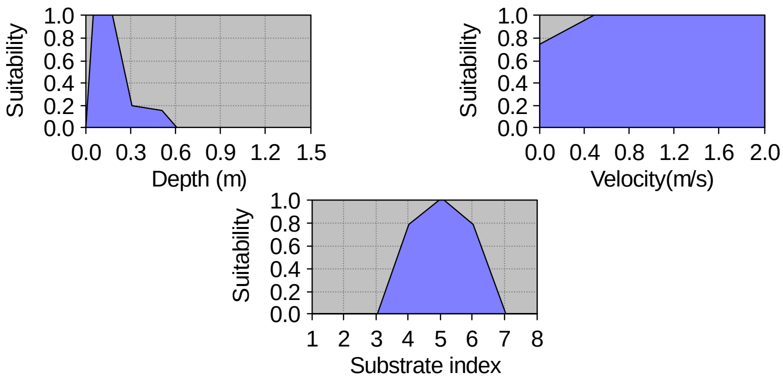
Longfin eel



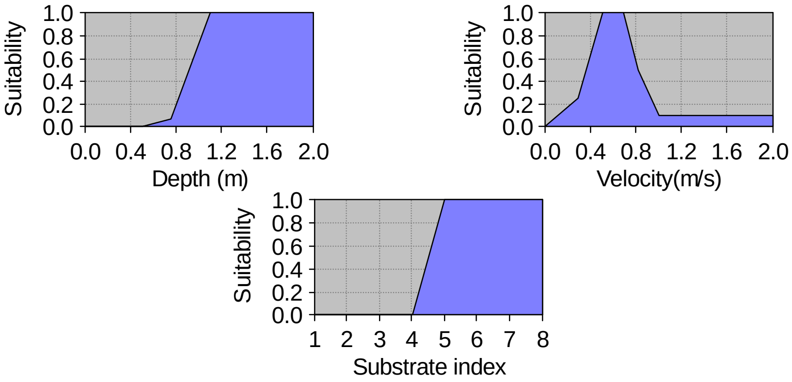
Shortfin eel



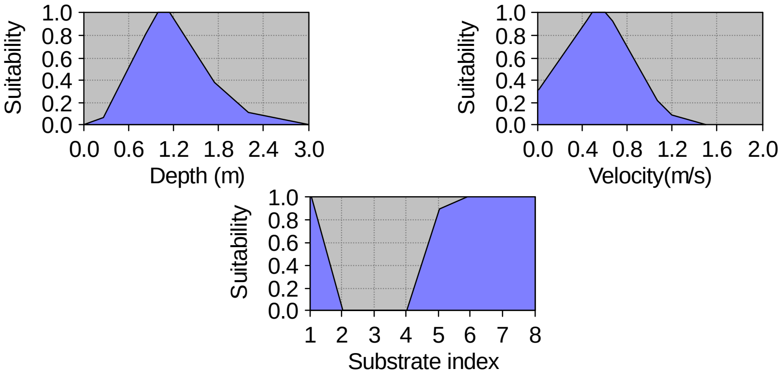
Dwarf Galaxias



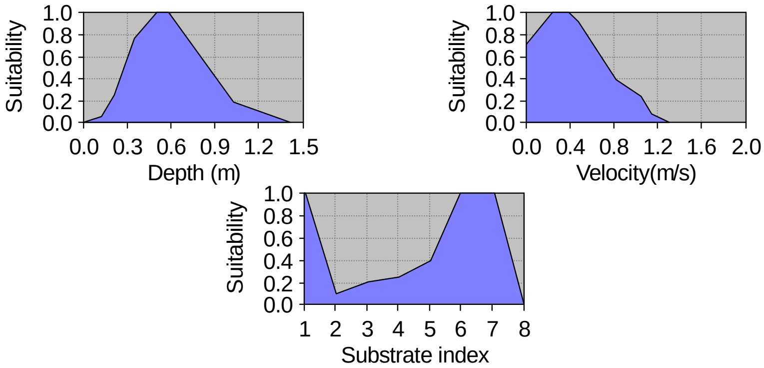
Rainbow trout adult (Tongariro)



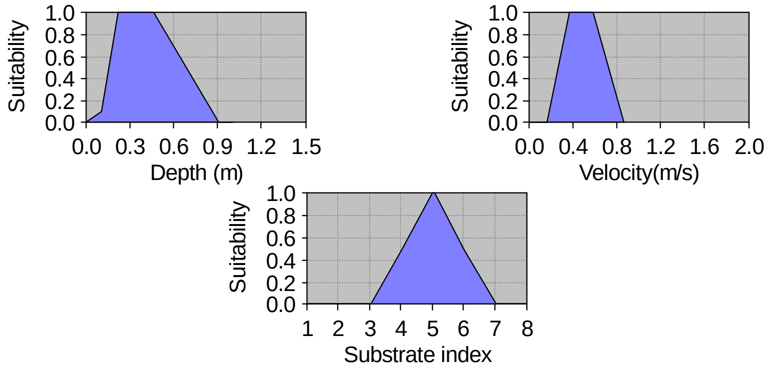
Rainbow trout adult (30-40cm) feeding (Bovee pers. comm.)



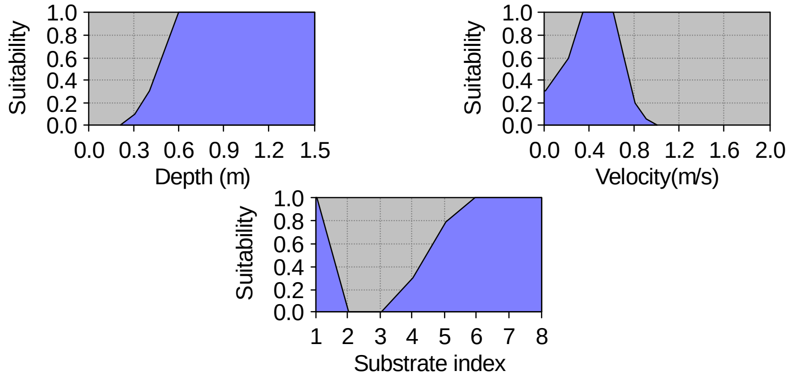
Rainbow trout juvenile feeding (Bovee pers. comm.)



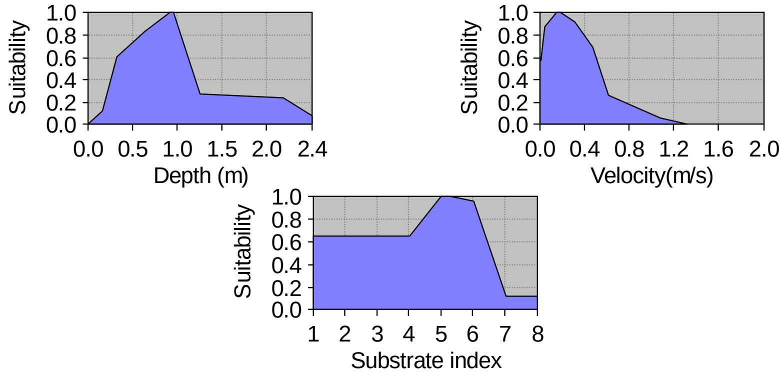
Rainbow trout spawning (Tongariro)



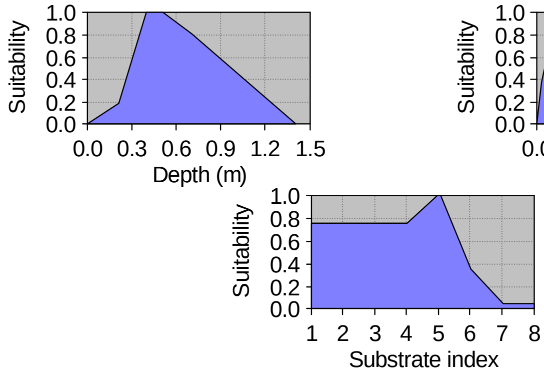
Brown trout adult (Hayes & Jowett 1994)



Brown trout yearling (Raleigh et al. 1984)



Brown trout fry to 15cm (Raleigh et al. 1984)



Brown trout spawning (Shirvell & Dungey 1983)