Ian Jowett Consulting

Instream habitat and minimum flow requirements in the middle and lower Oreti River

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Client Report: IJ0903
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Prepared for

Environment Southland

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Executive Summary

The purpose of this study was to investigate the flows required to maintain acceptable habitat for native fish and trout in the middle and lower reaches of Oreti River.

The selection of appropriate minimum flows for fish is a compromise between the contrasting requirements of the different species. For example, upland bullies prefer low velocity water and thus require relatively low flows, whereas trout, especially adult trout, prefer moderate water velocities and require reasonably high flows. Thus, the selection of an appropriate minimum flow depends on the fish species present and flow management objectives that balance the degree of environmental protection against the value of water for other uses. The levels of environmental protection, in terms of habitat retention at the minimum flow, are set out in Environment Southland's Proposed Regional Water Plan for Southland. These are expressed as a percentage of habitat at the 7-day mean annual low flow (7-day MALF), or a proportion of maximum habitat if it occurs at a flow less than the mean annual low flow. The Oreti River is a high quality trout fishery and the appropriate standard would be to set a minimum flow that maintains 90% of adult brown trout habitat.

The middle reaches of the Oreti River are between Mossburn and a point about 3 km north of Dipton and are mainly multi-channel. A reach at Ram Hill about 12 km below the Lumsden cableway water level recorder was selected by Environment Southland as representing the multi-channel character of the middle Oreti. Below Dipton, the river is mainly in a single channel and existing instream habitat surveys at Centre Bush and Branxholme were used to represent this section of river.

Instream flow requirements were determined by examining the relationships between flow and suitable habitat using instream habitat modelling. Habitat suitability was determined from habitat suitability curves developed from studies in other rivers.

Minimum flow requirements for adult brown trout in the Oreti River vary with the river width. In the wide braided middle section of the river typified by the Ram Hill reach, a flow of 9 m^3/s provides maximum habitat and habitat begins to decline sharply when flows fall below 6.5 m^3/s. A flow of 4.9 m^3/s maintains 90% of the habitat available at the 7-day MALF. This minimum flow also maintains about 80% of habitat at the 7-day MALF for the fast-water native fish species and for food producing habitat.

In the predominantly single channel section below Dipton, the river is almost half the width of the braided section and flow requirements are less. A flow of 6 m^3/s provides maximum adult brown trout habitat and this begins to decline sharply when the flow falls below 5 m^3/s. A flow of 4.4 m^3/s maintains 90% of maximum brown trout habitat. The minimum flow of 4.4 m^3/s also maintains about 80% of habitat at the 7-day MALF for the fast-water native fish species and for food producing habitat.

Further downstream at Branxholme, the river is wider and flow requirements appear to be higher. A flow of 7.5 m^3/s maintains 90% of habitat at the 7-day MALF and this would override minimum flow requirements at Centre Bush, as the increase in flow from tributaries is small at times of low flow.

When different sections of river have different flow requirements, there are various options for flow management. If flow requirements increase with distance downstream at a higher rate than the natural increase in flow, then the flow requirement at the most downstream site will dictate the minimum flow. However, if flow requirements decrease with distance downstream because the river character changes, it is possible to set minimum flows for the different sections of river and this will allow more water to be abstracted from the river, while still meeting environmental protection standards.

In the case of the lower Oreti River, minimum flow requirements at Branxholme appear to dictate flow requirements as far upstream as Mossburn. Under normal low flow conditions, abstraction would cease when flows fell below 7.5 m^3/s at Branxholme. At this time, the flow at Centre Bush would be about 6.72 m^3/s and the flow at Ram Hill would be 5.24 m^3/s.

Another alternative is to retain the 90% protection standard as an average over the middle and lower sections of the Oreti River. This would involve maintaining an average minimum flow requirement, rather than different minimum flows at various points along the river. For example, a minimum flow of 4.9 m^3/s at Ram Hill would retain near maximum adult brown trout habitat at Centre Bush (6.4 m^3/s) and slightly less than 90% trout habitat at Branxholme (7.16 m^3/s and 88% of habitat at the 7-day MALF).

1. Introduction

1.1 Study Brief and Background

Environment Southland requested an assessment of minimum flow requirements in the middle and lower Oreti River. Examination of the 1:50000 topographic maps indicated that the middle section of the river between Mossburn and a point about 3 km north of Dipton is braided with occasional sections of single channel. Environment Southland requested an instream habitat survey of the Oreti River at Ram Hill about 12 km downstream of Lumsden (Fig. 1.1) to represent the middle section of the Oreti River. Below Dipton, the river is mostly single channel with occasional braiding. Environment Southland have carried out an in-stream habitat survey of a 2.5 km section of the Oreti River at Centre Bush E45:480540, about 30 km down stream of Lumsden. This survey was in autumn 1996 and is representative of the character of the river downstream of Dipton. Another survey was made at Branxholme near the mouth of the river by Ryder Consultants on behalf of the Invercargill City Council (Ryder Consultants 2001). No data is available for this survey but the graphical results were used to compare with Centre Bush results.

The minimum flows derived from these surveys will assist with water resource management in the middle and lower reaches of the Oreti River.

The study brief was to:

- Carry out an in-stream habitat survey in the Ram Hill reach.
- Carry out a hydraulic analysis of the Ram Hill and Centre Bush reaches using RHYHABSIM (Jowett 1989) to determine how weighted usable area (WUA) for fish habitat varies with discharge.
- Assess flow requirements based on habitat retention for adult trout.

The Ram Hill survey was carried out by NIWA with the assistance of Environment Southland staff and Ian Jowett carried out the analysis and prepared this report.

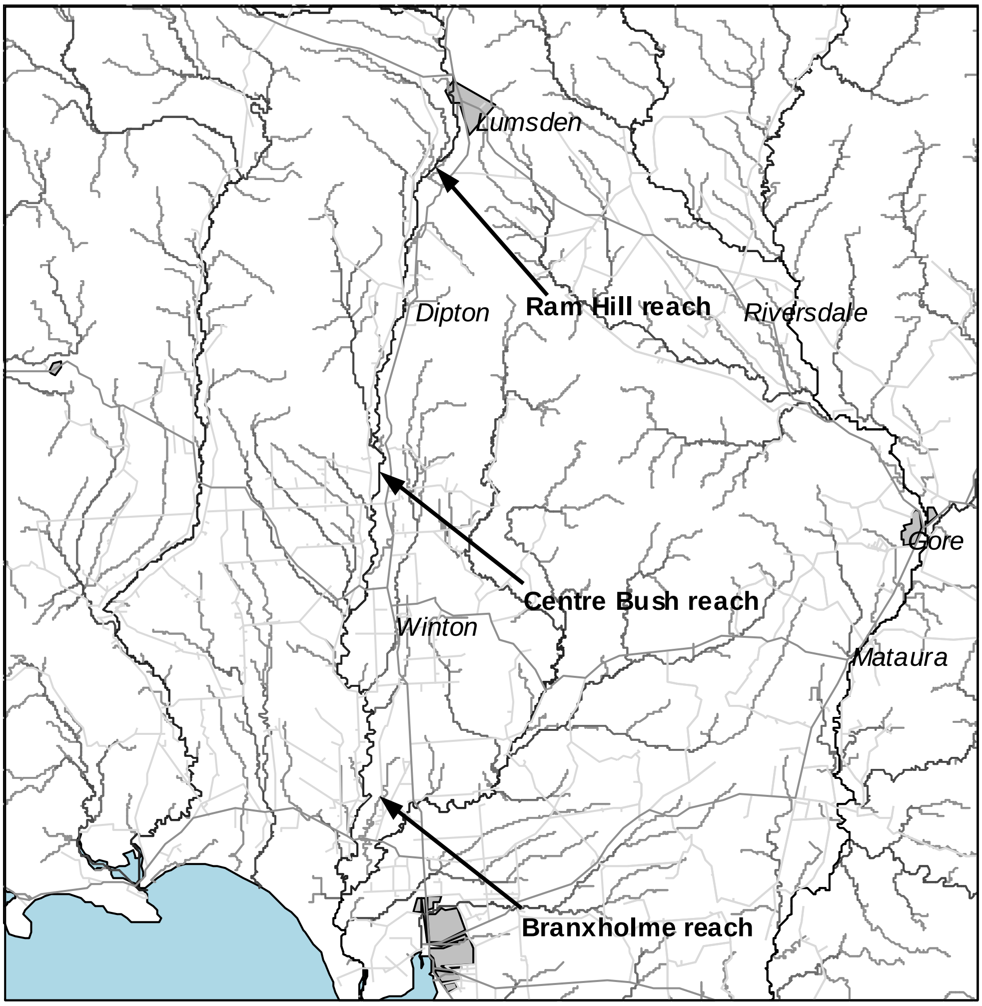

Figure 1.1: Location of survey reaches.

2. Methods of determining instream flow requirements

Sustaining in-stream values when there is demand for out-of-stream water use is challenging for water resource managers. It is naive to expect that in-stream habitat conditions and the stream ecosystem will remain exactly the same once the flow regime is altered. It also needs to be appreciated that there is often no clearly identifiable point at which in-stream conditions become untenable as flows are reduced, except when rivers cease flowing. In the face of this knowledge, the challenge is to determine the degree of change in flow and in-stream conditions before in-stream values are eroded noticeably and reach levels that dissatisfy community interest. Science can provide partial answers for this problem if the critical in-stream values and levels of protection are specified. Ministry for the Environment guidelines (1998) describe the process (Fig. 2.1).

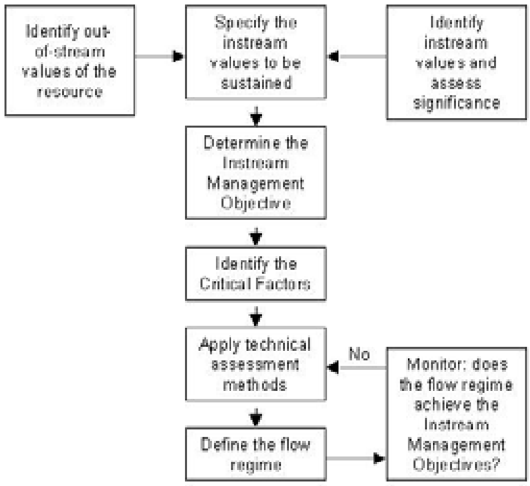

Figure 2.1: The process of setting objectives for management of in-stream flow regimes (from Ministry for the Environment 1998).

A basic principle established in the Flow Guidelines (Ministry for the Environment 1998) is that in-stream values and their requirements must be identified and appraised within the context of definite in-stream management objectives. Where objectives have been developed consultatively to reflect community aspirations, they can be accorded appropriate weight, even though they might not be expressed in monetary terms. These objectives provide a reference point from which council officials, special tribunals, or the Environment Court can compare the merits of alternative uses of a given body of water, and in particular, the extent to which in-stream values must be provided for. In-stream flow management is a complex process, usually involving a combination of technical, public, and legal considerations. To be effective, the in-stream flow management process should consider the present status of the river and its ecosystem, and then, in consultation with public and institutional organisations, set goals and objectives before establishing appropriate flow requirements. In-stream flow methods play a part in this process by showing how the requirements of in-stream uses in terms of their various parameters, such as wetted perimeter, in-stream habitat, and water quality, vary with flow. Once these relationships are established, the next important decision is the level at which in-stream values should be maintained.

The instream flow incremental methodology (IFIM; Bovee 1982) is 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, river morphology, physical habitat, water temperature, water quality, and sediment processes (Fig. 2.2). 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. This report only examines the effect of flow on instream physical habitat. Other issues, such as cultural or aesthetic values of river flows, may also need to be considered when deciding on a proposed minimum flow level, but are not discussed in this report.

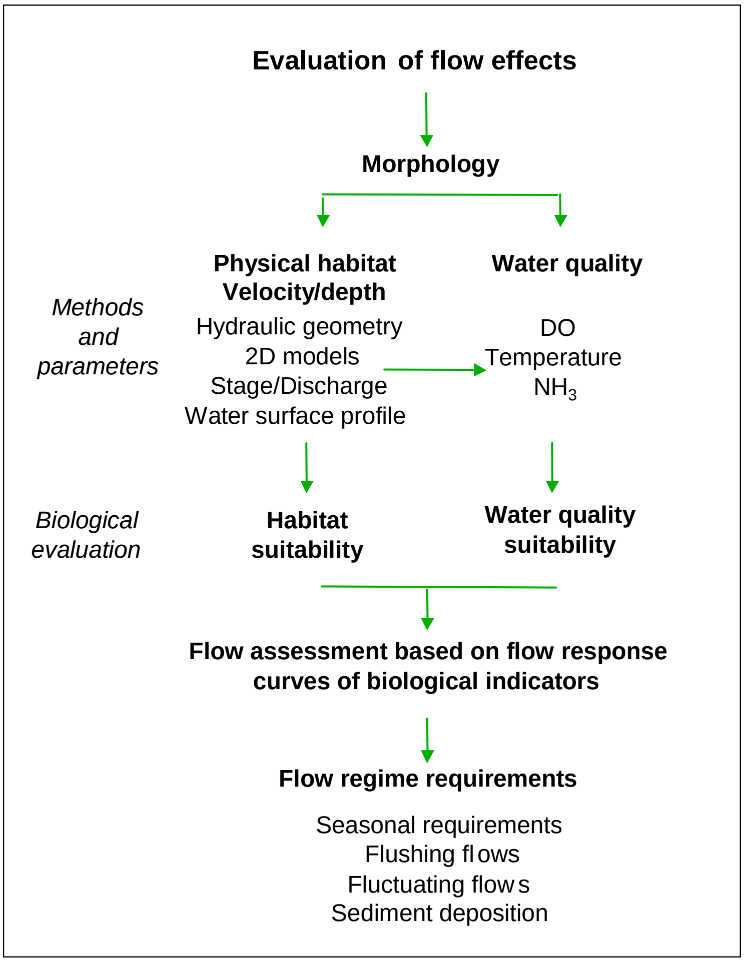

Figure 2.2: A framework for the consideration of flow requirements.

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.

Obviously, maintaining the natural flow regime will maintain the hydrologic and hydraulic conditions necessary for sustaining natural ecosystems. However, if there is adequate knowledge of what ‘values’ need to be maintained in a waterway, and the hydraulic/flow variability requirements of the constituent taxa are also known, then regimes can be designed that target these requirements and thus optimise conditions for the ‘values’.

A process-based assessment of ecosystem requirements, such as used here, can achieve the best balance between resource use and sustaining ecosystem function and value as shown by examples where changes to natural flow regimes have maintained, or even improved, instream values in some New Zealand rivers (Jowett & Biggs 2006). Simple flow-based rules, such as those that might be developed under the natural flow paradigm, could be unnecessarily restrictive on multiple use of water in New Zealand whilst, at the same time, preclude the opportunity for enhancement of key ecosystem values in many waterways.

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 two basic types; historic flow and hydraulic-habitat 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 — $Q_{7,5}$) is rather arbitrary. Hydraulic-habitat 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 the river. The consequences of loss of 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., Fig. 2.3), 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 is calculated as a joint function of depth, velocity and substrate type using the method shown in Figure 2.3. The area of suitable physical habitat, or weighted usable area (WUA), is calculated by multiplying the area represented by each point by its joint habitat suitability. For example in Figure 2.3, at a given point in the river (representing 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 substrate = 1). This exercise is 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 is multiplied by the point suitability. These areas, which have been weighted by their respective point suitability values, are then summed to give a measure of total area of suitable physical habitat for the given species at the given flow. This process is 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 is 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, such as an objective in a regional plan.

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.

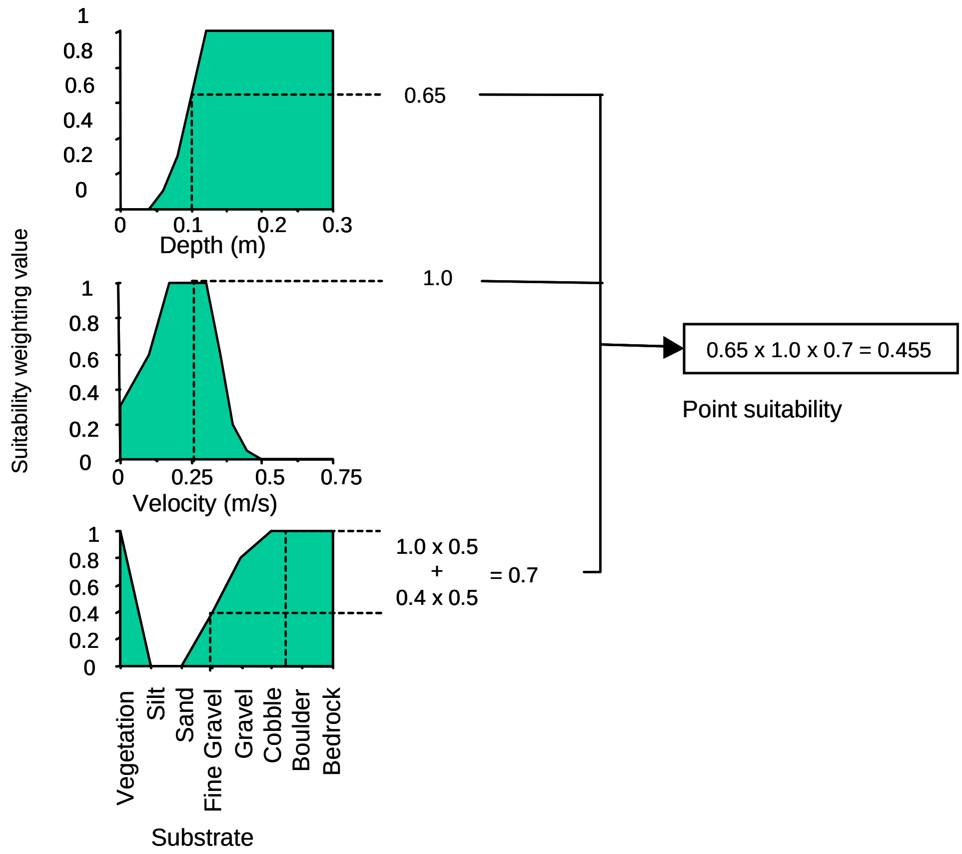

Figure 2.3: Calculation of habitat suitability for a fish species at a point with a depth of 0.1 m, velocity of 0.25 m/s, and substrate comprising 50% fine gravel and 50% cobble. The individual suitability weighting values for depth (0.65), velocity (1.0), and substrate (0.7) are multiplied together to give a combined point suitability of 0.455.

Various approaches to setting levels of protection provided by a minimum flow have been used, from maintaining a maximum amount of habitat, a percentage of habitat at median flow, or using a breakpoint (or "inflection point") on 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 a breakpoint, 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.

3. 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 resists 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.

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 enough. The initial fish response is to move to better habitat. This is presumably associated with some mortality caused by movement or increased densities. 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; Richardson & Jowett 2006).

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 so that the magnitude of minimum flows relative to a flow statistic should increase with stream size. Similarly, the minimum flow in spring-fed streams that are relatively deep with steep banks can be higher than in gravel-bed streams.

3.1 Relationship between total allocation and minimum flow requirements

With an adequate minimum flow, there is little need for an allocation limit (assuming that abstractions cease at the minimum flow). The effect of abstraction (or allocation) is to increase the amount of time that the stream is at low flows. With high allocation, the river could be “flat-lined” at the low flow and the detrimental effect of the low flow will be increased.

As the amount of water abstracted increases, so does the potential to reduce river flows to a minimum for extended periods. This is not necessarily deleterious as is often assumed. The most common situation is probably where a relatively small amount of water is taken from a river, usually for irrigation and sometimes for town supply. This might amount to 10-20% of summer low flows, but not be a significant proportion of high flows and not a sufficiently large total allocation to reduce the stream flow to a minimum for extended periods of time. Summer is the critical period for this type of abstraction because this is when maximum abstraction usually occurs and when low flows and high water temperatures may limit biological communities.

If instream conditions at the minimum flow are adequate (i.e., provide optimal habitat quality or habitat levels that occur with annual natural low flows), then biota should not be detrimentally affected, provided the frequency of higher flows remains unchanged. However, if instream conditions at minimum flow provide less than optimal habitat quality (where quality is measured by the average habitat suitability index), an increase in the duration of low flows increases the risk of detrimental effects. Few studies have examined the effects of extended duration of low flow. Jowett et al. (2005) showed that in the Waipara River, where habitat is limited at low flow, the detrimental effect on fish numbers increased with the magnitude and duration of low flow. When summer flows were less than the mean annual low flow for about 30% of the time, there was a substantial decline in abundance of three of the four common native fish species in the river. When summer flows were less than MALF for about 10% of the time, there was little change in native fish abundance. The effect was more severe on fast-water species (torrentfish and bluegill bullies) than species that prefer lower velocity water (upland bullies and Canterbury galaxias).

3.2 Allocation limits

Allocation limits have been used to manage water resources and a common approach is to limit total allocation to a proportion of a flow statistic such as the mean annual low flow. If the total allocation is low, the degree of hydrologic alteration and thus environmental effect will be small. For example, if the total allocation is less than 10% of the MALF, abstractors will have high reliability of supply and there may be no need for a minimum flow requirement because 10% of MALF is very unlikely to have any biologically detectable effect.

One method of defining allocation limits is based on defining the acceptable level of risk to the environment and reliability of supply to the resource user. This is based on frequency and duration analyses of the hydrological record. For example, if the target reliability of supply is 95% and the minimum flow is exceeded 99% of the time, then the amount of water available for allocation is the difference between the flow that is exceeded for 94% of the time and the minimum flow. When the total allocation is being fully used, the amount of time at the minimum flow increases to the exceedence value of the minimum flow plus allocation (i.e., 6% of the time in the example). In terms of days, the average duration of the minimum flow increases from about 4 days per year to 22 days per year.

The effect of allocation extending the duration of low flows should be considered in terms of biological significance. Is there likely to be significant biological effects with the change in duration? In considering this, the quality of the habitat at low flow should be taken into consideration as described in the preceding section. If habitat at low flow is sub-optimal and limiting biota, extending the duration of low flows is likely to increase the detrimental effect on biota. If habitat at the minimum flow is optimal or higher, the biological effects of abstraction are likely to be minor or even beneficial, and there is no need to limit allocation from an environmental perspective until the volumes abstracted affect the magnitude and duration of minor freshes.

When total allocation is high, abstractors are usually required to cease taking water when the flow falls below a specified minimum. However, water users can work together to manage rosters and ration use of water while still meeting environmental flow requirements.

3.3 Minimum flow requirements under Environment Southland's Proposed Regional Water Plan for Southland

The Proposed Regional Water Plan for Southland (January 2009) requires flows to maintain the quality and quantity of aquatic habitat at levels that protect aquatic ecosystem health and the life-supporting capacity of surface water bodies, as well as meeting reasonable needs of existing and future water users.

Policy 16 and associated Appendix I set out a process and methodology to determine an instream minimum flow requirement. This involves first identifying a critical value that will have the highest flow requirement. For the Oreti River, this is adult brown trout. The next step is to determine a level of protection, or habitat maintenance level. This is based on retaining a percentage of the habitat at the 7-day mean annual low flow or a proportion of the maximum habitat if it occurs at a flow less than the 7-day mean annual low flow. The flow that corresponds to this habitat maintenance level is the minimum flow. The Oreti River contains a high quality perennial trout fishery, so the minimum flow should retain 90% habitat.

4. Survey reach, flow characteristics, and fish species

4.1 River and reach description

The Oreti River below Mossburn is generally braided, dominated by runs, some riffles and occasional pools as far as Dipton. The number of braids varies from 1 to about 4, depending on flow. The Ram Hill reach was selected to represent the character of the river in the braided middle reaches between Mossburn and Dipton. Below Dipton, the river is mainly single channel, and occasionally splits into 2 or 3 channels. Reaches at Centre Bush and Branxholme represent the predominant single channel character of the lower Oreti River.

Ram Hill

The survey was carried out on 20 January 2009 when the flow was about 15 m^3/s. A tributary stream, the Roe Burn, joins the Oreti River just below cross-section 2 (Fig. 4.1). The upstream cross-section was located at NZMG E 2151618 N 5480067 and the downstream section at NZMG E 2151171 N 5477977.

A total of 15 transects were surveyed with 34 cross-sections established in individual channels that included riffle, run and pool habitats (see Figs 4.2-4.5), in the proportion that they were present in the reach.

The Lumsden water level recorder showed that flows dropped by about 1 m^3/s (10 mm) during the survey. The analysis took both the variation in flow and the tributary stream into account.

Centre Bush

The survey was carried out in autumn 1996 when the river flow was about 15 m^3/s. The banks above water level were not surveyed. A total of 19 transects were surveyed along a 2.5 km reach just above Centre Bush. Four of the transects contained two braids. The transects were weighted according to the proportion of pool, run, and riffle in the reach. Two sets of calibration measurements were taken, one at a flow of 22.2 m^3/s and the other at 8.35 m^3/s.

Branxholme

The Branxholme reach was surveyed in 2001 by Ryder Consultants on behalf of the Invercargill City Council. They describe that habitat in the 2 km reach as 85% run, 10% riffle and 5% pool. Eighteen cross-sections were surveyed, 8 in runs, 7 in riffle, and 3 in pools. The most upstream cross-section was at NZMG E 2146403 N 5424092. Most of the habitat suitability curves were taken from various Jowett publications and cite course notes from 1996. The juvenile trout curves were those of

Raleigh et al. (1986). The original survey data are not available but graphs of habitat flow relationships can be compared with Centre Bush results.

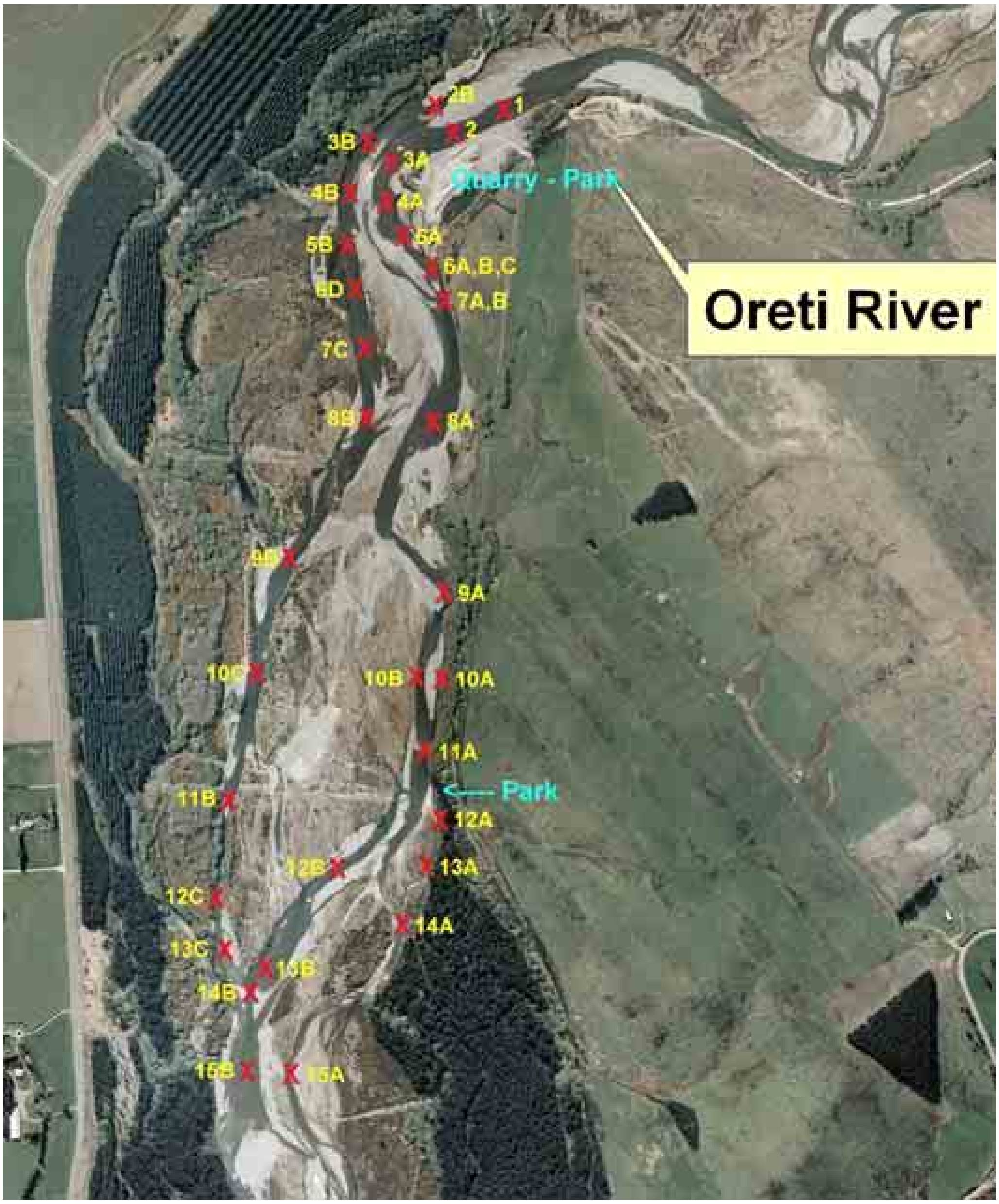

Figure 4.1: Oreti River at Ram Hill showing locations of cross sections on individual channels. The Roe Burn flows into the reach just below cross-section 2.

4.2 Hydrology

The water level recorder at the Lumsden cableway (site 78636) has been operating since 1976. The catchment area of the upstream end of the Ram Hill reach is about 109 km^2 greater than the Lumsden recorder catchment area and the estimated increase in mean flow is 1.8 m^3/s. The catchment area at Centre Bush is 474 km^2 greater than Lumsden and the estimated increase in mean flow is 7.25 m^3/s. The values for Ram Hill above Roe Burn, Centre Bush and Branxholme shown in Table 4.1 were calculated from River Environment Classification statistics, and Lumsden and Wallacetown flow statistics were provided by Environment Southland.

Table 4.1: Flow statistics for Oreti River at Lumsden and Wallacetown (source Environment Southland 2009). Catchment areas from River Environment Classification (REC).

	Catchment area (km^2)	Mean flow (m^3/s)	Median flow (m^3/s)	7-day MALF (m^3/s)	5-year 7-day low flow (m^3/s)
Lumsden	1129	28.76	18.80	5.50	3.66
Ram Hill above Roe Burn	1238	30.56	20.08	5.90	3.82
Centre Bush	1603	36.01	24.40	7.39	4.41
Branxholme	2115	40.40	27.17	8.17	4.71
Wallacetown	2141	40.59	28.18	8.19	4.72

4.3 Instream values and habitat suitability criteria

As noted in Section 2, identification of critical values and setting flow management objectives is a step that must be taken before it is possible to determine a flow regime that meets those objectives. The Oreti River is a valuable trout fishery and the critical biological value is adult brown trout habitat. However, other fish species and benthic invertebrates are also present in the river and these were also considered in the habitat analyses.

Jowett & Richardson (1995) found that native fish were mainly confined to the margins of medium to large sized gravel bed rivers. They divided the common native fish species into four habitat guilds: a fast-water guild (torrentfish and bluegill bullies) that occupied central portions of riffles, an edge-dwelling guild (upland bullies) found in low velocity water along the shallow margins of large rivers, a guild that was intermediate between the fast-water and edge-dwelling guild (redfin bullies and common bullies), and finally a ubiquitous guild (eels) that was found in a wide variety of habitats. The native fish habitat suitability curves used in this study are based on Jowett & Richardson (2008). These new habitat suitability curves are based on data from 124 different rivers with 5000 sampling locations and 21,000 fish.

A study of brown trout in New Zealand (Jowett 1992) suggested that brown trout abundance is closely linked to the availability of instream habitat and food. Habitat suitability curves for adult brown trout feeding (Hayes & Jowett 1994), juvenile brown trout rearing (Raleigh et al. 1986), brown trout spawning (Shirvell & Dungey 1983) and benthic invertebrate production (Waters 1976) were used in this study.

The Oreti River is similar in size and substrate characteristics to the rivers used to develop the benthic invertebrate habitat suitability curves described in Jowett et al. (1991) which have been used here. Periphyton habitat suitability criteria were based on unpublished NIWA data.

Habitat suitability criteria used are shown in Appendix 1.

4.3.1 Fish

Information from the New Zealand Freshwater Fish Database (NZFFD) up to August 2008 was used to determine the fish species that were present in the Oreti River below Lumsden. The few records of fish in the main stem record the presence of lamprey, brown trout, inanga, redfin, upland and common bullies and koura. Longfin and shortfin eels were reported from a tributary and must be also be present in the main stem of the river. No torrentfish or bluegill bullies have been reported to the NZFFD from the Oreti River, but they are present in other Southland rivers and Environment Southland staff have caught torrentfish in the Oreti River near Winton.

4.4 Habitat and cross-section selection

Ram Hill

The Oreti River at Ram Hill has a predominance of run habitats of 40-150 m in length that are between riffles of 30-40 m long. There were occasional pools where the river flowed against banks with vegetation. There were only 2 pools in the kilometre reach. Most of the reach was multi-channel, with 2 channels on 8 transects, 4 channels on 1 transect, 3 channels on 4 transects, and a single channel on 2 transects.

Centre Bush

The Centre Bush reach just above Centre Bush is more confined than the Ram Hill reach and is mainly single channel. Four of the 19 transects contained 2 channels. The 2.5 km reach contained about 15% pool habitat, 15% riffle habitat and 70% run habitat. Seven transects were located in runs, 6 in pools and 6 across riffles.

Figure 4.2 View of run in a single channel at the upstream end of the Ram Hill reach.

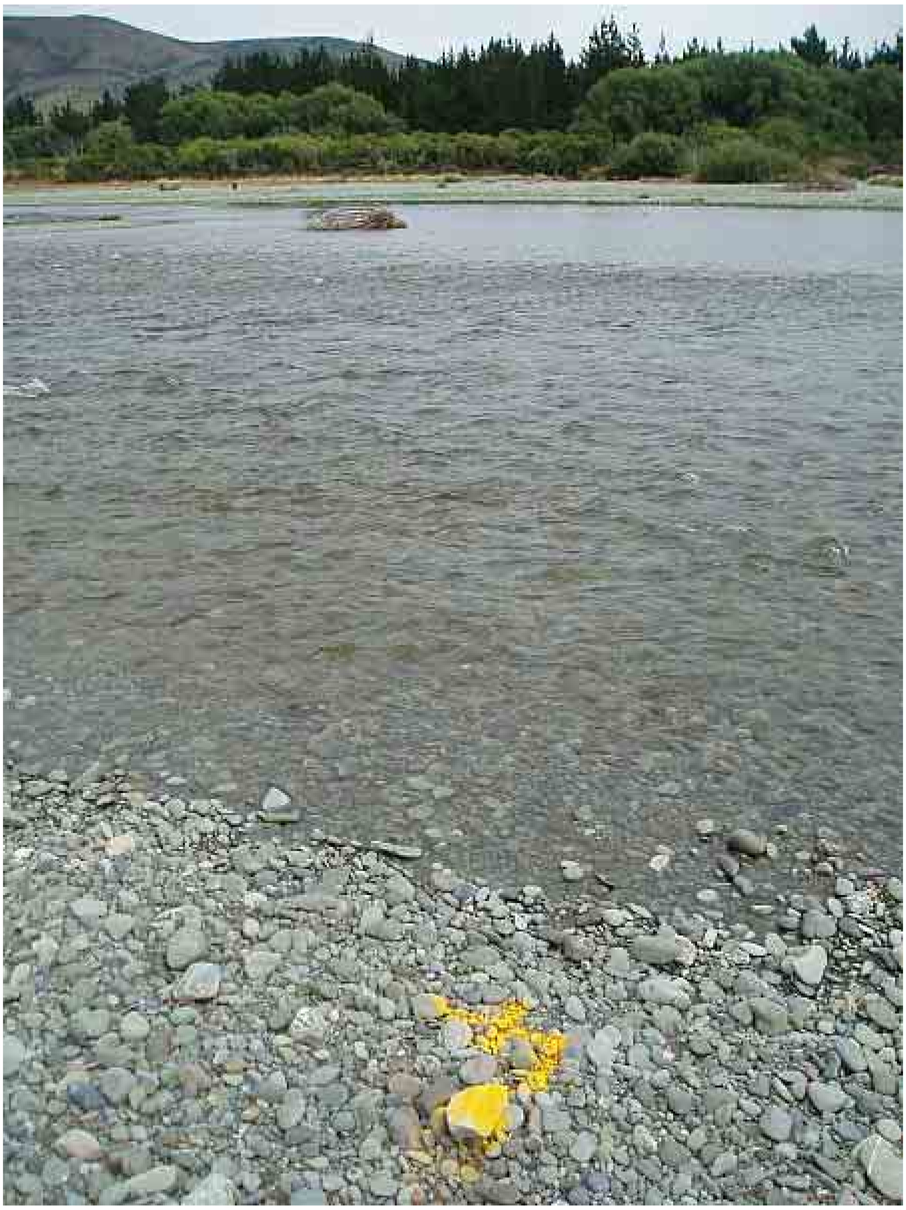

Figure 4.3 Riffle habitat at Ram Hill cross-section 4A.

Figure 4.4 Pool habitat at Ram Hill cross-section 9A.

Figure 4.5 View of small braid with a flow of 0.68 m^3/s at Ram Hill cross-section 12 A.

4.5 Instream habitat survey and analysis

The Ram Hill survey was carried out on 20 January 2009 on a flood recession when the flow was about 15 m^3/s, with flows reducing by about 1 m^3/s during the day. The variation in flow was monitored by the Lumsden water level recorder and this record and the flow measurements at each cross-section were used to get the best estimate of the flow at the time each cross-section was surveyed.

The methods for survey and analysis are described in Jowett (1989) and Jowett et al. (2008). Transects were established at approximately 60 m intervals through the reach and a temporary staff gauge was established in every channel (cross-section) on the transect lines. Water velocities and depths were recorded at a spacing that varied with the uniformity of the cross-section. At each cross-section, water level was measured and referenced against the temporary staff gauge. In order to establish a calibration relationship between water level and flow at each cross-section, the water level was measured on the temporary gauge at two other flows. The first set of Ram Hill calibration measurements was made on 4 February 2009, when the flow was 5.08 m^3/s. A second set of calibration measurements was made on 9 February 2009, when the river flow had reduced to 4.18 m^3/s. The flow of the Roe Burn was measured on each occasion. The date of the Centre Bush calibration measurements is not known.

Substrate composition was assessed visually at each measurement point across the cross-sections.

The habitat analysis 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 using a least squares fit to the logarithms of the measured flows and stages (water levels) including an estimated stage at zero flow.
3. A relationship between cross-section flow and total river flow was developed:

   Cross-section flow = constant * (Total river flow – Total river flow for zero cross-section flow)^{exponent}, where the constant and exponent are determined by least squares regression on logarithms of flow measurements and the total river flow for zero cross-section flow was determined either from field observation or a trial and error procedure to get the best fit of observed to predicted flows.
4. The water level for each simulated flow in each cross-section was then determined from the logarithmic relationship between water level and braid flow. Water depths and velocities were computed at each measurement point across each cross-section for a range of simulated flows, and habitat suitability (HSI) was evaluated (see Fig 2.3) at each measurement point from habitat suitability curves for each fish species.
5. The weighted usable area (WUA) for each simulated flow was calculated as the sum of the habitat suitability indices across each cross-section, with each transect given equal weighting.

6. Weighted usable area was plotted against flow and the resulting curves examined to determine minimum flow requirements.

Both reaches were modelled for flows of 2 to 20 m^3/s to show the overall effect of flow changes on instream habitat. A tributary flow increase of 0.37 m^3/s was assumed between Ram Hill transects 2 and 3. Ram Hill flows are presented in terms of the flow above Roe Burn. No adjustment for tributary inflow was made at Centre Bush and the flows are in terms of flow at Centre Bush.

5. Results

5.1 Physical characteristics

The Ram Hill instream habitat survey was carried out during a period of high flow (Table 5.1), followed by calibration measurements at low flow. The Centre Bush survey was also carried out at a high flow with calibration measurements at a higher and lower flow. The Centre Bush reach was almost half the width of the Ram Hill reach.

Table 5.1: Survey flows, calibration flows, and average physical characteristics of reach at the survey flow.

Reach	Survey flow (m^3/s)	Calibration flow 1 (m^3/s)	Calibration flow 2 (m^3/s)	Width (m)	Depth (m)	Velocity (m/s)
Ram Hill	15.5-14.3	5.077	4.178	61.1	0.43	0.53
Centre Bush	15.84	22.2	8.35	38.4	0.54	0.71

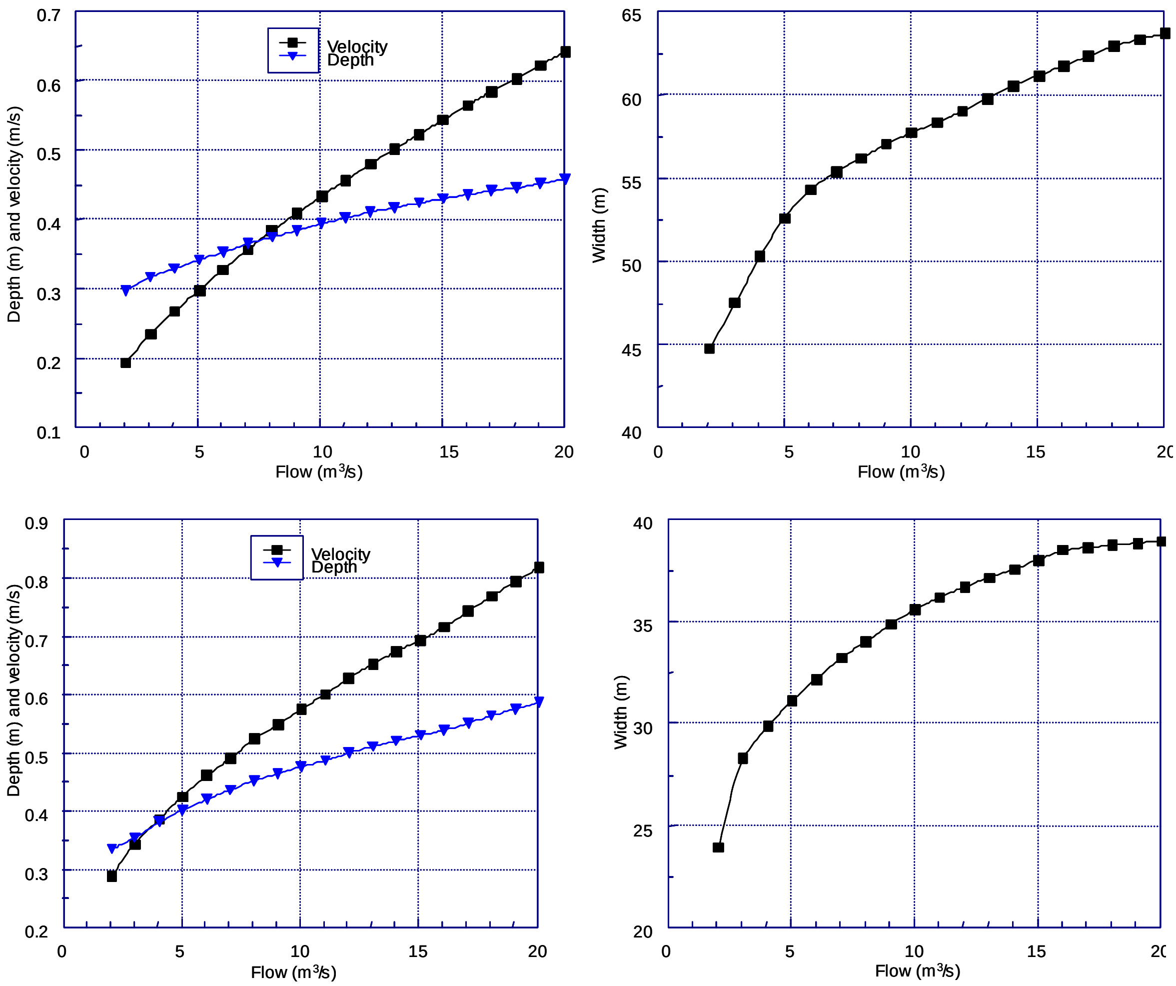

Figure 5.1: Variation of average depth (left blue line), velocity (left black line) and width (right) with flow in the Oreti River at Ram Hill (upper) and Centre Bush (lower).

The average depth and velocity tend to increase linearly with flow in both reaches. However in the Ram Hill reach, the width began to reduce sharply as flows fell below 5-6 m^3/s (Fig. 5.1). Average water velocity began to fell below 0.25 m/s at a flow of 3.5 m^3/s in the Ram Hill reach and in the Centre Bush reach velocities were greater than 0.25 m/s at 2 m^3/s.

5.2 Instream habitat

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.

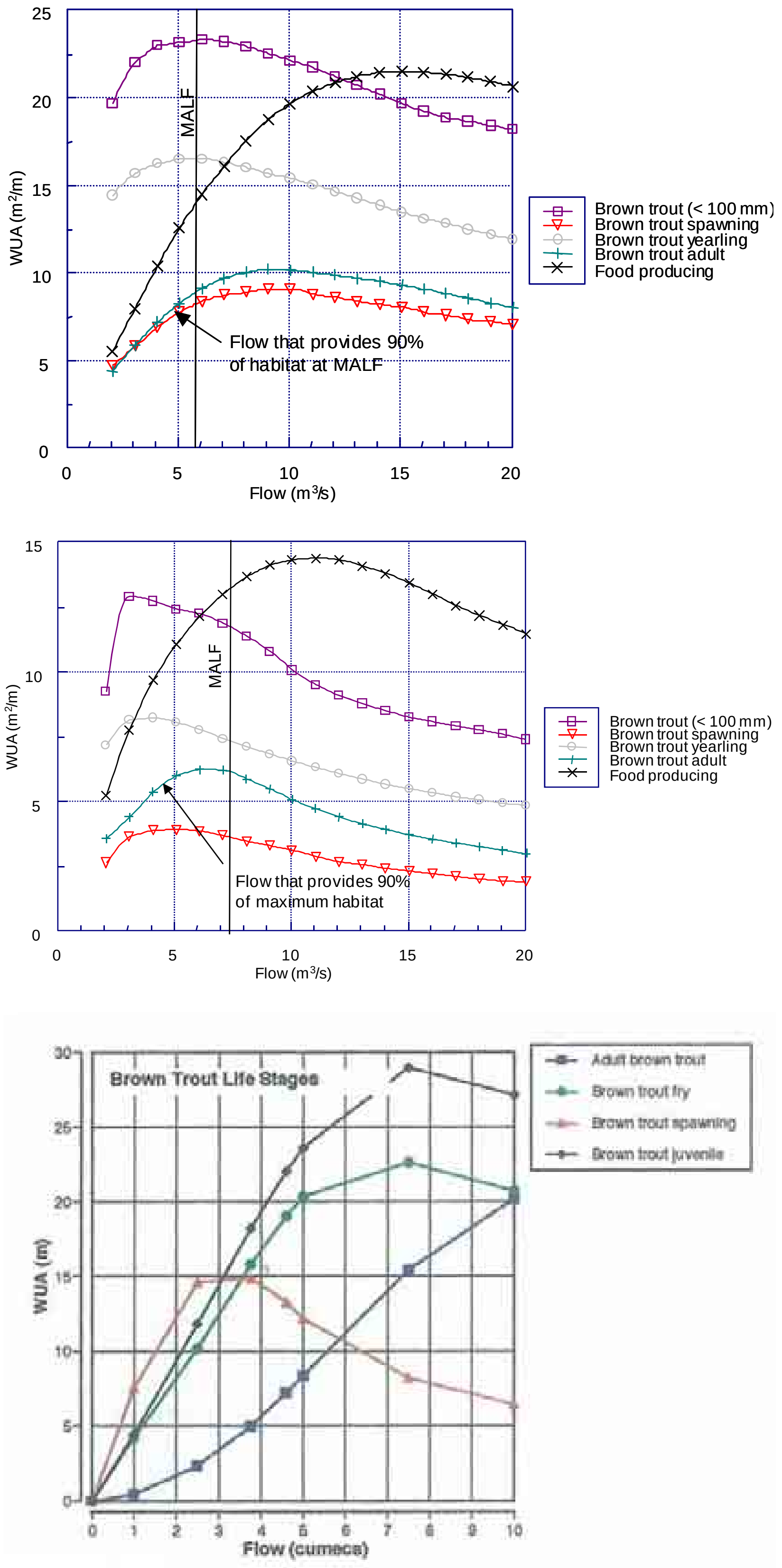

Figure 5.2: Variation of weighted usable area (WUA m^2/m) with flow for adult and yearling brown trout habitat, brown trout spawning and food production in the Oreti River at Ram Hill (upper) Centre Bush (middle) and Branxholme (lower).

Maximum yearling brown trout habitat was provided by a flow of 4-5 m^3/s in both the Ram Hill and Centre Bush reaches (Fig. 5.2). Maximum adult trout habitat was provided by a flow of 9 m^3/s at Ram Hill and 6 m^3/s at Centre Bush. The flow that provided maximum food producing habitat was slightly higher than that for adult trout (15 m^3/s at Ram Hill and 11 m^3/s at Centre Bush). Spawning habitat flow requirements were similar to those of adult trout in the Ram Hill reach. Maximum habitat for spawning occurred at flows of 4 to 6 m^3/s at Centre Bush, and 2.5 to 4 m^3/s at Branxholme. A flow of about 7.5 m^3/s provided maximum habitat for fry and juvenile brown trout in the Branxholme reach. It is very unusual to find that fry and juvenile flow requirements are significantly greater than spawning requirements. The Branxholme analysis appeared to use the same adult trout habitat, spawning habitat, and juvenile (yearling) criteria as used in this analysis. Maximum habitat for adult trout in the Branxholme reach occurs at a flow higher than 10 m^3/s, whereas it occurred at a flow of about 6 m^3/s in the Centre Bush reach. At 10 m^3/s, the Centre Bush reach was 36 m wide and the Branxholme reach was 53 m wide.

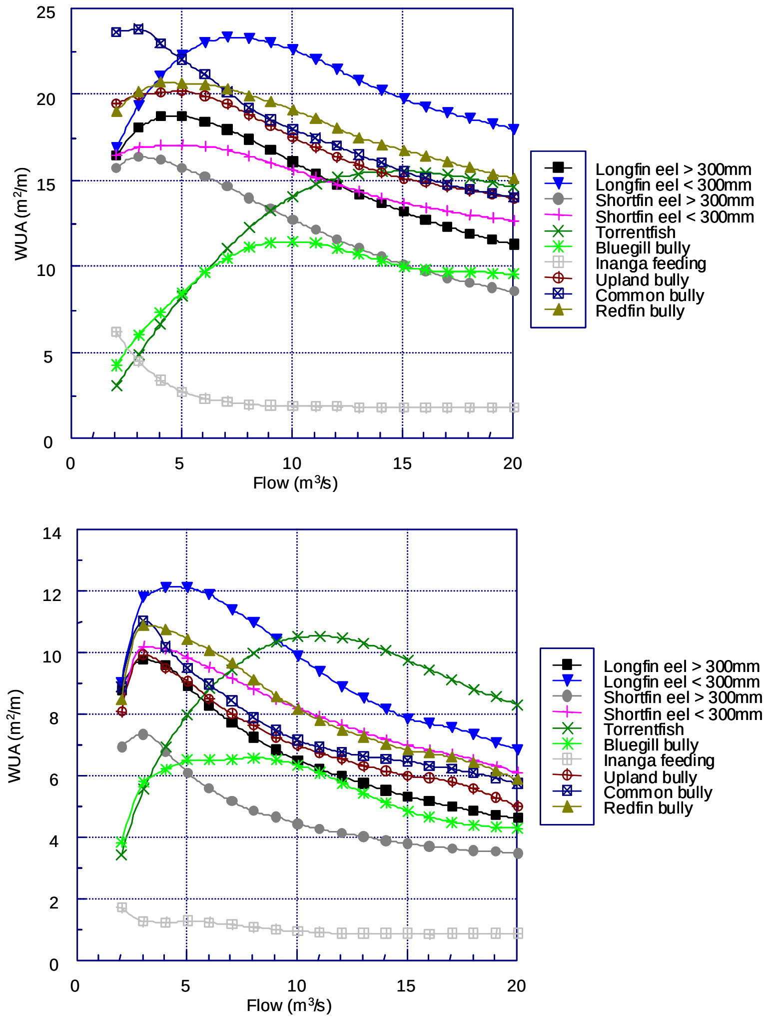

Figure 5.3: Variation of weighted usable area (WUA m^2/m) with flow for native fish habitat in the Oreti River at Ram Hill (upper) and Centre Bush (lower).

Native fish habitat/flow relationships were similar in both reaches, with flows providing maximum habitat slightly higher in the Ram Hill reach because of its greater width (Fig. 5.3). Flow requirements for the fast-water species, torrentfish and bluegill bullies, were higher than for other species, with flows of 10-15 m^3/s providing maximum habitat. Maximum eel habitat was provided by flows of 5-7.5 m^3/s. Flows of less than 5 m^3/s provided maximum habitat for bullies and inanga.

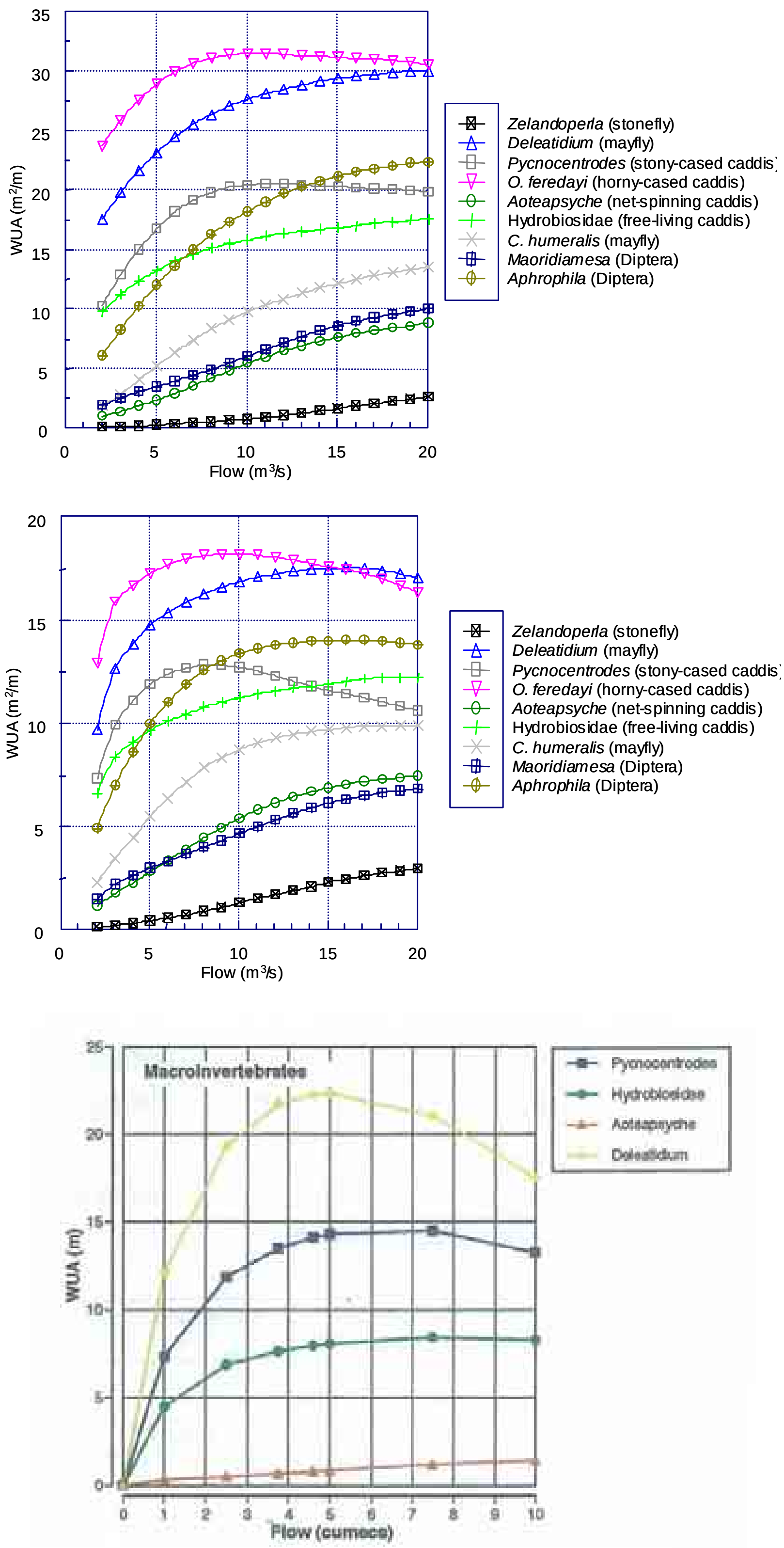

Figure 5.4: Variation of weighted usable area (WUA m²/m) with flow for benthic invertebrate habitat in the Oreti River at Ram Hill (upper), Centre Bush (middle) and Branxholme (lower).

As with native fish, benthic invertebrate flow requirements in the Ram Hill reach were slightly greater than at Centre Bush (Fig. 5.4). In both reaches, the amount of suitable habitat for the benthic invertebrate species modelled increased with flow up the highest flow modelled. At Branxholme, flows of 5 to 7.5 m^3/s provided maximum habitat for *Deleatidium*, *Pycnocentrodes* and Hydrobiosidae, whereas at Centre Bush maximum habitat for these species was provided by flows of 8 (for *Pycnocentrodes*) to 19 m^3/s (for Hydrobiosidae). I find it unusual for invertebrate habitat flow requirements to be less than those for adult trout, as appears to be the case at Branxholme. However, the Branxholme analysis probably used an old version of the benthic invertebrate habitat suitability curves.

5.3 Minimum flow

The selection of appropriate minimum flow is a matter of judgement, 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. However, Environment Southland's Proposed Regional Water Plan for Southland specifies adult trout as the critical species. The minimum flow should maintain 90% of the amount of adult brown trout habitat at the 7-day MALF or 90% of maximum adult brown habitat if the maximum is at a flow less than the mean annual low flow.

Table 5.2: Estimation of minimum flow requirements for fish species in the Oreti River at Ram Hill. The mean annual low flow (7-day MALF) is 5.9 m^3/s.

Species/life stage	Flow that provides maximum habitat (m^3/s)	Flow at which habitat begins to decline sharply	Flow for 90% habitat retention	Flow for 80% habitat retention
Brown trout < 100 mm	6	3	2.5	<2
Brown trout adult	9	6.5	4.9	4.1
Brown trout spawning	9	6.5	4.7	3.8
Brown trout yearling	5	3	2.3	<2
Food producing habitat	15	9.5	5.1	4.5
Longfin eel > 300mm	4	3	2.6	<2
Longfin eel < 300mm	7	5	3.7	2.6

Shortfin eel > 300mm	3	<2	<2	<2
Shortfin eel < 300mm	4	<2	<2	<2
Torrentfish	15	10	5.2	4.6
Bluegill bully	10	7	5.1	4.3
Inanga feeding	<2	<2	<2	<2
Upland bully	5	<2	<2	<2
Common bully	3	<2	<2	<2
Redfin bully	4	<2	<2	<2

Table 5.3: Estimation of minimum flow requirements for fish species in the Oreti River at Centre Bush. The mean annual low flow (7-day MALF) is 7.39 m^3/s.

Species/life stage	Flow that provides maximum habitat (m^3/s)	Flow at which habitat begins to decline sharply	Flow for 90% habitat retention	Flow for 80% habitat retention
Brown trout < 100 mm	3	3	2.2	2.1
Brown trout adult	6	5	4.4	3.5
Brown trout spawning	5	3	2.6	2.1
Brown trout yearling	4	3	2.1	2
Food producing habitat	11	7	5.8	4.7
Longfin eel > 300mm	3	3	2	<2
Longfin eel < 300mm	4	3	2.4	2.1
Shortfin eel > 300mm	2	3	<2	<2
Shortfin eel < 300mm	3	3	2.2	2
Torrentfish	11	6	5.8	4.3
Bluegill bully	8	4	3.2	2.

Inanga feeding	<2	<2	<2	<2
Upland bully	3	2	2.1	2
Common bully	3	2	2.2	2
Redfin bully	4	2	2.2	2

A minimum flow of 4.9 m^3/s at Ram Hill will maintain 90% of habitat at the 7-day MALF for adult brown trout. It retains close to 90% habitat (> 80%) for torrentfish, bluegill bullies, and food producing habitat.

A minimum flow of 4.4 m^3/s at Centre Bush retains 90% of maximum adult brown trout habitat and slightly less than 80% of habitat for food producing habitat and more than 80% of habitat for torrentfish and bluegill bullies (Fig. 5.2). As the estimated tributary flow contribution between Ram Hill and Centre Bush is estimated to be 1.49 m^3/s at mean annual low flow, a minimum of 4.9 m^3/s at Ram Hill would maintain 6.39 m^3/s at Centre Bush, assuming no abstraction between. Thus, an additional 2 m^3/s (6.36 less 4.4) could be abstracted below Dipton before the Centre Bush minimum flow is reached.

At Branxholme, 90% of adult trout habitat at the 7-day MALF (8.17 m^3/s) was provided by a flow of 7.5 m^3/s and a flow of 4.9 m^3/s at Ram Hill would result in a flow of 7.16 m^3/s at Branxholme, assuming no abstraction when flows were close to the 7-day MALF. The Branxholme reach is about 50% wider than the Centre Bush reach and may be less steep, so that flow requirements could be expected to be greater.

6. Conclusion

Minimum flow requirements for adult brown trout in the Oreti River vary with the river width. In the wide braided middle section of the river typified by Ram Hill, a flow of 9 m^3/s provides maximum habitat and habitat begins to decline sharply when flows fall below 6.5 m^3/s. A flow of 4.9 m^3/s maintains 90% of the habitat available at the 7-day mean annual low flow. This minimum flow also maintains about 80% of habitat at the 7-day MALF for the fast-water native fish species and for food producing habitat. In my opinion, such a minimum flow would retain the existing ecosystem in good condition, while allowing some abstraction.

In the predominantly single channel section below Dipton, the river is almost half the width of the braided section and flow requirements are less. A flow of 6 m^3/s provides maximum adult brown trout habitat and this begins to decline sharply when the flow falls below 5 m^3/s. A flow of 4.4 m^3/s maintains 90% of maximum habitat. As in the braided reach, the minimum flow of 4.4 m^3/s also maintains about 80% of habitat at the 7-day MALF for the fast-water native fish species and for food producing habitat.

Further downstream at Branxholme, the river is wider and flow requirements appear to be higher. If the Ryder Consulting results are accepted, a flow of 7.5 m^3/s maintains 90% of habitat at the 7-day MALF and this would override minimum flow requirements at Centre Bush and Ram Hill, as the increase in flow from tributaries is small at times of low flow.

When different sections of river have different flow requirements, there are various options for flow management. If flow requirements increase with distance downstream at a higher rate than the natural increase in flow, then the flow requirement at the most downstream site will dictate the minimum flow. However, if flow requirements decrease with distance downstream because the river character changes, it is possible to set minimum flows for the different sections of river and this will allow more water to be abstracted from the river, while still meeting environmental protection standards.

In the case of the lower Oreti River, minimum flow requirements at Branxholme appear to dictate flow requirements as far upstream as Mossburn. Under normal low flow conditions, abstraction would cease when flows fell below 7.5 m^3/s at Branxholme. At this time, the flow at Centre Bush would be about 6.72 m^3/s and the flow at Ram Hill would be 5.24 m^3/s.

Another alternative is to retain the 90% protection standard as an average over the middle and lower sections of the Oreti River. This would involve maintaining an average minimum flow requirement, rather than different minimum flows at various points along the river. For example, a minimum flow of 4.9 m^3/s at Ram Hill would retain near maximum adult trout habitat 90% at Centre Bush (6.4 m^3/s) and slightly less than 90% habitat at Branxholme (7.16 m^3/s and 88% of habitat at the 7-day MALF).

7. Acknowledgments

The field work for this study was carried out by NIWA staff at Dunedin with the assistance of Environment Southland staff.

8. References

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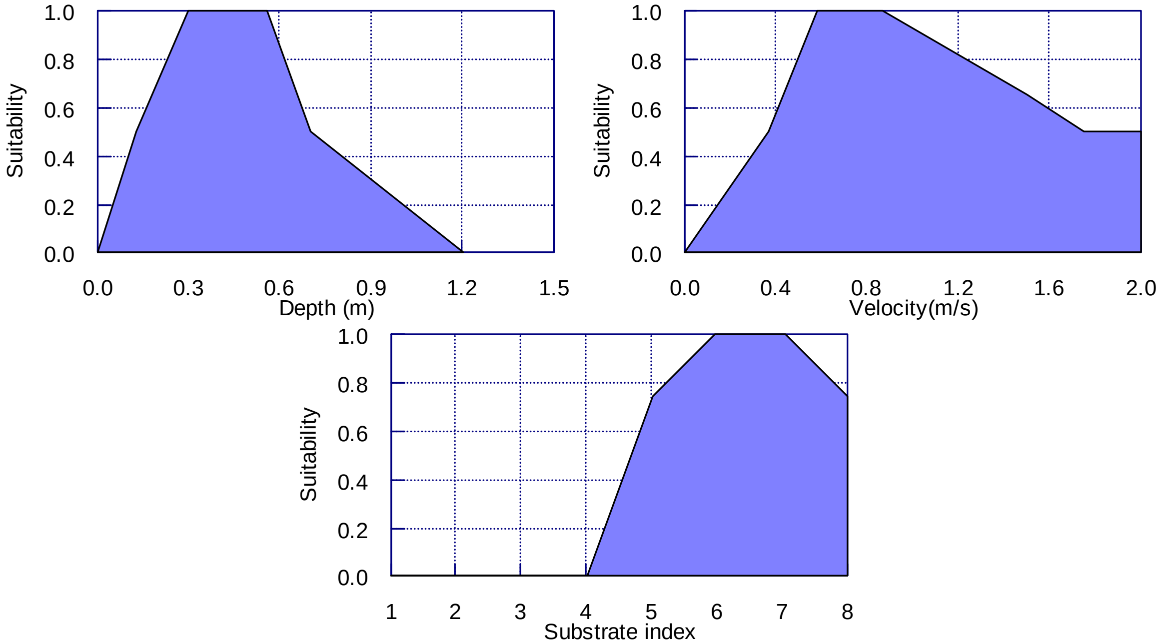
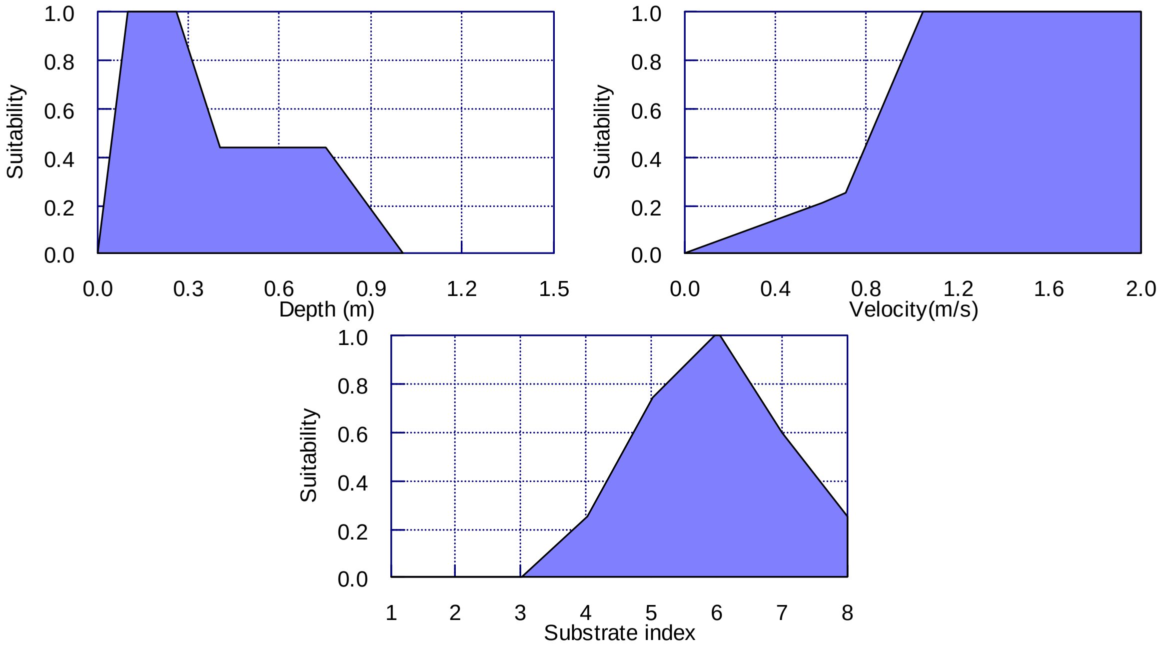
9. Appendix 1

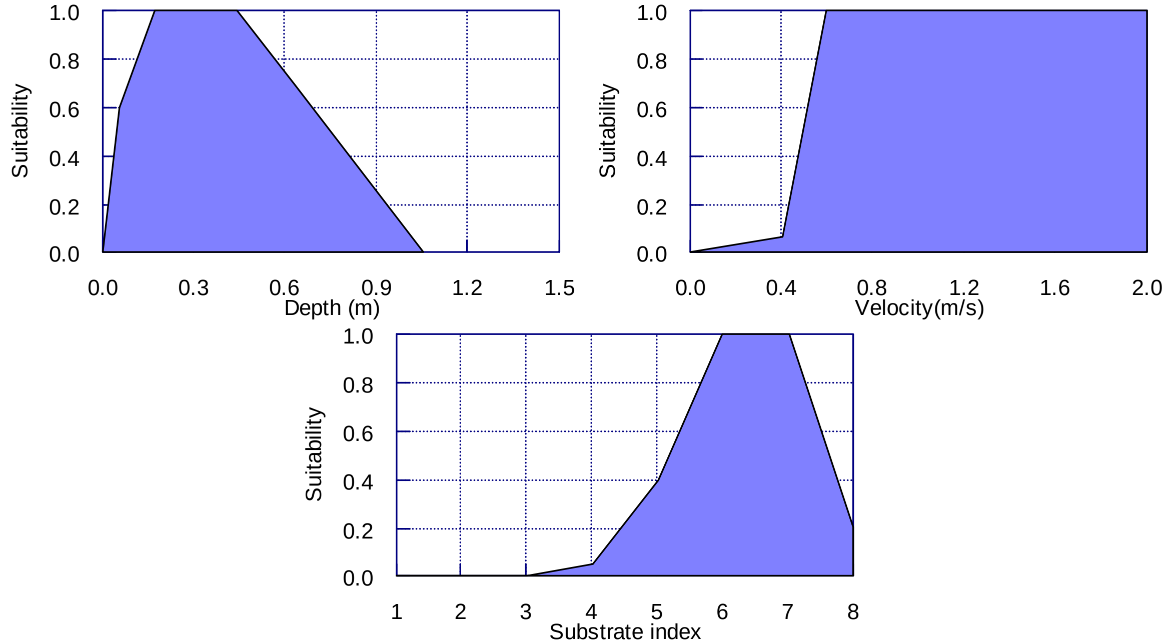
Aphrophila (Diptera) (Jowett et al. 1991)



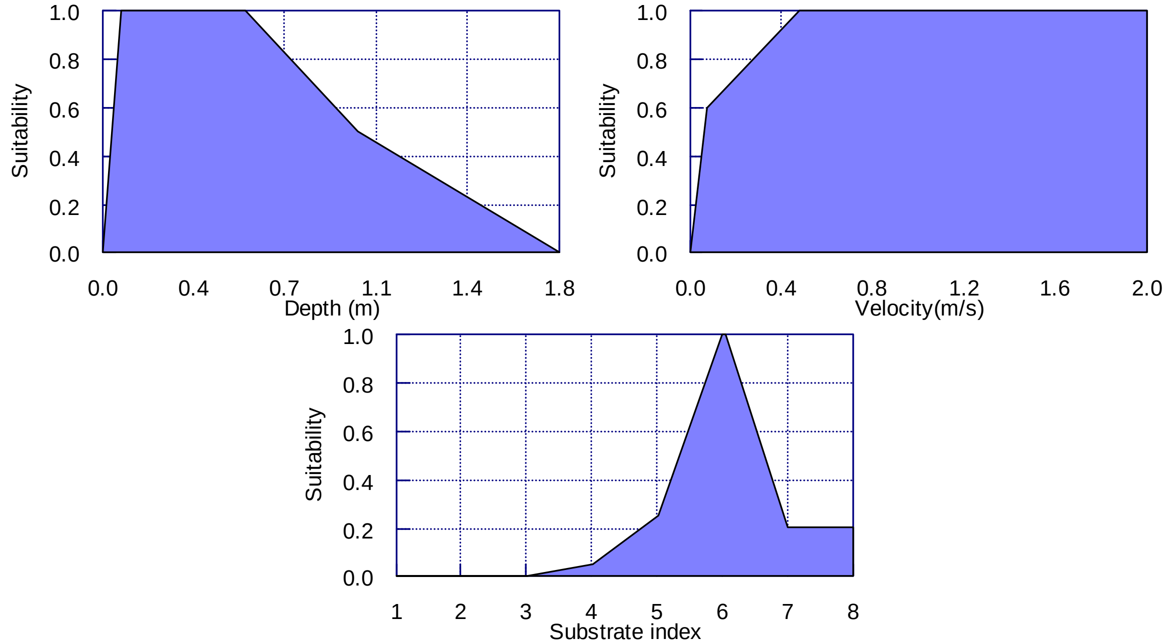
Maoridiamesa (Diptera) (Jowett et al. 1991)



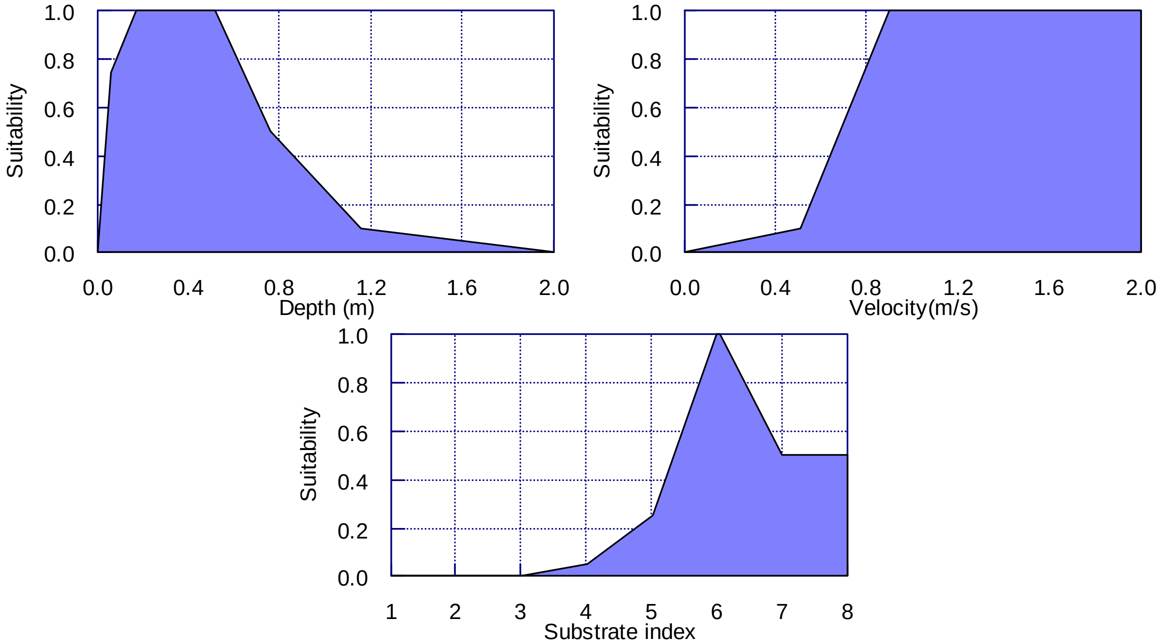
C. humeralis (mayfly) (Jowett et al. 1991)



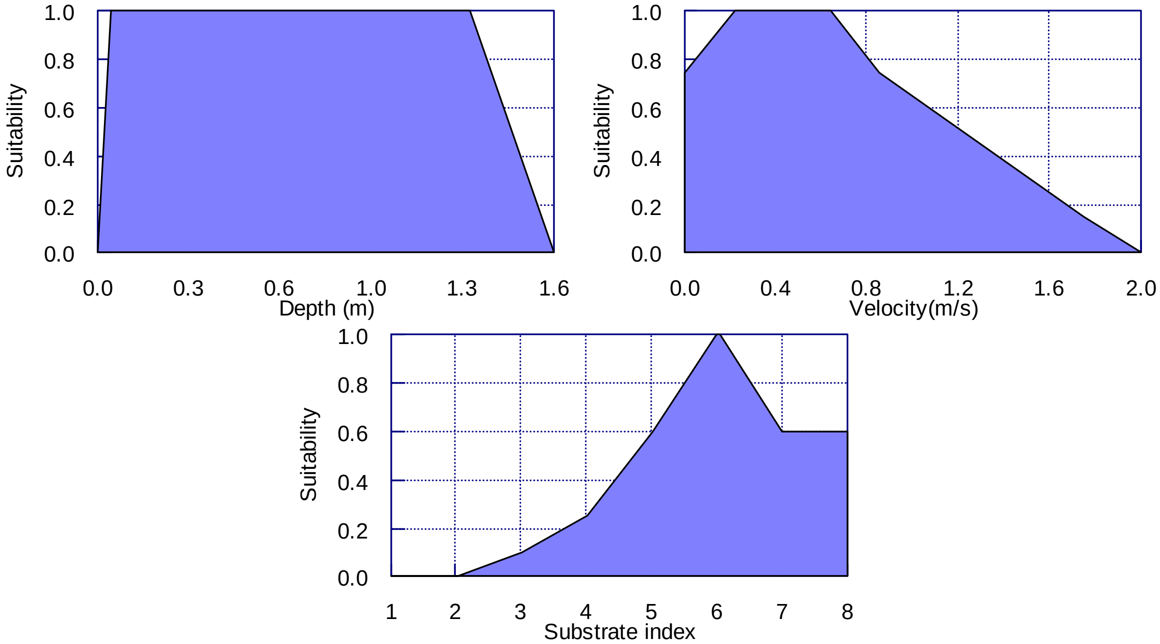
Hydrobiosidae (free-living caddis) (Jowett et al. 1991)



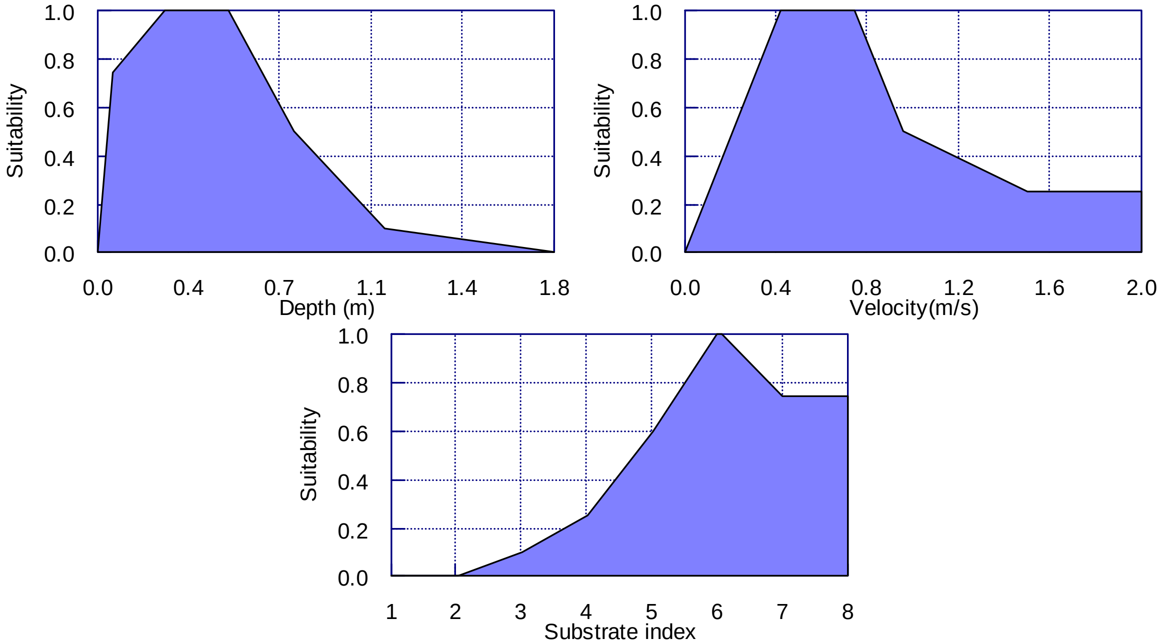
Aoteapsyche (net-spinning caddis) (Jowett et al. 1991)



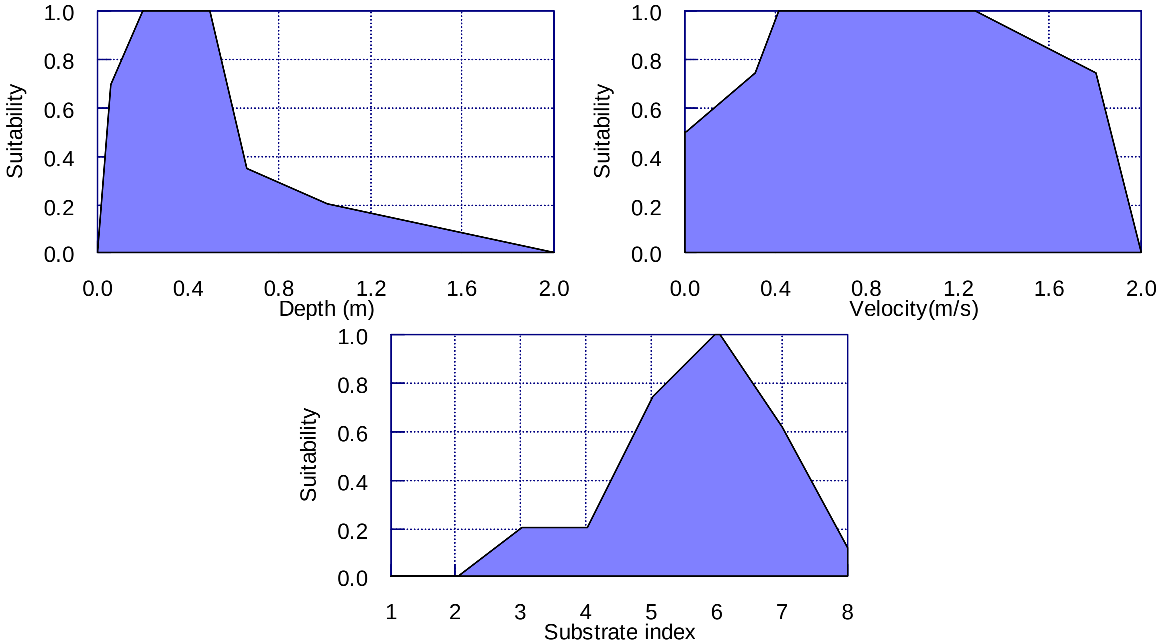
O. feredayi (horny-cased caddis) (Jowett et al. 1991)

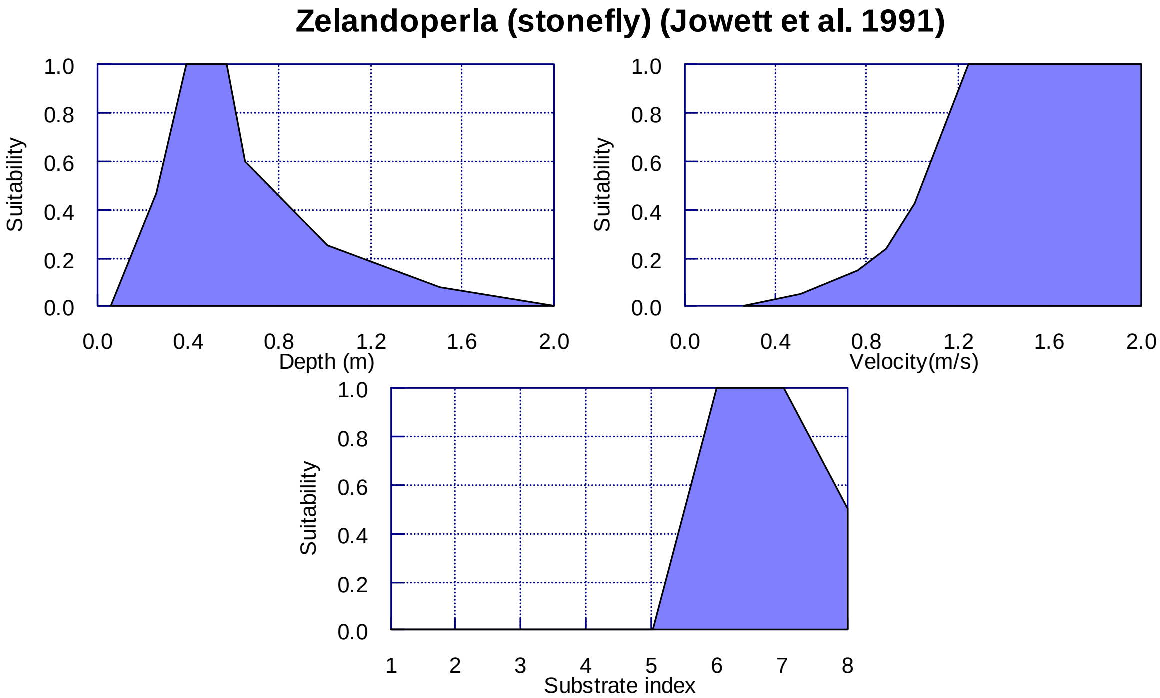


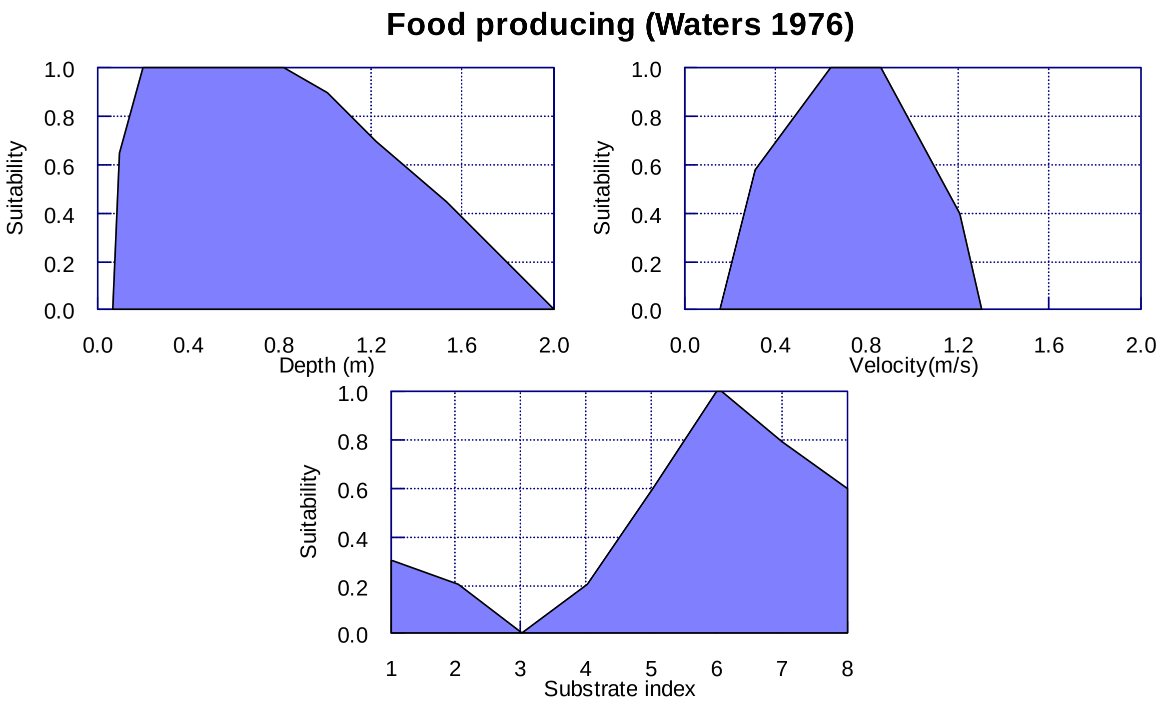
Pycnocentrodes (stony-cased caddis) (Jowett et al. 1991)



Deleatidium (mayfly) (Jowett et al. 1991)




Zelandoperla (stonefly) (Jowett et al. 1991)
Suitability
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.4
0.8
1.2
1.6
2.0
Depth (m)
Velocity(m/s)
1
2
3
4
5
6
7
8
Substrate index


Food producing (Waters 1976)
Suitability
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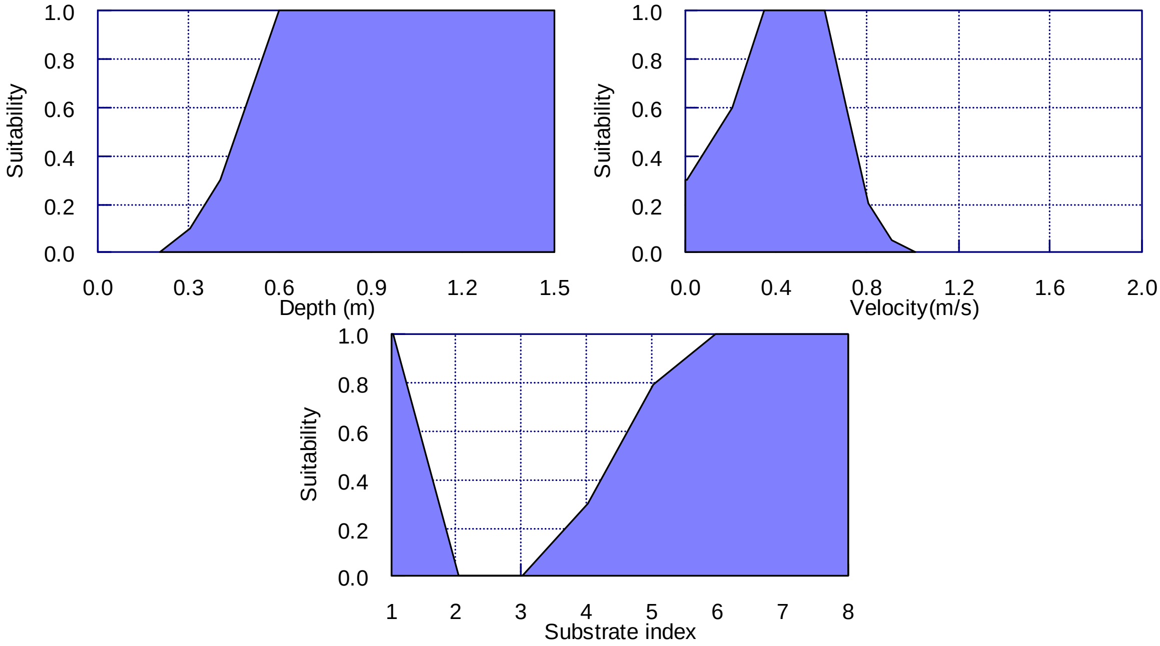
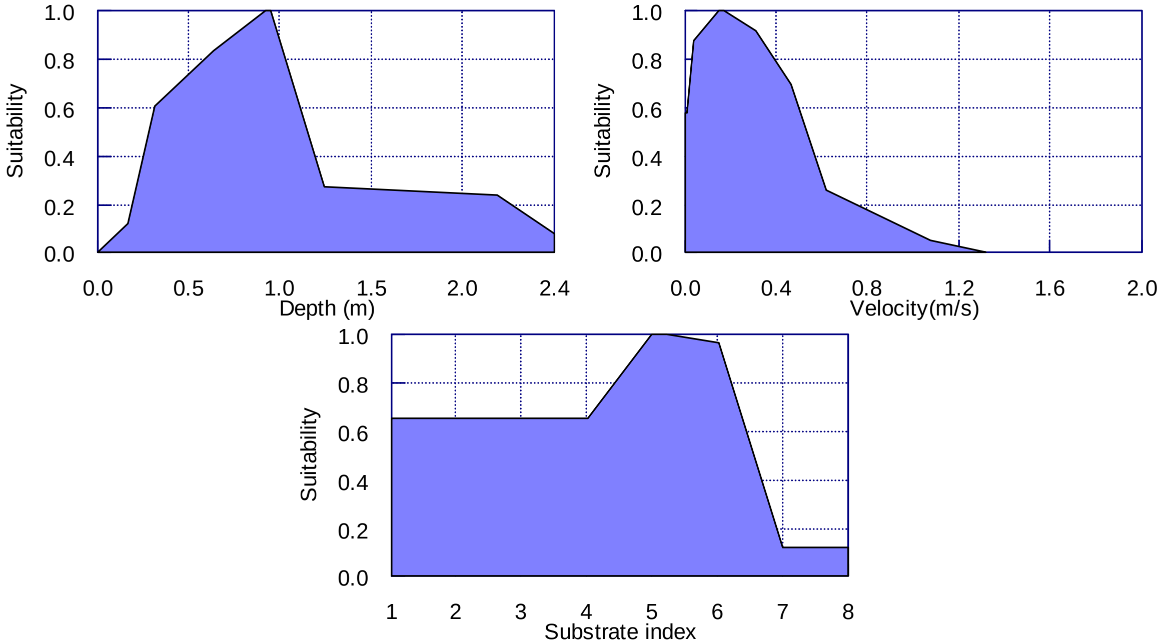
0.6
0.4
0.2
0.0
0.0
0.4
0.8
1.2
1.6
2.0
Depth (m)
Velocity(m/s)
1
2
3
4
5
6
7
8
Substrate index

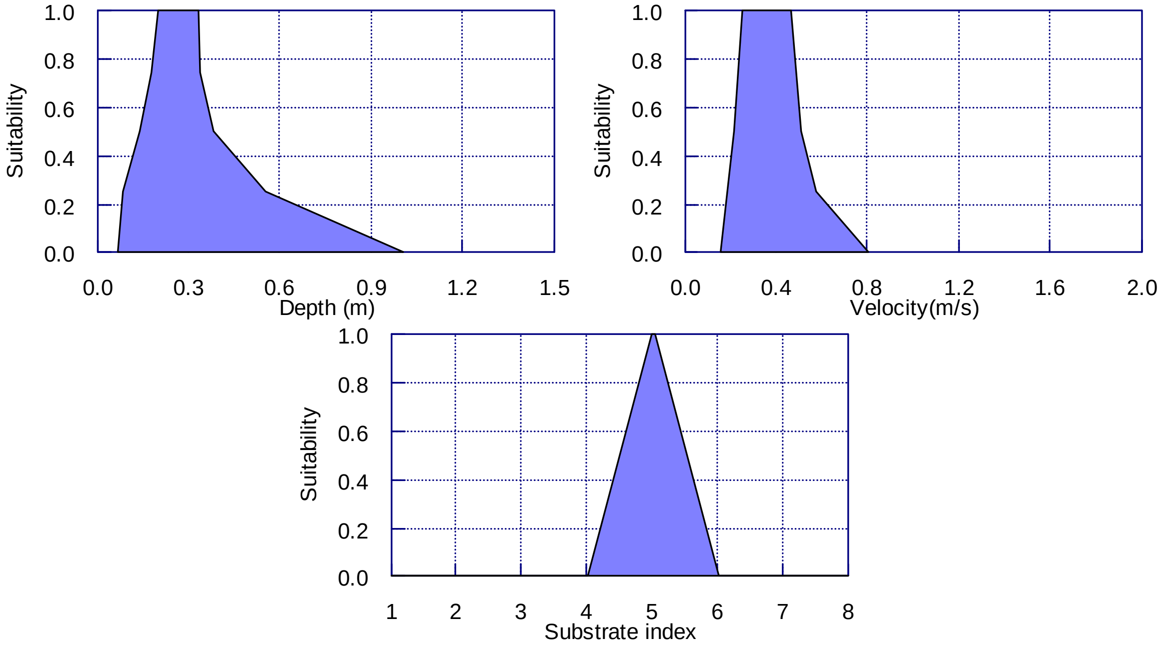
Brown trout adult (Hayes and Jowett 1994)



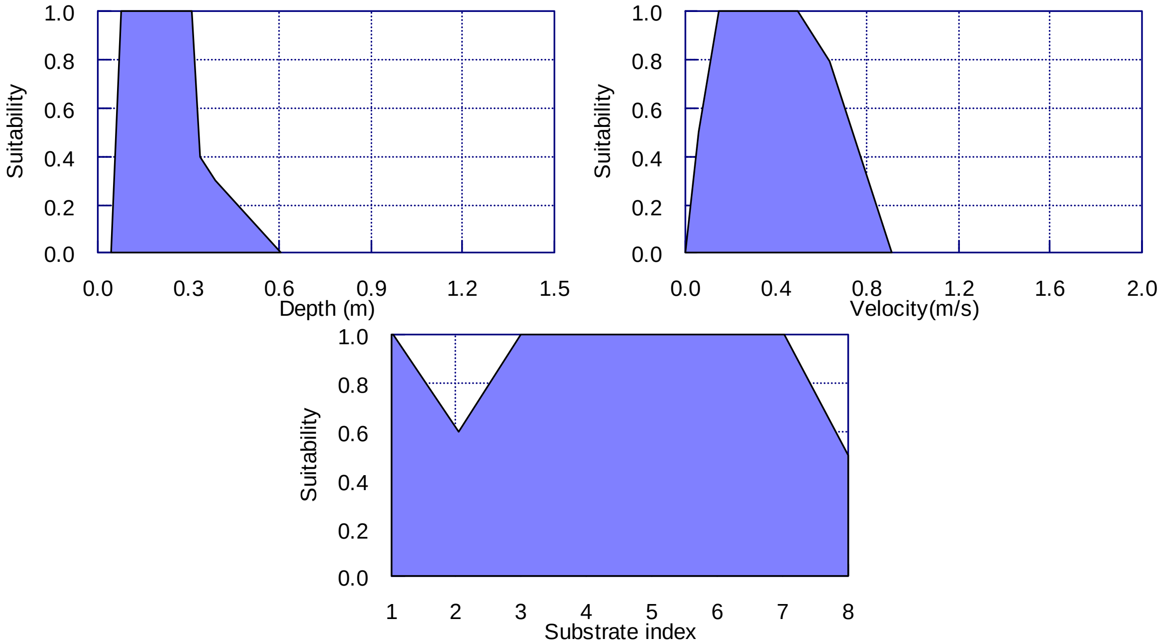
Brown trout yearling (Raleigh et al 1986)

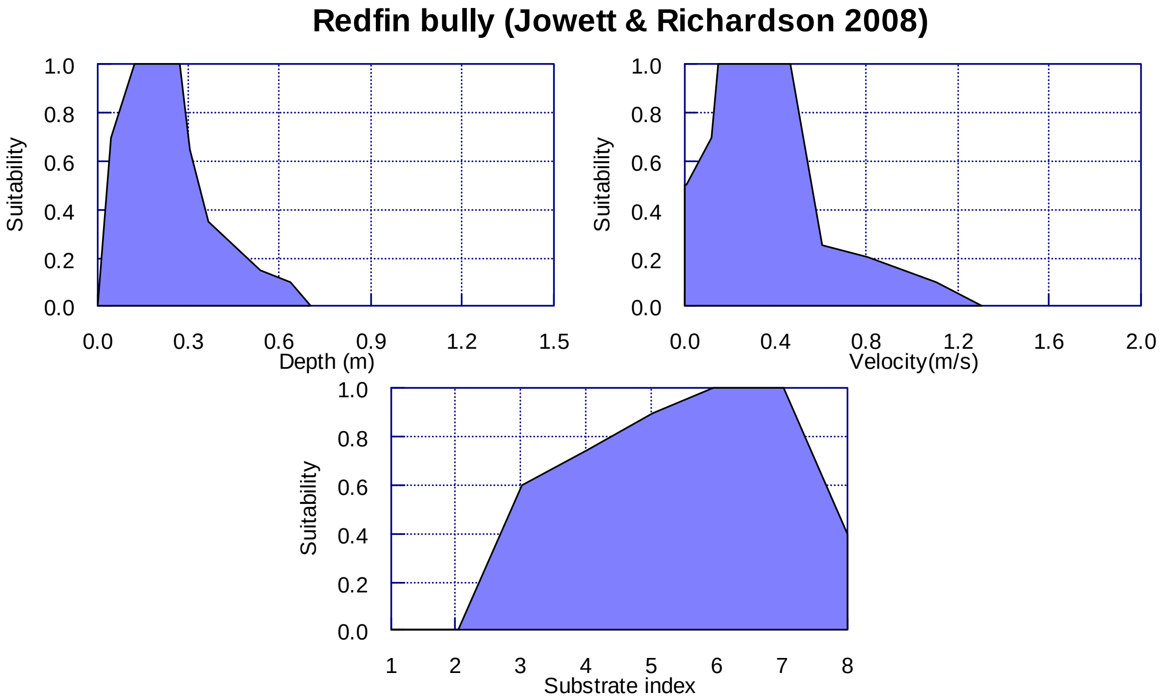


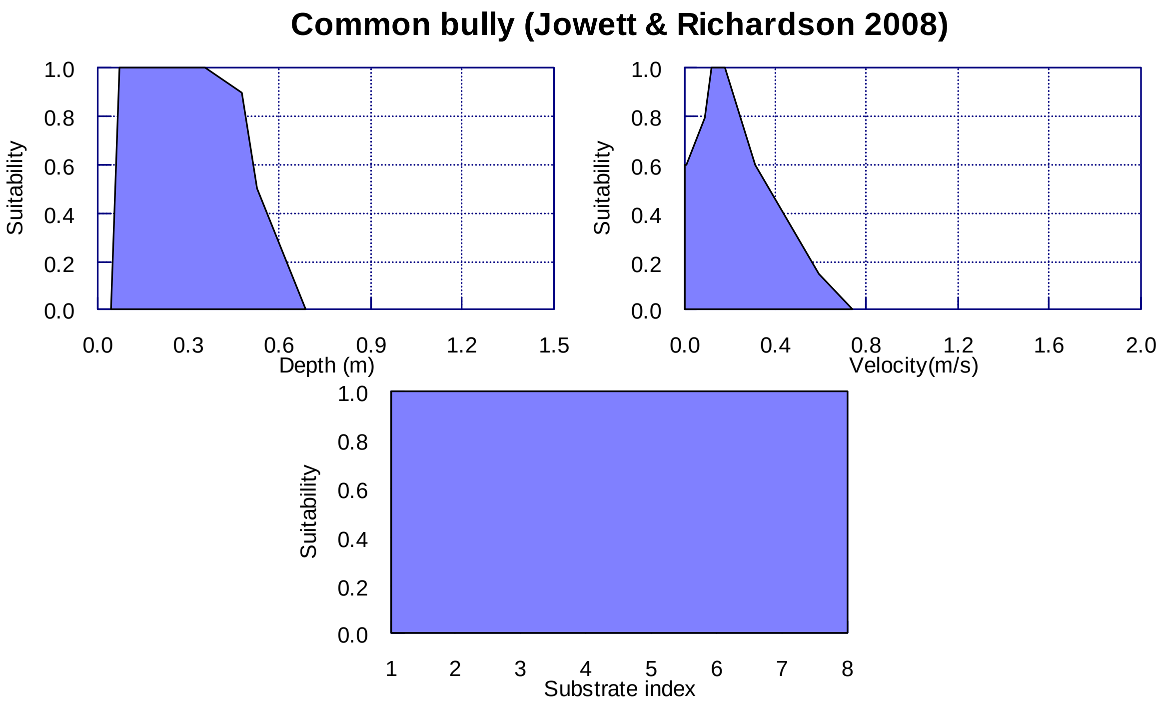
Brown trout spawning (Shirvell and Dungey 1983)

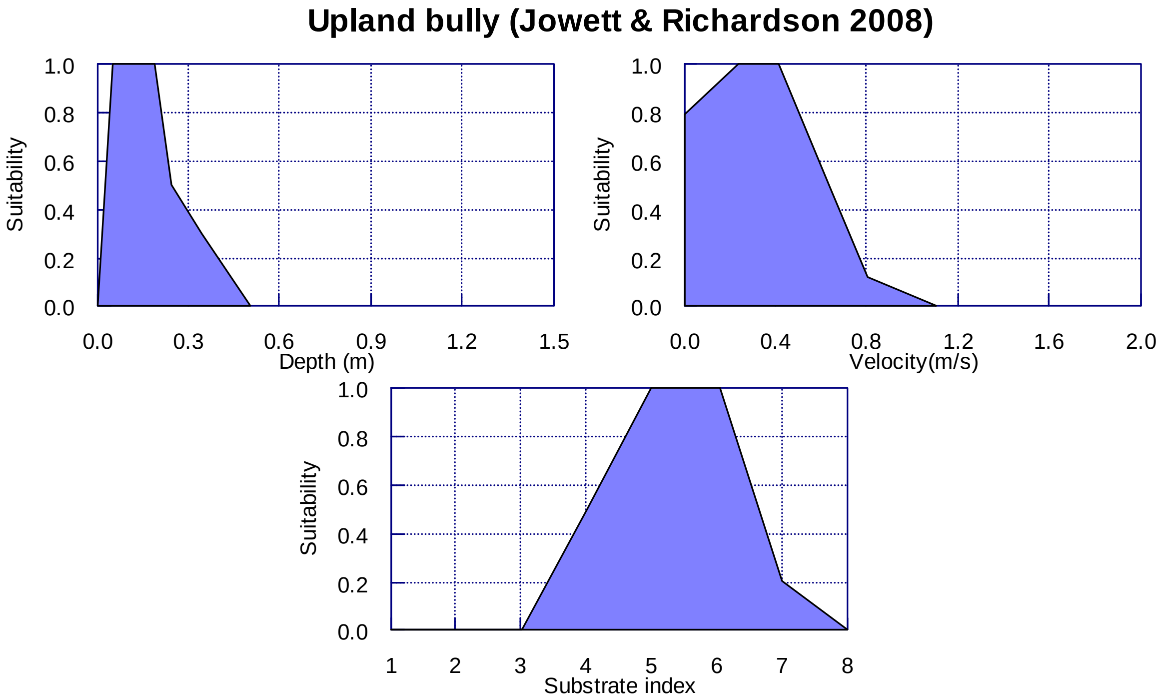


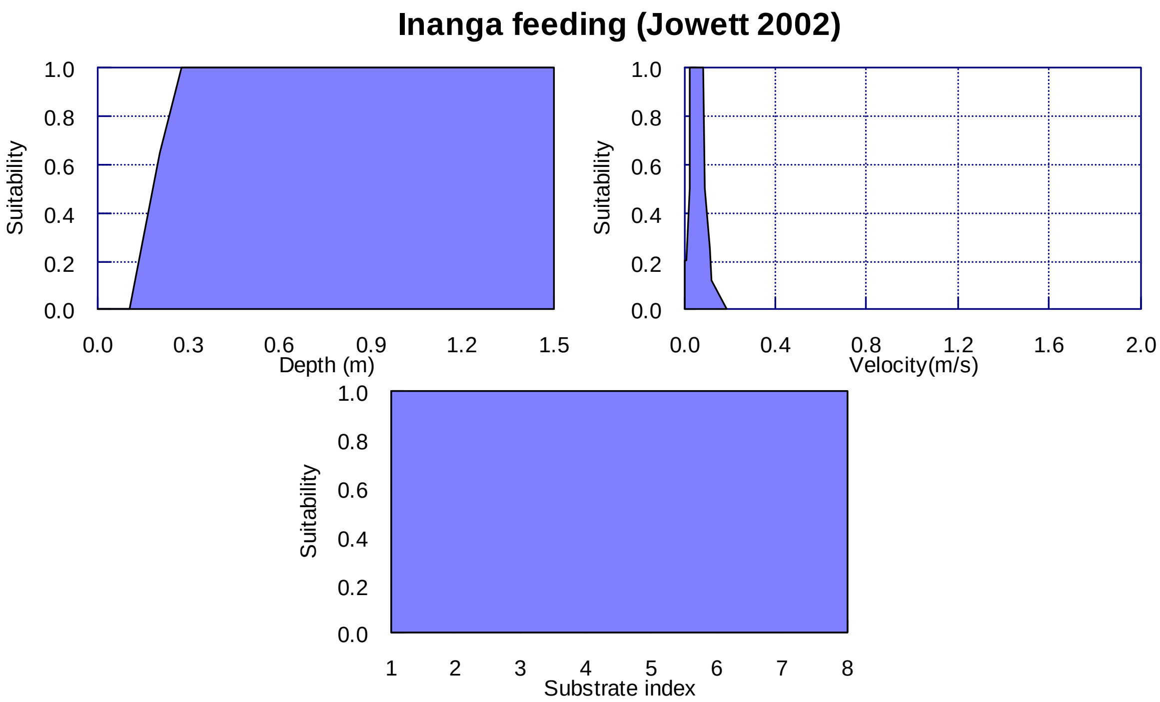
Brown trout (< 100 mm) (Jowett & Richardson 2008)



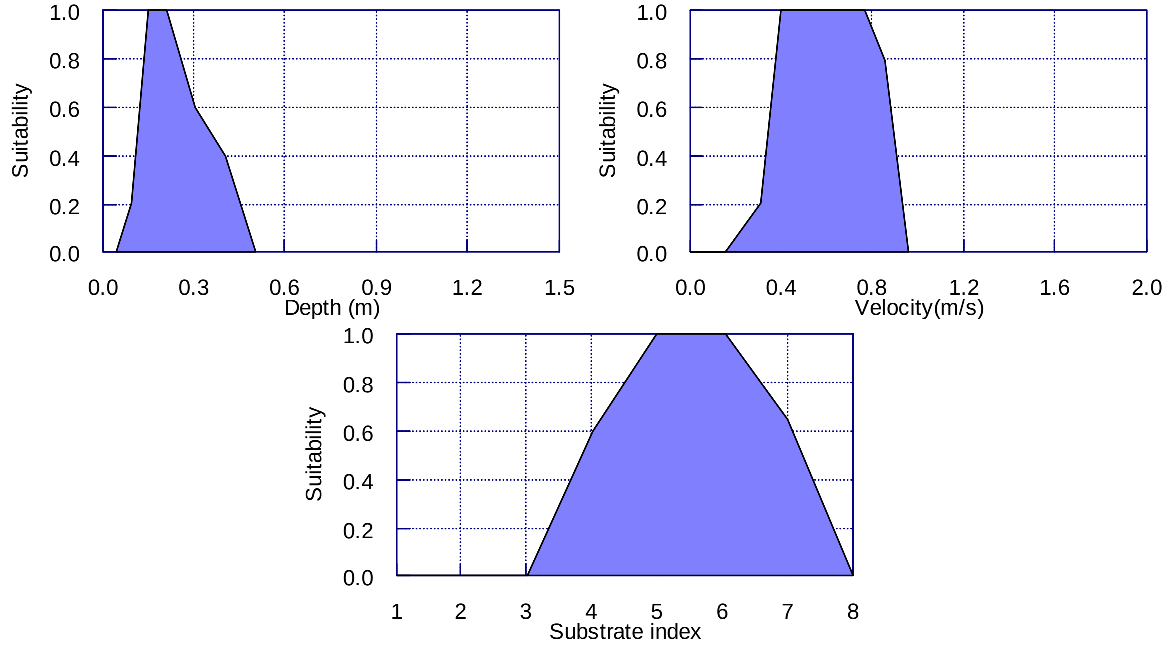

Redfin bully (Jowett & Richardson 2008)
Suitability
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.3
0.6
0.9
1.2
1.5
Depth (m)
0.0
0.4
0.8
1.2
1.6
2.0
Velocity(m/s)
1
2
3
4
5
6
7
8
Substrate index


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

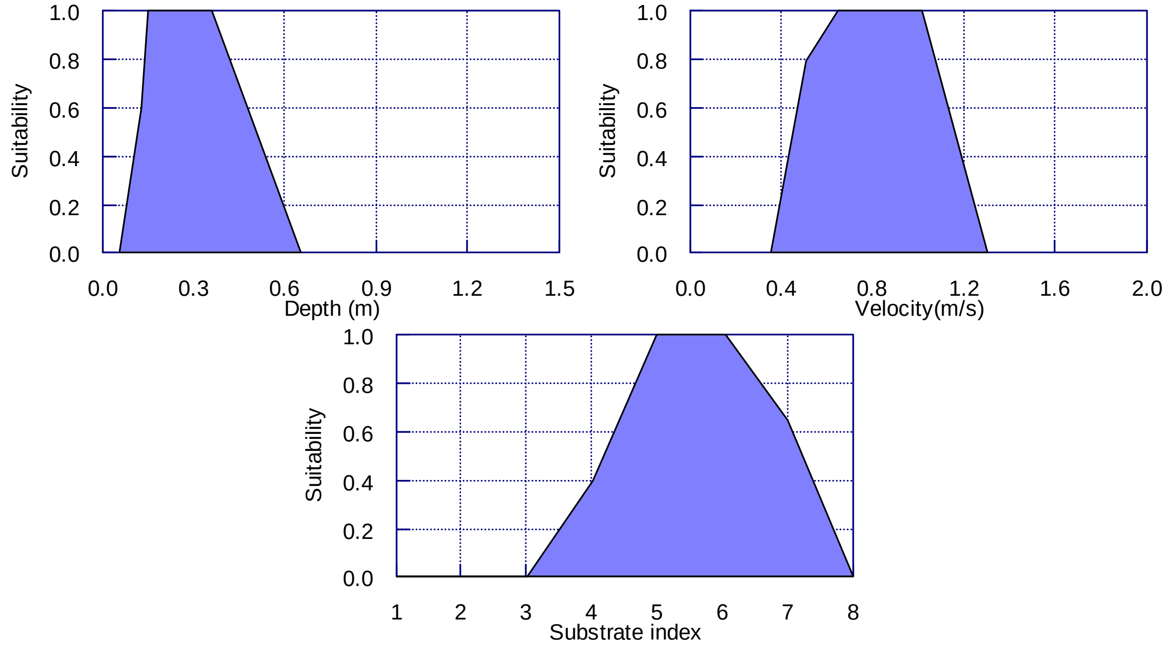

Upland bully (Jowett & Richardson 2008)
Suitability
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.3
0.6
0.9
1.2
1.5
Depth (m)
0.0
0.4
0.8
1.2
1.6
2.0
Velocity(m/s)
1
2
3
4
5
6
7
8
Substrate index


Inanga feeding (Jowett 2002)
Suitability
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.3
0.6
0.9
1.2
1.5
Depth (m)
0.0
0.4
0.8
1.2
1.6
2.0
Velocity(m/s)
1
2
3
4
5
6
7
8
Substrate index

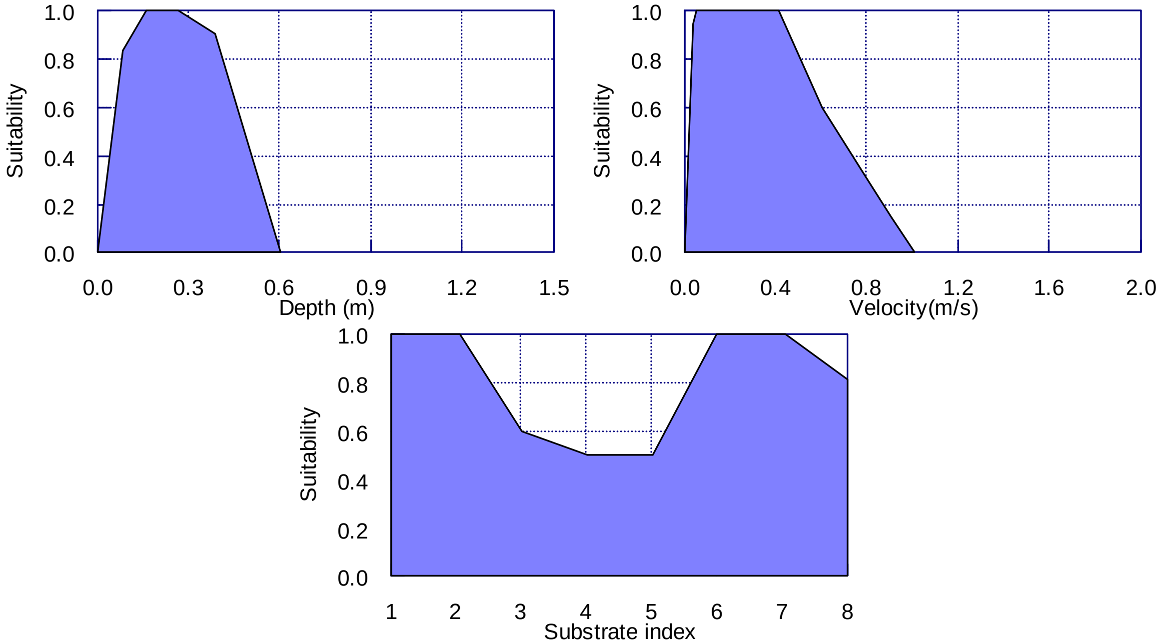
Bluegill bully (Jowett & Richardson 2008)



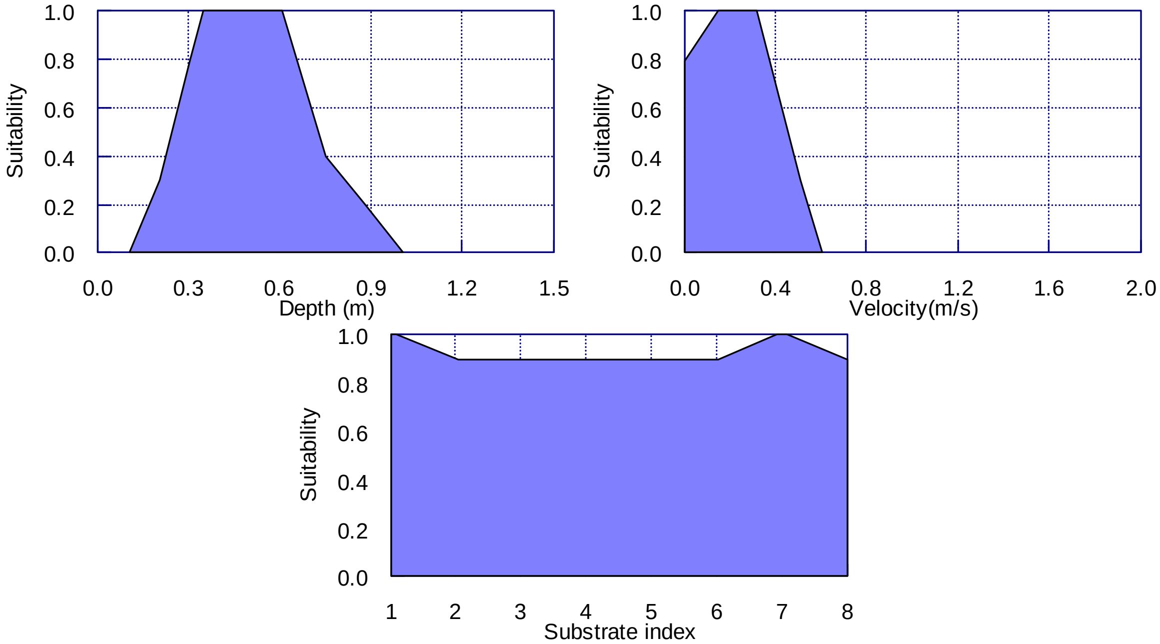
Torrentfish (Jowett & Richardson 2008)



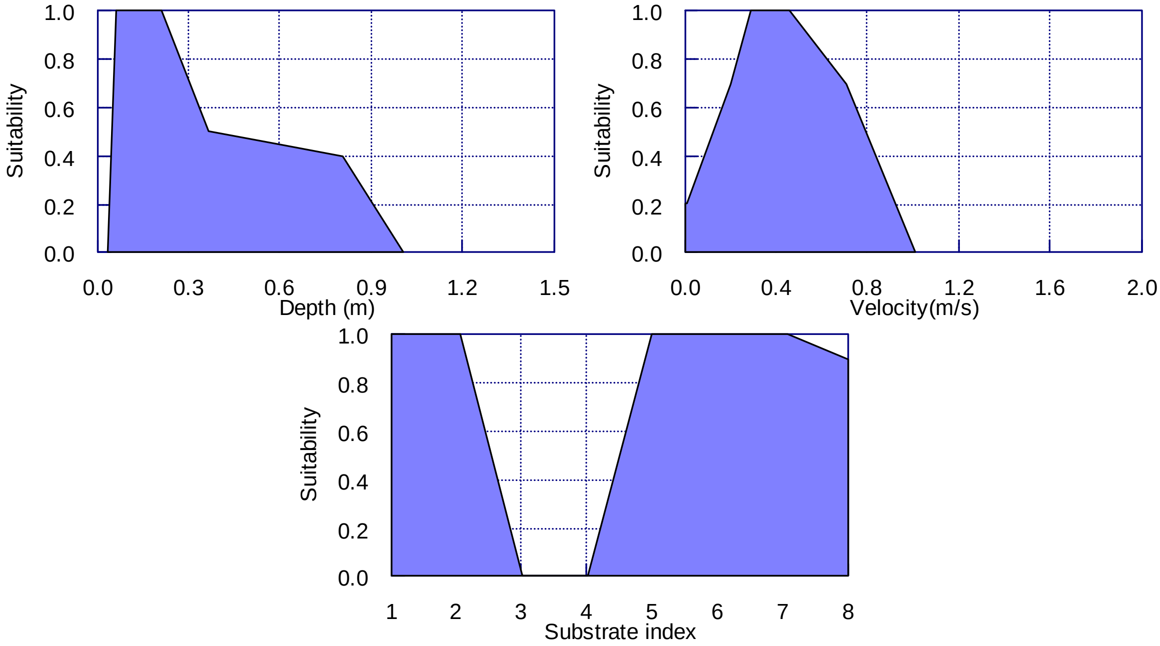
Shortfin eel < 300mm (Jowett & Richardson 2008)



Shortfin eel > 300mm (Jowett & Richardson 2008)



Longfin eel < 300mm (Jowett & Richardson 2008)



Longfin eel > 300mm (Jowett & Richardson 2008)