Jowett Consulting Limited

Considerations of Stream Size in Determining Minimum Flows and Water Allocation Limits in Taranaki rivers

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Prepared for

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Executive Summary

The National Policy Statement for Freshwater Management 2017 (NPSFM) requires regional councils to set environmental flows that include an allocation limit and a minimum flow.

As part of its review of the Freshwater Plan and development of a Proposed Natural Resources Plan (that combines the current freshwater, soil and air plans), the Taranaki Regional Council will be developing draft plan provisions setting minimum flows and allocation limits. One of the key objectives of such limits is to give effect to te mana o te wai[1], which includes providing for the ecosystem health of waterways as a first order of priority and then for other uses and values as a second order of priority. The limits developed through this process will applied to any new applications to take water across the region.

A report by Jowett (2019) presented various minimum flow and allocation options based on the combined ecological effects of minimum flow and allocation. The 2019 report used trout and torrentfish as key indicator species as they are the species most likely to be affected by any reductions in flow, given their preference for high flow habitat. In the analysis, it was assumed that there was a linear decline in the amount of trout and/or torrentfish habitat as flows reduce below the MALF. On this basis, default limits were assumed to provide the same level of protection to instream fauna across the full range of river/stream sizes. Following discussions with iwi and the Wai Maori Group post the publication of the 2019 report, it was agreed that additional work was required to test these assumptions in both small streams and large rivers.

Instream habitat surveys were initially carried out at sites on 12 Taranaki streams and rivers (Kapoaiaia, Kaupokonui, Manganui, Mangaoraka, Patea, Tangahoe, Waingongoro (2 sites), Waiongana, Waiwhakaiho, Hangatahua (Stony), Tawhiti and Kapuni). As part of this study, this group of sites was broadened by including sites on two small streams and two large Taranaki rivers to give a total of 17 sites.

A group of common species with high to moderate velocity preferences (brown trout, common bully, smelt, longfin eel, redfin bully and torrentfish) was selected to evaluate the effect of low flows on habitat at the 17 study sites and to examine the assumption that there is a linear decline in fish habitat with flow. Flow requirements in terms of the flow required to retain a percentage of habitat at MALF were calculated for each species. The minimum flow requirement was the maximum requirement over all species. Of the 17 sites, minimum flow requirements were based on torrentfish habitat for 11, on adult trout habitat for 4 and on smelt habitat for 2. This means that the minimum flow requirement is conservative for other species that have lesser flow requirements.

The assumption that the decline in habitat would be linear or less was met in larger rivers (mean annual low flow > 1 m^3/s) but not in smaller streams. Small streams were more "at risk" from water takes than larger rivers. This was recognised in default recommendations in the proposed National Environmental Standard (NES) for ecological flows where a higher minimum flow was set for small streams than larger rivers (mean flow > 5 m^3/s). In the Taranaki region, a river with a mean annual low flow (MALF) of 1 m^3/s will have a mean flow of about 5 m^3/s.

Minimum flow criteria were developed so that a consistent level of protection applies over a range of river sizes. Although the minimum flows suggested in Jowett (2019) are applicable to moderately

[1] As defined in the National Policy Statement for Freshwater Management, 2017

sized streams and rivers (MALF > 1 m^3/s), the minimum flow would need to be increased in smaller rivers and could be decreased in larger rivers to maintain a consistent level of protection.

The protection levels are conservative because they are based on the assumption that all consented water will be taken from the river whenever possible, and this is rarely the case.

The setting of minimum flows and allocation limits also dictates the amount of water available for water takes, including any potential new takes, and the reliability of water supply for water users. The number of days with total restriction depends on the minimum flow, as generally no take is allowed once the river flow falls below the minimum flow. Allocation affects the number of days there is likely to be partial restrictions with a 10% increase in allocation increasing the number of days per year with partial restriction by about 10 days.

Minimum flow and allocation options in Table 1 are based on maintaining ecosystem health at a prescribed level. In assessing an appropriate minimum flow and allocation for a particular river, a number of additional factors could be taken into consideration. The setting of minimum flows and allocation limits is a process that involves the Regional Council and community in order to achieve the best water management outcomes for the region taking into account environmental, cultural and economic considerations, such as restrictions to water supply.

Table 1: Minimum flow options varying with stream size.

	Small stream	Moderate stream/river	Large river	Allocation volume as % MALF	Benthic invertebrate protection level	Fish habitat protection level
Mean flow (m^3/s)	< 5	> 5	> 30			
	Minimum flow as % MALF					
Option 1	79%	67%	45%	30	89	80
Option 2	81%	71%	52%	30	91	80
Option 3	87%	82%	71%	40	90	80
Option 4	89%	85%	77%	40	91	80
Current policy setting	*66%*			*33*[2]	*87*	*77*

[2] Inferred allocation limit as no limits are specified in the existing plan

1 Introduction

As part of its review of the Freshwater Plan and development of a Proposed Natural Resources Plan (that combines the current freshwater, soil and air plans), the Taranaki Regional Council (the Council) will be developing draft plan provisions setting minimum flows and allocation limits. One of the key objectives of such limits is to give effect to te mana o te wai[3], which includes providing for the ecosystem health of waterways as a first order of priority and then for other uses and values as a second order of priority.

In the Plan review to date the Council has prepared and undertaken targeted consultation on a draft Freshwater and Land Management Plan (Draft Plan) that takes into account the National Policy Statement for Freshwater Management 2017 (NPSFM). The Draft Plan establishes four freshwater management (FMU) units within which they can set minimum flows and allocation limits.

Flows in rivers classified as outstanding water bodies (FMU A) are given a high level of protection in the Draft Plan and only allow minimal water takes. Two rivers, the Hangatahua (Stony) and Maketawa, are considered outstanding freshwater bodies and along with the Lake Rotokare Scenic Reserve form FMU A.

The Taranaki ring plain (FMU B), centred around Mt Taranaki, is the most populated part of the region and has fertile and free-draining volcanic soils that are well suited to pastoral farming. Dairying is the most common land use and is more intensive on the flatter lands of southern Taranaki. Typically, ring plain rivers are short, small and fast-flowing.

The coastal terraces along the north and south Taranaki coast (FMU C) also have versatile and productive soils. However, the combination of light, sandy soils and strong winds in some localities (e.g. coastal sand country) make them susceptible to wind erosion if vegetation cover is lost.

By contrast to ring plain rivers, the eastern hill country rivers (FMU D) are formed in older rock - siltstone, mudstone and sandstone, known locally as papa, and display a branch-like (dendritic) pattern of drainage. The rivers of the hill country are generally longer than ring plain rivers and are contained by narrow valleys that carry relatively high sediment loads as a result of hill country erosion.

The overall effect of the minimum flow and allocation on the state of the benthic invertebrate community was assessed using the benthic production model. This model predicts an index of benthic invertebrate density for selected species with and without maximum allowable takes. The protection level is the predicted benthic invertebrate density with maximum allowable takes as a percentage of the benthic invertebrate density with natural flows.

Instream habitat is very important because fish and benthic invertebrates cannot survive in a river if there is no suitable habitat. Native fish and trout can be affected by low flows through a reduction in the amount of suitable habitat if the flows are low for a sufficiently long period. At low flows, the amount of habitat suitable for fish with high flow requirements, such as torrentfish, koaro and adult trout, declines as flows reduce towards zero, so that any reduction in long duration low flow has the potential to affect the fish population. To maintain populations of these fish species with high flow requirements, low flows over a 30-day period should be maintained at an adequate level (Jowett et al. 2005).

[3] As defined in the National Policy Statement for Freshwater Management, 2017

A report by Jowett (2019) used a combination of these two methods (benthic production model and instream habitat) to examine the combined ecological effects of minimum flow and allocation on the benthic invertebrate community and fish population (i.e., ecosystem health). He suggested minimum flow and allocation options based on average benthic and fish protection levels for representative Taranaki waterways (Table 2).

Table 2: Possible choices of minimum flows and allocation and the protection levels that they provide. Protection levels are percentages of benthic invertebrate production or fish habitat relative to invertebrate production and fish habitat at MALF (Jowett, 2019)

Description	Minimum flow as % MALF	Allocation volume as % MALF	Benthic invertebrate protection level	Fish habitat protection level
Current Plan	66	33[4]	87	77
Draft Plan	90	30	93	86
Alternative 1	85	40	90	81
Alternative 2	80	30	91	83

The effect of water takes varies with flow regime and morphology. The morphology of a river is determined by gradient, geology and high flows which occur relatively infrequently. Biota are controlled by frequently occurring low flows. If the low flows are low compared to normal river flows, the quality of the habitat will be significantly lower than normal and any further reduction in flow will compound the detrimental effect. However, if the low flows are close to normal flow, there is relatively little reduction in habitat and potentially less effect when flows are reduced.

Jowett (2019) assumed that the average effects of abstraction on the 9 rivers studied were representative of Taranaki rivers, recognising that the effects would be greater in some rivers and less in others depending on morphology. He assumed that there would be a linear decline in the amount of trout and/or torrentfish habitat as flows reduce below the MALF.

Jowett (2019) qualified his assessments depending on river size and fish community. He suggested that it was possible that a lower minimum flow and higher allocation might apply to rivers with mean flows greater than 10 m^3/s and that small streams may not contain torrentfish or trout and may have lower flow requirements than the larger rivers.

It is apparent that one limit (i.e. minimum flow as a percentage of MALF) may not fit all rivers because of differences in morphology and fish community. For example, there are obvious morphological differences between the low gradient reaches of large rivers such as the Whenuakura and Waitara rivers and the shorter steeper rivers of the ring plain.

This report extends the range of river sizes described by Jowett (1993, 2019) by including two very small streams and two of the largest rivers in Taranaki. It then examines the assumption that there is a linear decline in fish habitat with flow by evaluating the variation in habitat with flow in a range of rivers from very small to large. A set of minimum flow options have been developed so that a consistent level of protection applies over a range of river sizes.

[4] Inferred allocation limit as no limits are specified in the existing plan

2 Study Rivers

Instream habitat surveys have been carried out on nine Taranaki rivers (Kapoaiaia Stream, Kaupokonui River, Manganui River, Mangaoraka River, Patea River, Tangahoe River, Waingongoro River, Waiongana Stream and Waiwhakaiho River) and these were used to assess the effects of a range of minimum flow and allocation options on habitat and benthic invertebrate production (Jowett 2019). Additional instream habitat surveys of the Hangatahua (Stony), Waingongoro, Tawhiti and Kapuni rivers (Jowett 1993) were also used.

For the purposes of this revised report, this group of rivers was broadened by including two large Taranaki rivers and two small streams to give a total of 17 study sites. A number of the sites surveyed are known to be culturally significant for mahinga kai (pers. comm. Sam Tamarapa, TRC). The four additional survey sites were selected based on their size (mean flow) and the availability of a long-term flow record. These additional study rivers are described below.

2.1 Waitara River

The Waitara River is the largest river in the region with a mean flow of 58 m^3/s at Bertrand Road. The Waitara River drains both the eastern hill country and the slopes of Mt Taranaki. The area draining the eastern hill country is about half the total catchment area. The main tributary from Mt Taranaki is the Manganui River, which joins the Waitara River about 18 km from the mouth and drains about a quarter of the total catchment area.

Instream habitat was surveyed in a 2.5 km reach of the Waitara River on 18/2/20 when the flow was 5.1 m^3/s. The reach was between Bertrand Road (39 2.946S 174 15.279N) and Methanex's Motonui Plant water intake (39 3.072S 174 16.124N) and is about 8.5 km from the sea. For most of the reach, the river flowed against a steep boulder lined right bank and the other bank was a gently sloping bank comprising a mixture of gravel, cobble, and boulders.

Figure 1: Run habitat in Waitara River survey reach just below the Methanex intake at a flow of 5.1 m^3/s.

The river comprised long runs interspersed short riffles. The habitat types identified were riffles (6%), slow runs (almost pools) (78%) and runs (16%). At a flow of 5.1 m^3/s the average water surface width was 34 m with an average depth of 0.92 m and velocity of 0.21 m/s. Calibration measurements were made on 21/2/2020 and 24/2/2020 when the flow was 5.12 m^3/s and 16.1 m^3/s, respectively.

Figure 2: Waitara River showing riffle with gravel bank in foreground and steep boulder bank at the far side of the river at a flow of 5.1 m^3/s.

Figure 3: Slow run habitat in the Waitara River downstream of the Bertrand Road Bridge at a flow of 5.1 m^3/s.

Fifteen cross-sections were surveyed in three in riffles, six in runs, and six in pools. Because the banks were wide and the flow relatively low, bank topography was surveyed by laser. The substrate was predominantly cobbles (50%), with gravel and boulders each making up 25% of the substrate.

The fish community in this reach comprised grey mullet, common bullies and inanga in low velocity areas and redfin bullies, juvenile eels and torrentfish in the riffles.

2.2 Whenuakura River

The Whenuakura River (mean flow 9.95 m^3/s) is the fourth largest river in the region after the Waitara, Patea (mean flow 29 m^3/s at McColls Bridge) and Waitotara (mean flow 16 m^3/s at Rimunui). The Whenuakura River drains the eastern hill country. About 1.7 km of river was examined just above the tidal influence and the Nicholson Rd water level recorder. This section of river is typical of many lowland Taranaki papa rivers. It had steep papa banks and logs in the river that formed constrictions (log jams) where water velocities were higher than the long low velocity runs. The river was inspected on 27/2/2020 when the flow was about 1.9 m^3/s and the survey was carried out on 4/3/2020 when the flow was 2.4 m^3/s. A second calibration measurement was made at a flow of 1.73 m^3/s on 13/3/2020.

Figure 4: Section of run habitat in Whenuakura River at a flow of about 1.9 m^3/s.

In the 1.6 km surveyed, there were 10 constrictions forming about 12% of the habitat with runs making up the remaining 88%. 15 cross-sections were surveyed; five located in the constrictions and 10 in the runs between them. The substrate was mostly sand and fine gravel with some cobbles and gravel where logs had increased water velocities. At a low flow of 2.4 m^3/s, the river was 12.8 m wide with an average depth of 0.7 m and velocity of 0.28 m/s.

Figure 5: Cross-section 5 on Whenuakura River at flow of about 1.9 m^3/s (above) and flow of 2.4 m^3/s (below).

Figure 6: Constrictions at cross sections 5 and 7 at a flow of about 1.9 m^3/s.

Figure 7: Measuring run habitat at cross section 6 (left) 9 (right) at a flow of 2.4 m^3/s.

The fish community in the lower section of the Whenuakura River has not been surveyed but migratory fish including eels, redfin bullies, common smelt, inanga, torrentfish, shortjaw kokopu, and common bullies are likely to pass through. Non-migratory species that have been reported upstream are brown trout, Crans bully, upland bully and perch. The habitat in this section of river would be particularly suitable for grey mullet, eels, inanga, common smelt, but redfin bullies and common bullies could be present.

2.3 Mangatawa Stream

The Mangatawa Stream is a tributary of the Punehu Stream. It is a small stream about 2.4 m wide draining wetlands on the lower south-west slopes of Mt Taranaki. Its headwaters are 16 km from the sea whereas the headwaters of the Punehu Stream are on the higher slopes of Mt Taranaki 30 km from the sea.

Instream habitat was surveyed on 19/2/20 just below the old water level recorder site at McKay's (39 29.712S 173 54.910N) when the flow was 28 L/s. The reach is well shaded (Fig. 8).

Figure 8: Survey reach in the Mangatawa Stream.

The reach contained mostly run (51%) and riffle (41%) habitat with an occasional pool (8%) associated with boulders. The substrate was usually fine gravel and coarse sand with aquatic macrophytes along the edges. At a flow of 28 L/s the average width was 2.4 m and the average depth was 0.15 m with a velocity of 0.09 m/s. A calibration measurement was made at a flow of 36 L/s on 22/2/2020.

Figure 9: Run habitat dominated by macrophytes in the Mangatawa Stream at a flow of 28 L/s.

Figure 10: Pool habitat created by boulders which provide cover for large eels in the Mangatawa Stream at a flow of 28 L/s.

The fish community (based on a single electric fishing survey of the reach) comprised eels, redfin bullies, and inanga, but large galaxiids and common bullies could be present.

2.4 Waiokura Stream

The Waiokura Stream is spring-fed stream about 3.5 m wide on the lower southern slopes of Mt Taranaki. Access to the stream was difficult because of gorse and blackberry along the fenced off margins. It has sections of run habitat below the 'Number 3 Fairway' flow recorder which are typical of spring fed streams. However, it also has long sections containing run and riffle habitat. Approximately 500 m of stream was surveyed and about 35% was riffle habitat and 65% run habitat. Five cross-sections were located in riffles and 10 in runs. The substrate was relatively coarse with a mixture of boulder, cobble, gravel, fine gravel and sand. At a flow of 133 L/s, the stream width was 3.5 m with an average depth of 0.15 m and velocity of 0.25 m/s.

Electric fishing of this reach in March 2020 found longfin and shortfin eels, koaro and trout (unidentified but thought to be rainbow).

Figure 11: Run habitat at cross-section 14 in the Waiokura Stream at a flow of 133 L/s.

Figure 12: Riffle habitat at cross-section 15 in the Waiokura Stream at a flow of 133 L/s.

3 Hydrology

Available data (up to March 2020) for the 17 study sites were analysed to determine the estimated 7-d MALF (Table 3; Fig. 13). Naturalised flows were estimated based on the assumption that holders with consents to take water at flows less than MALF would be exercising that right during periods of low flow. Where the instream habitat survey was at a different location to the flow recorder, recorded flows were scaled or estimated from the specific discharge (L/s/km^2) at a hydrologically similar site.

Table 3: Seventeen streams and rivers with instream habitat survey data and their estimated means, 7-day mean annual low flows (MALF), potential take when flow is below MALF and Naturalised 7-d MALF. TRC data based on all recorded data up to March 2020.

River	Catchment area (km^2)	Mean flow* (m^3/s)	7-d MALF* (m^3/s)	Potential take (m^3/s)	Naturalised 7-d MALF (m^3/s)	Source of flow record
Kapoaiaia (lighthouse)	18.58	1.12	0.289	0.011	0.300	TRC
Kaupokonui (Skeet Rd)	38.68	2.06	0.520	0.098	0.618	Scaled 0.65 of Glen Rd site
Manganui (Croyden Rd)	50.54	4.24	0.792	0.005	0.797	Scaled 0.63 of Tariki Rd site
Mangaoraka (Corbett Rd)	53.92	2.07	0.271	0.023	0.294	TRC
Mangatawa (McKays)	10.92	0.20	0.021	0.000	0.021	NIWA
Patea (Stratford)	28.72	1.82	0.307	0.041	0.348	Scaled 0.35 of Skinner Rd
Tangahoe (mouth)	284.51	6.54	1.396	0.000	1.396	Correlation with Whenuakura
Waingongoro (Normanby loop)	194.47	7.01	1.394	0.173	1.567	Scaled from Eltham and SH3
Waingongoro (Eltham)	50.29	2.87	0.540	0.086	0.626	TRC
Waiokura (No. 3 Fairway)	23.03	0.48	0.124	0.005	0.129	NIWA
Waiongana (SH3A)	38.64	2.74	0.435	0.007	0.442	TRC
Waitara (Bertrand Rd)	1113.75	55.41	6.928	0.459	7.387	TRC
Waiwhakaiho (SH3)	51.21	7.88	2.122	0.000	2.122	TRC
Whenuakura (Nicholson Rd)	443.82	10.21	2.086	0.092	2.178	TRC
Stony (Okato)	47.11	6.85	2.514	0.000	2.514	Scaled 1.09 of Mangatete site
Kapuni (SH45)	41.57	1.85	0.444	0.198	0.642	TRC
Tawhiti (Duffys)	61.27	0.71	0.196	0.211	0.407	Jowett (2014)

* Values of mean flow and MALF in Jowett 2019 are for the 11-year period 2006-2017.

4 Fish species

The New Zealand freshwater Fish database contains records of fish caught in New Zealand rivers. Rivers with access to the coast are dominated by diadromous fish species, which migrate from the sea as juveniles and spend their adult lives in freshwater. In general, a similar assemblage of native fish is found in Taranaki rivers with access to sea. Brown trout, common bully, inanga, lamprey, longfin eel, redfin bully, shortfin eel, shortjaw kokopu and torrentfish have been reported from more than 50% of the 16 study rivers (Table 4). The species list is probably not comprehensive and additional sampling is likely to find that more native fish species are present than those listed in Table 4.

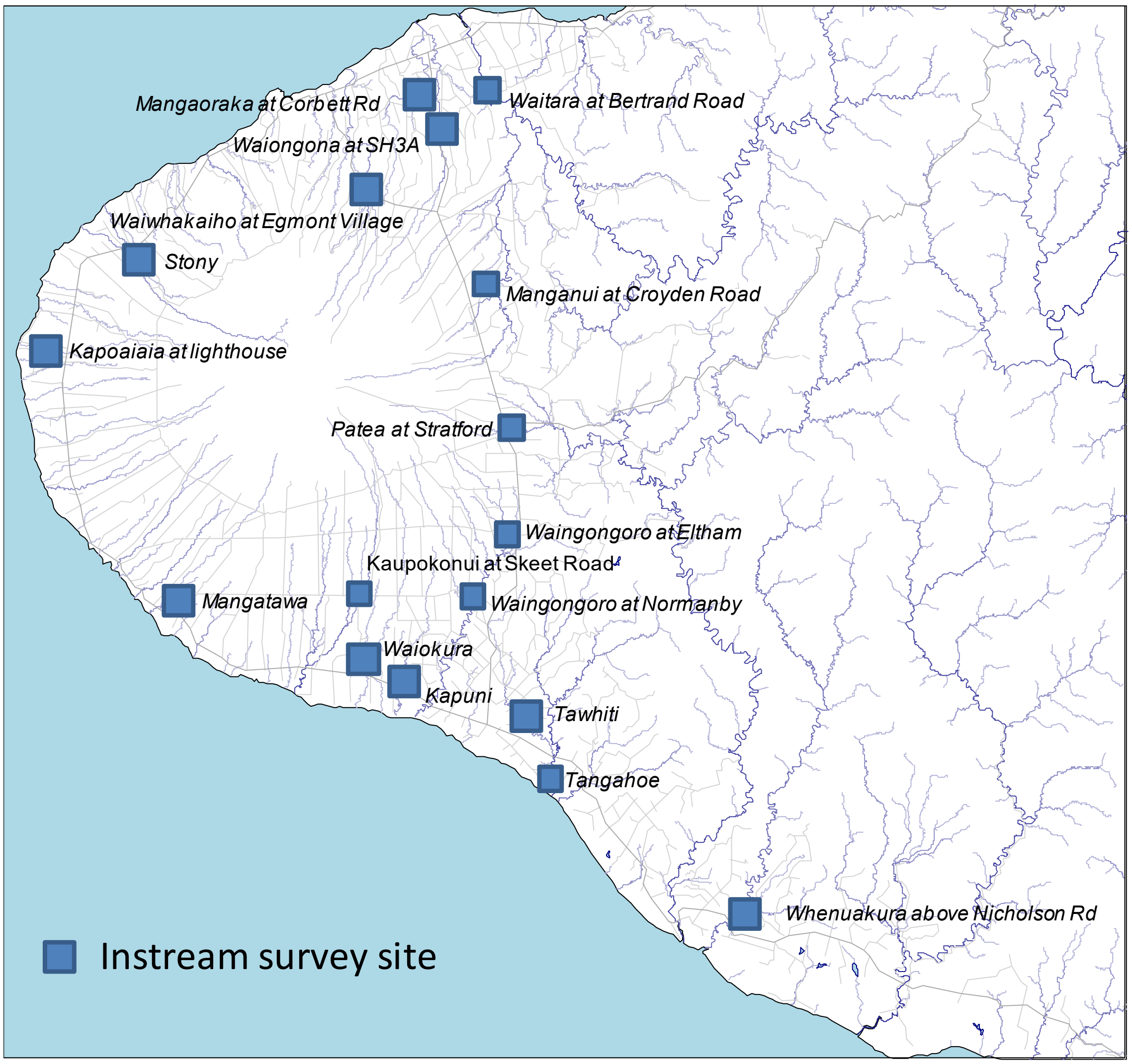

Figure 13: Location of instream habitat surveys in Table 3.

The distribution of fish within reaches of these river systems depends on elevation or the distance from the sea and the type of habitat (primarily controlled by gradient) with highest densities at sites with gravel (< 50 mm) substrate (Jowett & Richardson 1996).

In a national study using information from the NZFFD Jowett & Richardson (2003) examined the characteristics of different fish communities and found that stream width and land use (native forest or pastoral) were the most important environmental after elevation and distance from the sea. Percentage native forest in the catchment was positively related to the abundance of koaro, shortjaw kokopu, banded kokopu and redfin bully. In contrast, the percentage of catchment that was farmed was positively related to the abundance of three bully species (Crans, upland and common) and shortfin eels. The area of wetland in the catchment was positively related to the abundance of giant kokopu. There were relationships between species abundance and stream habitat types. Koaro were positively related to cascade and rapid habitat, inanga negatively related to rapid habitat, banded kokopu positively and torrentfish negatively related to pool habitat, and non-diadromous bullies (upland and Crans) positively related to backwater habitat.

Table 4: Recorded presence (P) of fish species in 16 Taranaki rivers. The occurrence of marine species (e.g. mullet and flounder) is not shown. The recorded species do not necessarily represent the fish found or likely to be found in the habitat survey reaches.

Species	Kapoaiaia	Kaupokonui	Manganui	Mangaoraka	Patea	Tangahoe	Waingongoro	Waiongana	Waiwhakaiho	Waitara	Mangatawa	Waiokura	Whenuakura	Stony	Kapuni	Tawhiti
Banded kokopu	P	P		P	P			P	P	P						
Bluegill bully									P	P				P		
Brown mudfish					P		P									
Brown trout	P	P	P	P	P		P	P	P	P		P	P	P	P	P
Common bully	P		P	P	P	P	P	P	P	P			P	P		
Common smelt		P			P		P		P	P			P			P
Crans bully			P		P		P		P	P			P			
Giant bully					P	P			P	P						
Giant kokopu	P				P	P	P			P						
Inanga	P	P	P	P	P	P	P	P	P	P	P		P	P		P
Koaro		P			P			P	P	P		P		P	P	
Lamprey	P	P			P	P	P	P	P	P					P	
Longfin eel	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Rainbow trout		P			P		P					P		P		P
Redfin bully	P	P	P	P	P	P	P	P	P	P			P	P	P	
Shortfin eel	P	P	P	P	P	P	P	P	P	P		P	P	P	P	P
Shortjaw kokopu	P	P	P	P	P			P	P	P			P	P	P	
Torrentfish		P	P		P	P	P	P	P	P			P	P	P	P
Upland bully			P		P		P			P			P			

As part of a wider study of stream modification, the TRC (2010) carried out an analysis to determine instream values of small streams. They considered that small streams provide important habitat for longfin and shortfin eels. Habitats preferred by eels include deep, slow water i.e. pools, during the day. Eels also use large substrate and undercut banks as cover. At night eels forage for food in shallower and swifter water. Giant kokopu are usually nocturnal, and use undercut banks and wooden debris for cover during the day. This species tends to favour small to medium-sized streams (McDowall, 2000). Banded kokopu show a preference for pools usually spending the day taking cover using instream debris, or undercut banks. Inanga favour gently flowing and still water and are found near the coast, where gradient and water velocity are lower than further upstream. The analysis of species occurrence carried out by the TRC (Table 5) shows that the likelihood of species occurrence usually declines with stream width with only banded kokopu and brown mudfish showing a clear preference for very small streams. Bluegill bully, common smelt, lamprey, rainbow trout, upland bully, torrentfish and brown trout are less likely to be found in small streams than in the larger streams.

Species occurrence is probably related to the elevation of the stream – whether it is a small coastal stream or a small headwater stream – and the type of habitat in the stream which is dependent on the flow. At low flows, the habitat will favour species that prefer low water velocities and shallow water and disadvantage species that prefer high velocities or deep water.

Table 5: Species occurrence as a percentage of all samples for stream width. Stream width with highest percentage shown in bold.

Species	Stream width		
	<2m	2-8m	>8m
Banded Kokopu	**21**	5	1
Bluegill Bully	0	0	**3**
Brown Mudfish	**11**	3	0
Brown Trout	7	37	**42**
Common Bully	4	6	**16**
Common Smelt	0	2	**3**
Crans Bully	2	3	**10**
Giant Bully	0	**1**	0
Giant Kokopu	**7**	*4*	1
Inanga	**9**	**9**	8
Koaro	4	**11**	5
Lamprey	0	2	**5**
Longfin Eel	41	61	**78**
Rainbow Trout	0	**1**	**1**
Redfin Bully	12	33	**50**
Shortfin Eel	12	13	**26**
Shortjaw Kokopu	5	**11**	1
Torrentfish	1	7	**24**
Upland Bully	0	1	**5**

5 Instream habitat

As noted in the previous section, brown trout, common bully, inanga, lamprey, longfin eel, redfin bully, shortfin eel, shortjaw kokopu and torrentfish have been reported from more than 50% of the study rivers. The flow requirements of a fish species depend on the water depths and velocities in which the species is found. Jowett & Richardson (2008) reported the results of measuring the depth and velocity in which fish species were found. Jowett et al. (2008) calculated optimum flows for a number of species. These are shown in order of flow requirement in Table 6. A group of common species with high to moderate velocity preferences was selected to evaluate the effect of low flows on habitat at the 17 study sites (Table 7).

The amount of habitat at MALF (as a percentage of stream width) was examined (Table 7). This showed that for 4 groups (adult brown trout, torrentfish, longfin eels > 300 mm, and common smelt) there was an increase in habitat with MALF (Fig. 14) and for the other 4 (juvenile brown trout, common bully, redfin bully and longfin eel < 300mm) habitat decreased with MALF (Fig. 15). This indicates that the larger rivers with their higher MALFs provided relatively more habitat for adult brown trout, torrentfish, longfin eels > 300 mm, and common smelt than the smaller rivers.

Table 6: Average flow and habitat requirements for fish species.

Common name	Scientific name	Number sampled	Mean depth (m)	Mean velocity (m/s)	Optimum flow (m^3/s)
Brown trout (adult)	*Salmo trutta*				6.8
Torrentfish	*Cheimarrichthys fosteri*	784	0.22	0.66	5.2
Bluegill bully	*Gobiomorphus hubbsi*	3253	0.24	0.68	3.65
Koaro	*Galaxias brevipinnis*	690	0.2	0.66	
Rainbow trout (juvenile)	*Oncorhynchus mykiss*	252	0.21	0.53	
Common smelt	*Retropinna*	107	0.39	0.25	
Brown trout (juvenile)	*Salmo trutta*	1777	0.2	0.48	1.6
Common bully	*Gobiomorphus cotidianus*	1224	0.21	0.35	1.0
Redfin bully	*Gobiomorphus huttoni*	564	0.21	0.25	0.51
Longfin eel (<300 mm)	*Anguilla dieffenbachii*	1625	0.2	0.33	0.48
Longfin eel (>300 mm)	*Anguilla dieffenbachii*	389	0.35	0.15	
Shortfin eel (>300 mm)	*Anguilla australis*	181	0.37	0.13	
Shortfin eel (<300 mm)	*Anguilla australis*	2137	0.23	0.2	0.89
Shortjaw kokopu	*Galaxias postvectis*	4	0.26	0.18	0.13
Crans bully	*Gobiomorphus basalis*	560	0.19	0.18	0.16
Lamprey	*Geotria australis*	24	0.27	0.1	
Giant kokopu	*Galaxias argenteus*	39	0.53	0.05	
Inanga	*Galaxias maculatus*	595	0.3	0.05	0.10
Giant bully	*Gobiomorphus gobiodes*	1	0.41	0.03	
Banded kokopu (adult)	*Galaxias fasciatus*	204	0.17	0.03	
Banded kokopu (juvenile)	*Galaxias fasciatus*	87	0.15	0.03	0.16

Table 7: Habitat available at MALF expressed as a % of wetted width.

Species	Brown trout (adult)	Brown trout (juvenile)	Common bully	Common smelt	Longfin eel > 300mm	Longfin eel <300 mm	Redfin bully	Torrentfish
Kapoaiaia (lighthouse)	3	44	78	6	22	51	67	7
Kaupokonui (Skeet Rd)	10	41	66	10	33	52	55	8
Manganui (Croyden Rd)	12	25	66	14	47	33	43	3
Mangaoraka (Corbett Rd)	4	30	69	7	27	29	50	2
Mangatawa (McKays)	0	17	56	1	6	13	32	0
Patea (Stratford)	8	25	73	6	40	36	51	0
Tangahoe (mouth)	31	15	32	16	8	52	29	13
Waingongoro (Normanby loop)	22	15	36	36	64	23	18	6
Waingongoro (Eltham)	14	36	56	9	39	42	45	7
Waiokura (No.3 Fairway)	0	53	66	4	6	32	55	7
Waiongana (SH3A)	17	16	49	3	53	26	31	1
Waitara (Bertrand Rd)	44	6	19	24	70	15	12	2
Waiwhakaiho (SH3)	22	28	42	5	40	38	35	12
Whenuakura (Nicholson Rd)	2	9	34	41	38	8	9	0
Stony (Okato)	27	29	32	6	31	38	29	15
Kapuni (SH45)	6	55	37	8	17	41	43	21
Tawhiti (Duffys)	17	22	60	12	54	37	8	2

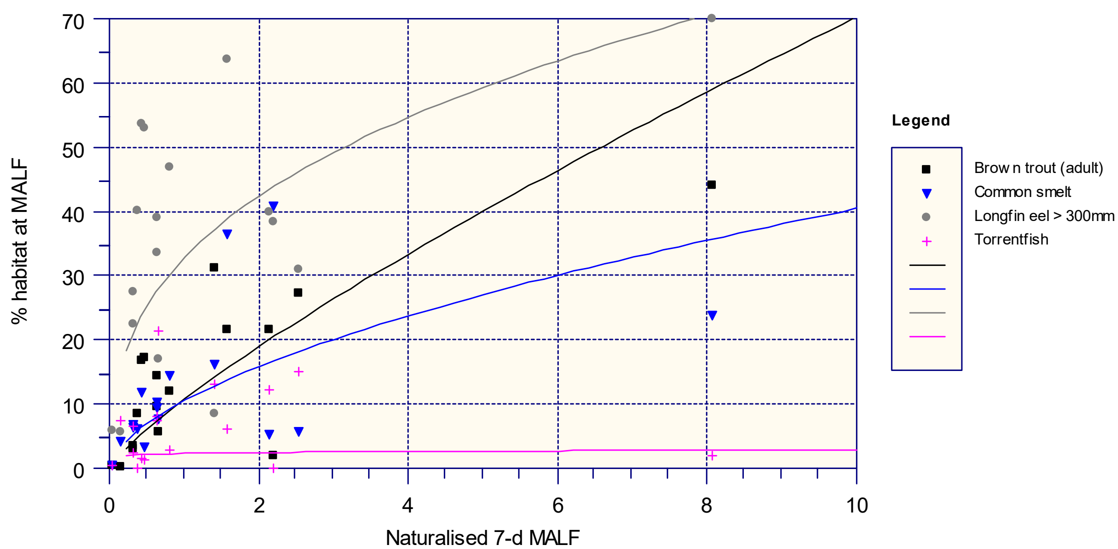

Figure 14: Habitat (as a percentage of river width) versus 7-d MALF (m^3/s) for adult brown trout, torrentfish, longfin eels > 300 mm, and common smelt showing log-log relationships for each species.

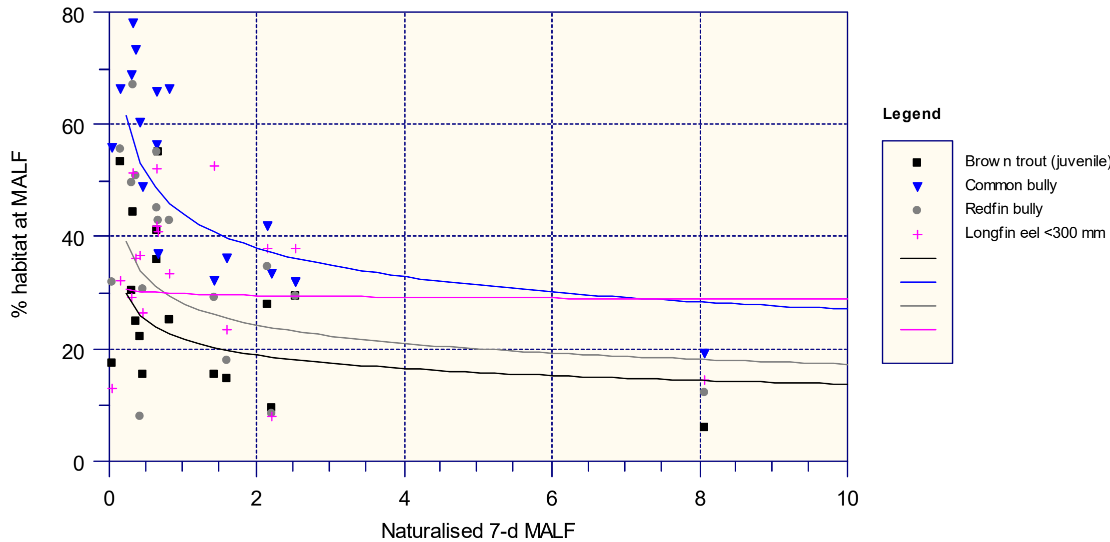

Figure 15: Habitat (as a percentage of river width) versus 7-d MALF (m^3/s) for juvenile brown trout, common bully, redfin bully and longfin eel < 300mm showing log-log relationships for each species.

5.1 Low flow habitat and the fish community

The minimum flow affects the amount of habitat available for aquatic species and at low flows the amount of habitat decreases as the flow decreases for most species. Low flows act as a "habitat bottleneck" for long-lived biota such as trout and native fish. This is because mortality occurs when flows are low and suitable fish habitat restricted, and the population can take several years to recover (Jowett et al. 2008).

As noted earlier, in evaluating the effects of water abstraction on fish, it was assumed that there would be a linear decline in habitat for adult brown trout and torrentfish as flows reduced below MALF (Jowett 2019). If a protection level of 90% of the habitat available at MALF is to be maintained by a flow of 90% of MALF then the habitat loss associated with that flow should not be greater than 10% and similarly for other protection levels. The assumption that the decline in habitat would be linear or less was tested by calculating the change in habitat as flows reduce below MALF for each of the 17 study sites listed in Table 3.

As flows reduce below MALF, the available habitat for species with high depth or velocity requirements usually decreases and the habitat available for other species can increase then decrease. For example, in the Waiwhakaiho River (Fig 16), habitat as a % of habitat at MALF decreases almost linearly for torrentfish, smelt and adult brown trout and habitat for redfin and common bullies increases then decreases. In this river, a reduction in flow from MALF to 90% of MALF would result in a habitat loss of 7% for smelt, 6% for adult brown trout and 5% for torrentfish and a gain of 1% for redfin bully and juvenile trout. In this river, the assumption that the decline in habitat would be linear or less was met.

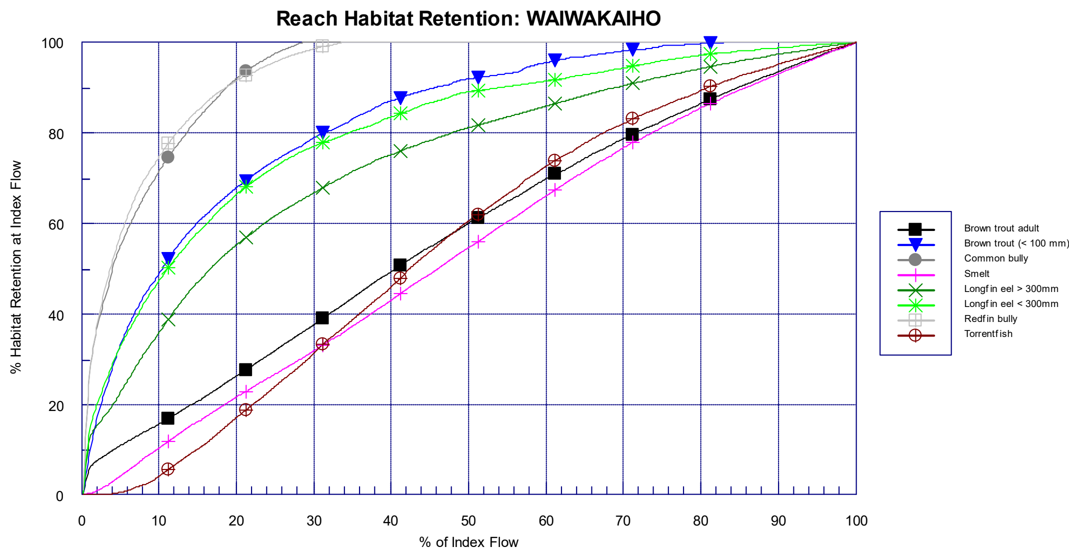

Figure 17: Percentage of habitat available at MALF in the Waiwhakaiho River for flows of 0 to 100% of MALF (2.122 m^3/s).

The analysis of the % habitat available at MALF as flows reduce below MALF (e.g. Fig. 17) was carried out for all rivers in order to calculate the flow requirement (as a % of MALF) required to retain 70%, 80% and 90% of the habitat available at the MALF (retention levels) for the common species (Tables A1-A3). The highest flow requirement was for either torrentfish, smelt or adult trout and usually torrentfish requirements were the highest. The highest flow requirements for all rivers were then plotted against the mean flow (Figs 18-20). The flow requirements fell into three distinct groups and stream size divisions were drawn between these groups and are shown as blue lines on Figs 18-20.

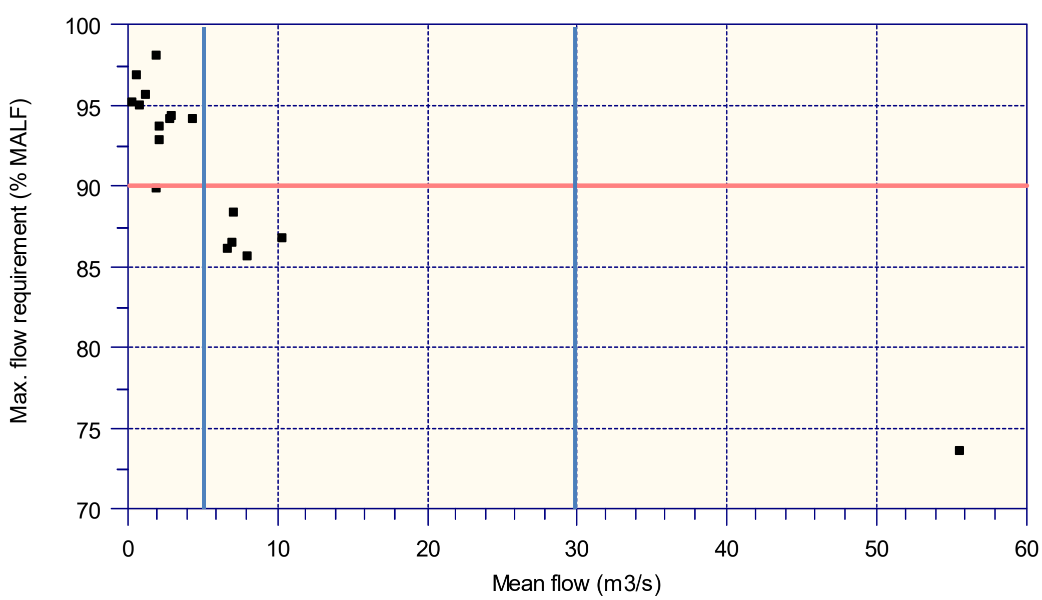

Figure 18: Highest flow requirement (% of MALF) required to retain 90% of the habitat available at the MALF at the 17 sites.

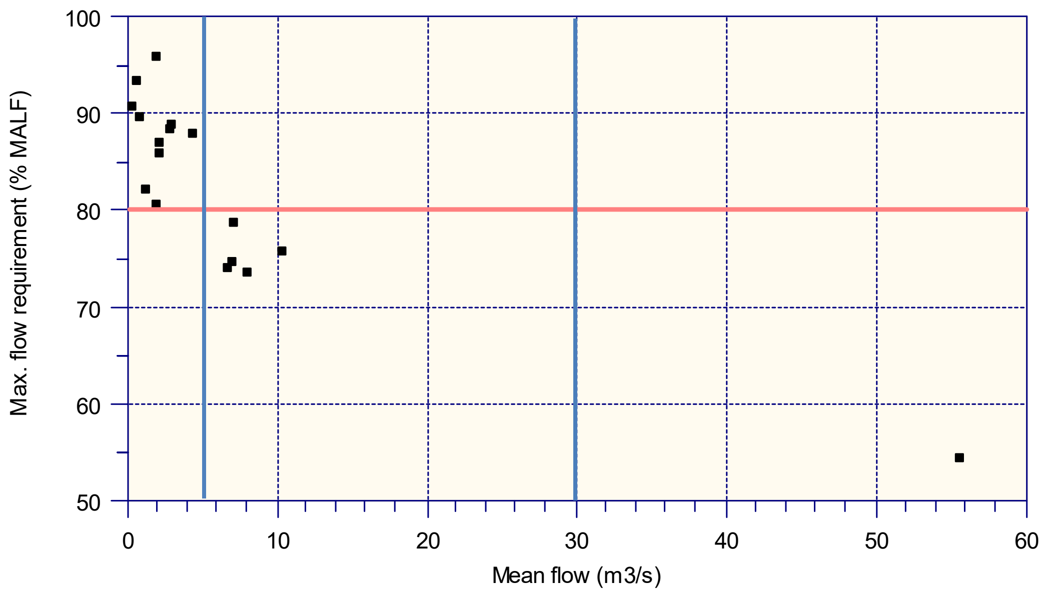

Figure 19: Highest flow requirement (% of MALF) required to retain 80% of the habitat available at the MALF at the 17 sites.

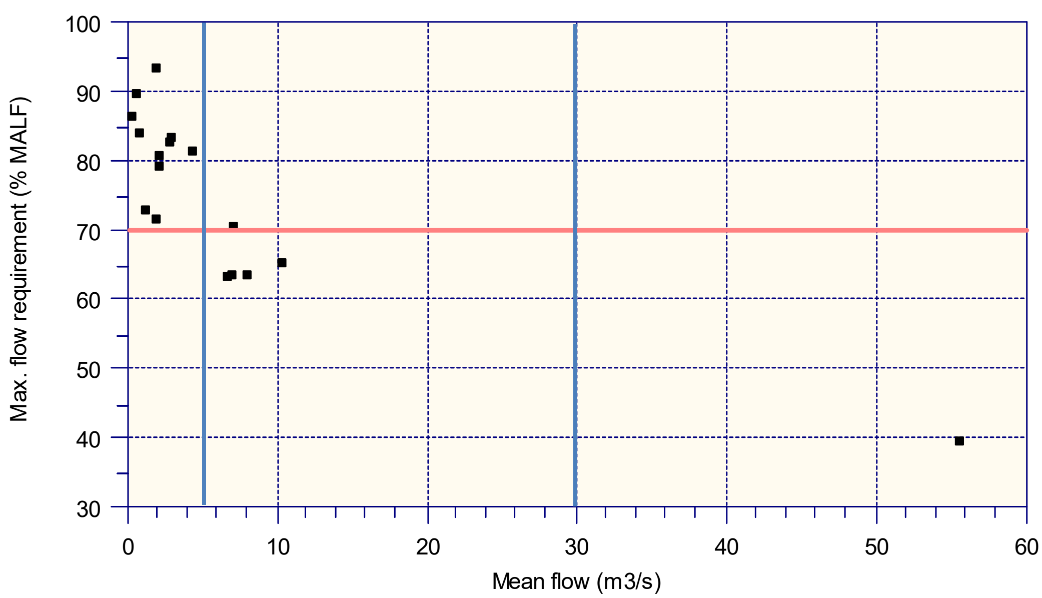

Figure 20: Highest flow requirement (% of MALF) required to retain 70% of the habitat available at the MALF at the 17 sites.

This analysis shows clearly that the assumption that the decline in habitat would be linear or less was met in larger rivers (mean flow > 5 m^3/s) but not in smaller streams. Small streams are more “at risk” from abstraction than larger rivers provided that the small streams provide suitable conditions for aquatic species with high velocity requirements, primarily torrentfish because adult trout and smelt are not usually found in such small streams.

That small streams were more “at risk” was recognised in default recommendations in the proposed National Environmental Standard (NES) for ecological flows (MfE 2008) where a higher minimum flow was set for small streams than larger rivers (mean flow > 5 m^3/s). In the Taranaki region, a river with a mean flow of 5 m^3/s will have a MALF of about 1 m^3/s (Table 3).

6 Minimum flows and stream size

Figures 18-20 show that flow requirements can be divided into three groups. There is one group of small rivers when the mean flow is less than 5 m^3/s and the flow requirement is higher than the habitat retention levels (horizontal red lines). There is another group of rivers where flows are greater than 5 m^3/s but less than 30 m^3/s and flow requirements are less than the habitat retention levels. The third group of 1 is for very large rivers. The 5 m^3/s and 30 m^3/s divisions are approximately half way between the groups. The minimum flow requirement for each group was taken as the average over the group. In the previous study (Jowett 2019) flow requirements were based on the average of all study rivers and division based on stream size was not possible because of the more limited range of rivers studied.

The small stream group includes three very small streams; the Mangatawa, Waiokura and Tawhiti. The average flow requirement in these three streams is slightly higher than the average for the other streams in the group. The difference increases with retention level from 1.6% higher at 90% retention to 5% at 80% retention and 7.5% at 70% retention (Tables A1-A3). However, the difference is more likely to be because the three streams are low gradient spring-fed streams with fine substrate than because of their size. These streams are also unlikely to support adult trout or significant numbers of torrentfish. Steeper gravel/boulder streams draining Mt Taranaki, such as the Kapoaiaia and Mangaoraka, have lower flow requirements than the very small streams even though their mean annual low flows are less than that of the Tawhiti.

Jowett (2019) examined fish protection levels and benthic invertebrate protection levels found a high degree of correlation ($r^2 = 0.99$) between the invertebrate and fish protection levels. Thus, minimum flow requirements in Table 8 will also maintain benthic production and benthic invertebrate protection levels.

The results of the analysis carried out confirms that different minimum flow limits in terms of % of MALF are required to achieve consistent levels of protection across the range of river/stream sizes in Taranaki. To achieve this consistency, the minimum flow limit needs to increase as the size of river decreases. This is illustrated in Table 8 where, depending on allocation, the minimum flow limit in small streams would need to be 5% to 12% of MALF higher than that in a moderately sized stream in order to achieve the same level of protection. Similarly, the same protection levels can be achieved in large rivers with a minimum flow limit 25% to 30% of MALF less than that required in a moderately sized stream.

Table 8: Minimum flow options varying with stream size.

	Small stream	Moderate stream/river	Large river	Allocation volume as % MALF	Benthic invertebrate protection level	Fish habitat protection level
Mean flow (m^3/s)	< 5	> 5	> 30			
	Minimum flow as % MALF					
Option 1	79%	67%	45%	30	89	80
Option 2	81%	71%	52%	30	91	80
Option 3	87%	82%	71%	40	90	80
Option 4	89%	85%	77%	40	91	80
Current policy setting	*66%*			*33*[5]	*87*	*77*

The fish habitat protection level depends on both the effect of the minimum flow on habitat and the allocation. The fish protection level is based on the reduction in the 30-d MALF assuming that water is abstracted whenever permissible. With a minimum flow of 90% of MALF, the reduction in 1-d MALF will be about 10% but the reduction in 30-d MALF is about 17%. With a minimum flow of 70% of MALF, the reduction in 1-d MALF will be about 30% but the reduction in 30-d MALF is about 21%. This shows that the cumulative effect of a flow reduction on fish increases with allocation.

7 Reliability of supply

The reliability of supply depends on minimum flow and allocation. Restrictions can be either total (i.e. no taking permitted) or partial, whereby some reduction in take rates is required to maintain compliance with minimum flows. The number of days with total restriction depends on the minimum flow, as no abstraction is allowed once the river flow falls below the minimum flow (Fig. 21). Allocation affects the number of days there is likely to be partial restrictions with a 10% increase in allocation causing about a 10 day increase in the number of days with partial restriction (Fig. 22, Table 9).

8 Further considerations

Minimum flow and allocation options in Table 8 are based on maintaining ecosystem health at a prescribed level. In assessing an appropriate minimum flow and allocation for a particular river, a number of additional factors could be taken into consideration. The setting of minimum flows and allocation limits is a process that involves the Regional Council and community in order to achieve the best water management outcomes for the region taking into account environmental, cultural and economic considerations, such as restrictions to water supply as shown in Table 9.

The fish species likely to be present in a river or section of river could be taken into account when consideration when assessing flow requirements for a river. Minimum flow requirements in Table 8 are largely based on the assumption that torrentfish are present in each stream and river and for

[5] Inferred allocation limit as no limits are specified in the existing plan

many rivers this will be true. However, there are rivers or parts of rivers where this will not be the case.

Torrentfish, bluegill bully, smelt, and trout are less likely to be found in small streams than in rivers (Table 5). Substrate rather than turbidity appears to be the main determinant of the presence of torrentfish (Richardson & Jowett 2002). The Mangatawa Stream is a tributary of the Punehu Stream. The Punehu Streams drains from Mt Taranaki and contains cobble and gravel substrate and torrentfish. The Mangatawa Stream contains fine substrate and is unlikely to contain a significant number of torrentfish. In the Whenuakura River, the fine substrate makes the habitat in the lower sections unsuited to either trout or torrentfish but torrentfish and trout have been reported from the headwaters. In contrast, although part of the Waitara River drains the papa hill country like the Whenuakura, the gravel and cobble substrate of the lower reaches supports a diverse native fish community, including torrentfish.

The streams analysed in this report included three small streams whose flows derive from springs and/or wetlands on the ring plain. These are the Tawhiti, Mangatawa and Waiokura streams. The first two streams contain fine substrate and aquatic plants with little or no gravel or cobble riffles. As a consequence, fish diversity and abundance appear to be limited in those streams. The Waiokura Stream does contain coarse substrate but its fish community is also limited, although possibly by a passage barrier.

The examples above show that it is difficult to determine whether a section of river or stream will contain torrentfish (or other species with high flow requirements) although the number of such cases will certainly be small. Developing specific flow requirements for specific rivers or streams would require detailed assessments of the habitat, particularly substrate, and fish species. For most Taranaki rivers and streams, default minimum flow and allocation limits based on the size classes presented in this report are likely to maintain the desired level of environmental protection.

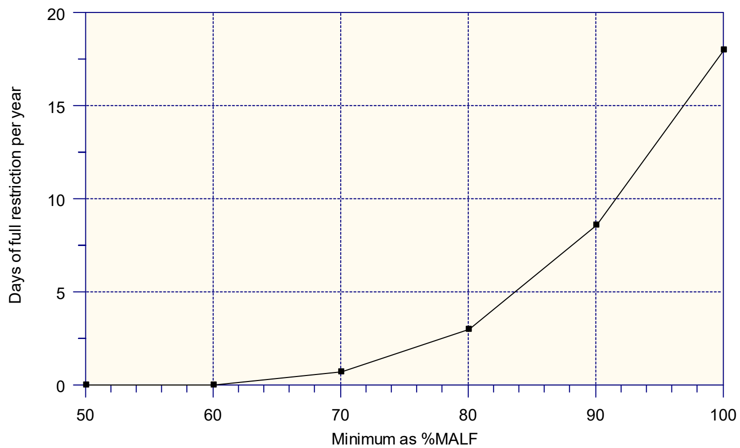

Figure 21: Number of days per year with full restriction.

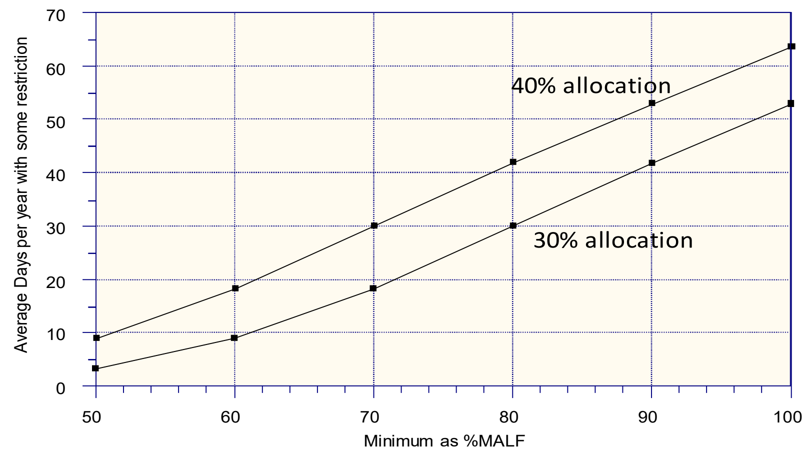

Figure 22: Number of days per year with partial restriction.

Table 9: Restrictions to abstraction for various minimum flow/allocation limit options (from Table 8).

	Small stream	Moderate stream/river	Large river	Allocation volume as % MALF	Benthic invertebrate protection level	Fish habitat protection level	Days per year of full / partial restriction		
Mean flow (m^3/s)	< 5	> 5	> 30						
	Minimum flow as % MALF						Small stream	Moderate stream/river	Large river
Option 1	79%	67%	45%	30	89	80	2.6 / 28	0.4 / 15	0.0 / 2
Option 2	81%	71%	52%	30	91	80	3.4 / 31	0.8 / 19	0.0 / 4
Option 3	87%	82%	71%	40	90	80	6.8 / 49	4.0 / 44	0.8 / 31
Option 4	89%	85%	77%	40	91	80	7.9 / 51	5.8 / 47	2.2 / 38
Current policy setting	*66%*			*33*[6]	*87*	*77*	*0.4 / 18*		

[6] Inferred allocation limit as no limits are specified in the existing plan

9 References

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10 Appendix

10.1 Results of habitat analysis

Table A1: Flow as % of MALF required to maintain the retention level of 90% of MALF

	Brown trout adult	Brown trout (< 100 mm)	Common bully	Smelt	Longfin eel > 300mm	Longfin eel < 300mm	Redfin bully	Torrentfish	Mean flow (m^3/s)	Maximum flow requirement
Kapoaiaia	96	88	63	93	92	87	67	93	1.12	96
Kaupokonui	90	74	54	81	80	75	53	94	2.06	94
Manganui	90	62	40	85	84	68	34	94	4.24	94
Mangaoraka	91	80	72	93	84	80	71	91	2.07	93
Mangatawa	77	85	64	94	80	78	67	95	0.20	95
Patea	89	78	63	91	82	77	64	98	1.82	98
Tangahoe	86	22	0	44	0	42	39	2	6.54	86
Waingongoro (Normanby Loop)	87	22	2	76	59	37	1	88	7.01	88
Waingongoro (Eltham)	90	71	39	72	76	74	45	94	2.87	94
Waiokura	93	78	30	87	89	72	40	97	0.48	97
Waiongana	84	80	38	91	68	76	53	94	2.74	94
Waitara	74	26	1	49	32	25	1	44	55.41	74
Waiwhakaiho	85	46	19	86	69	54	19	81	7.88	86
Whenuakura	87	5	5	46	59	26	3	0	10.21	87
Stony	61	69	4	14	13	51	28	86	6.85	86
Kapuni	83	79	69	80	71	77	68	90	1.85	90
Tawhiti	91	20	11	50	66	46	1	95	0.71	95

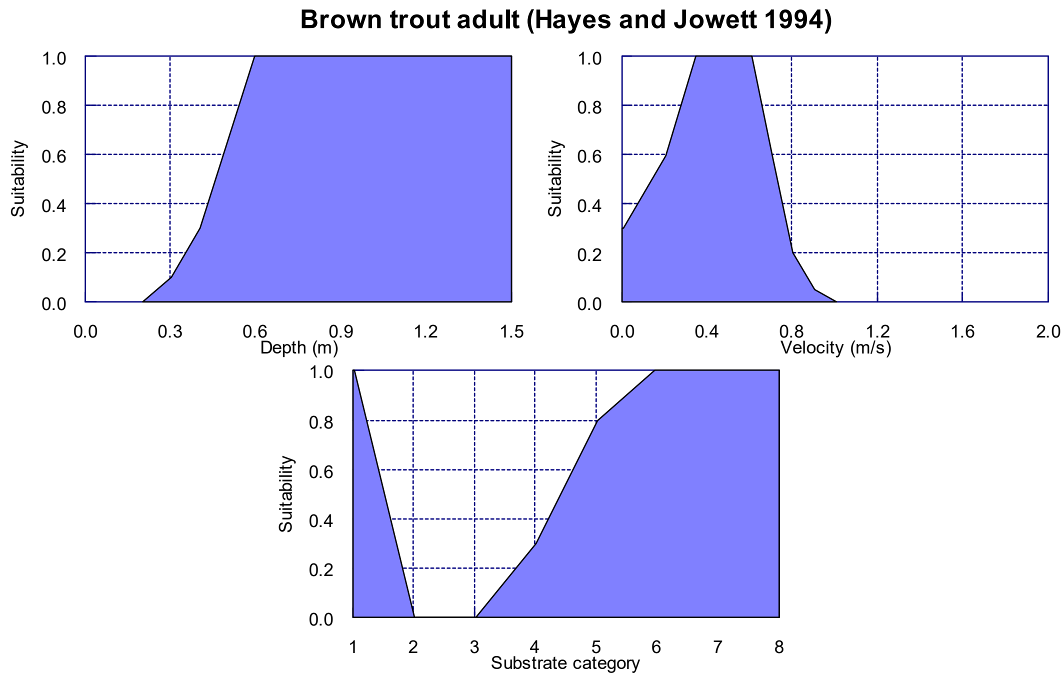
Table A2: Flow as % of MALF required to maintain the retention level of 80% of MALF

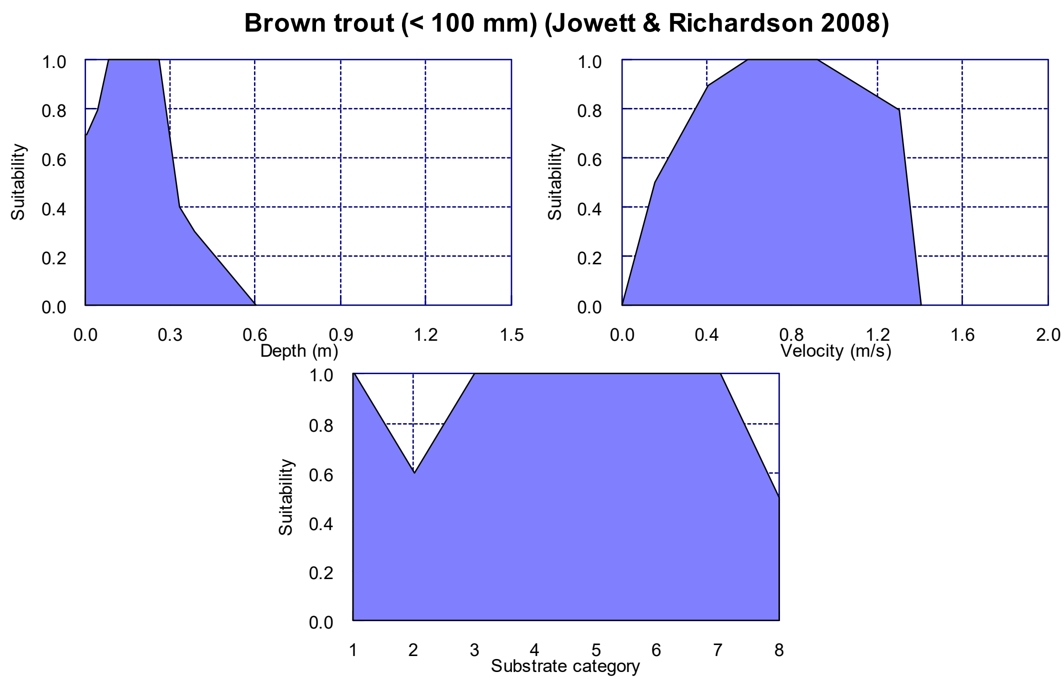
	Brown trout adult	Brown trout (< 100 mm)	Common bully	Smelt	Longfin eel > 300mm	Longfin eel < 300mm	Redfin bully	Torrentfish	Mean flow (m^3/s)	Maximum flow requirement
Kapoaiaia	82	62	35	76	73	60	37	72	1.12	82
Kaupokonui	81	59	31	69	64	61	39	87	2.06	87
Manganui	80	45	26	72	70	46	22	88	4.24	88
Mangaoraka	81	64	53	86	69	64	50	83	2.07	86
Mangatawa	53	71	43	88	60	60	43	91	0.20	91
Patea	78	61	44	82	66	59	42	96	1.82	96
Tangahoe	74	17	0	36	0	26	23	0	6.54	74
Waingongoro (Normanby Loop)	74	17	1	62	42	22	1	79	7.01	79
Waingongoro (Eltham)	80	55	22	56	58	54	29	89	2.87	89
Waiokura	87	60	21	76	79	54	28	93	0.48	93
Waiongana	69	65	24	81	46	58	23	88	2.74	88
Waitara	54	19	1	36	17	16	1	33	55.41	54
Waiwhakaiho	72	31	13	74	48	34	12	67	7.88	74
Whenuakura	76	4	4	35	45	19	2	0	10.21	76
Stony	50	50	2	12	10	37	13	75	6.85	75
Kapuni	65	63	46	67	46	59	50	81	1.85	81
Tawhiti	83	15	7	41	50	28	1	90	0.71	90

Table A3: Flow as % of MALF required to maintain the retention level of 70% of MALF

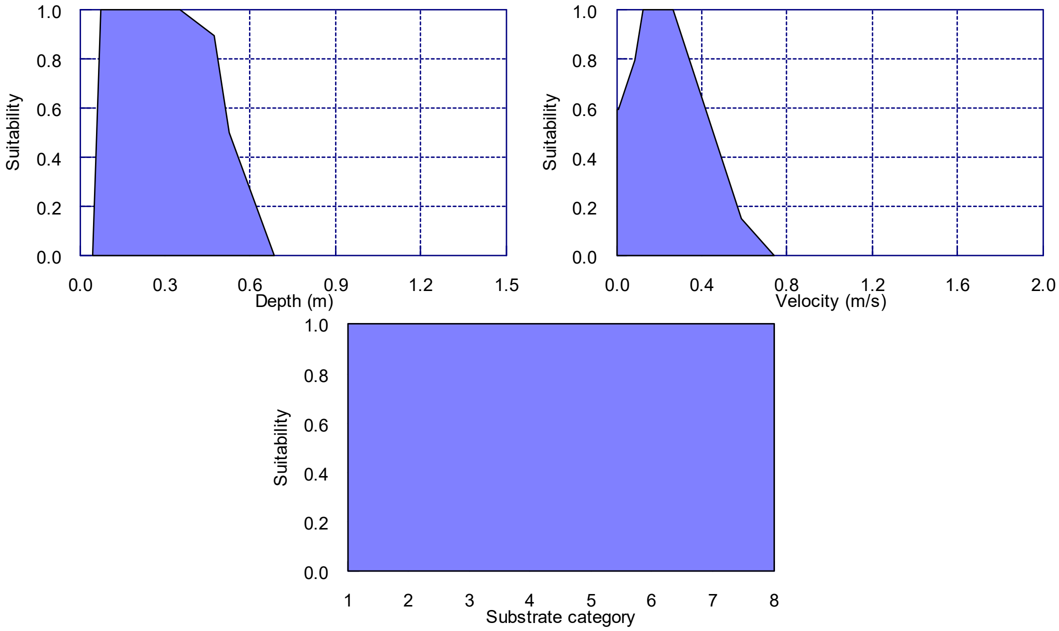
	Brown trout adult	Brown trout (< 100 mm)	Common bully	Smelt	Longfin eel > 300mm	Longfin eel < 300mm	Redfin bully	Torrentfish	Mean flow (m^3/s)	Maximum flow requirement
Kapoaiaia	73	49	24	67	62	47	26	58	1.12	73
Kaupokonui	71	46	20	59	51	48	26	81	2.06	81
Manganui	71	33	19	62	57	33	16	81	4.24	81
Mangaoraka	72	50	37	79	55	51	35	74	2.07	79
Mangatawa	30	58	29	82	39	46	24	86	0.20	86
Patea	67	48	31	74	52	43	27	93	1.82	93
Tangahoe	63	13	0	31	0	15	16	0	6.54	63
Waingongoro (Normanby Loop)	62	12	1	52	29	15	1	70	7.01	70
Waingongoro (Eltham)	70	42	16	45	45	41	19	83	2.87	83
Waiokura	80	46	14	68	71	43	19	90	0.48	90
Waiongana	56	51	12	72	31	42	8	83	2.74	83
Waitara	39	14	0	30	8	9	0	27	55.41	39
Waiwhakaiho	60	22	9	63	33	23	8	58	7.88	63
Whenuakura	65	3	3	30	34	14	2	0	10.21	65
Stony	41	34	1	10	7	27	5	63	6.85	63
Kapuni	48	49	28	57	26	43	33	72	1.85	72
Tawhiti	75	12	4	35	39	19	1	84	0.71	84

10.2 Habitat suitability curves used in this study

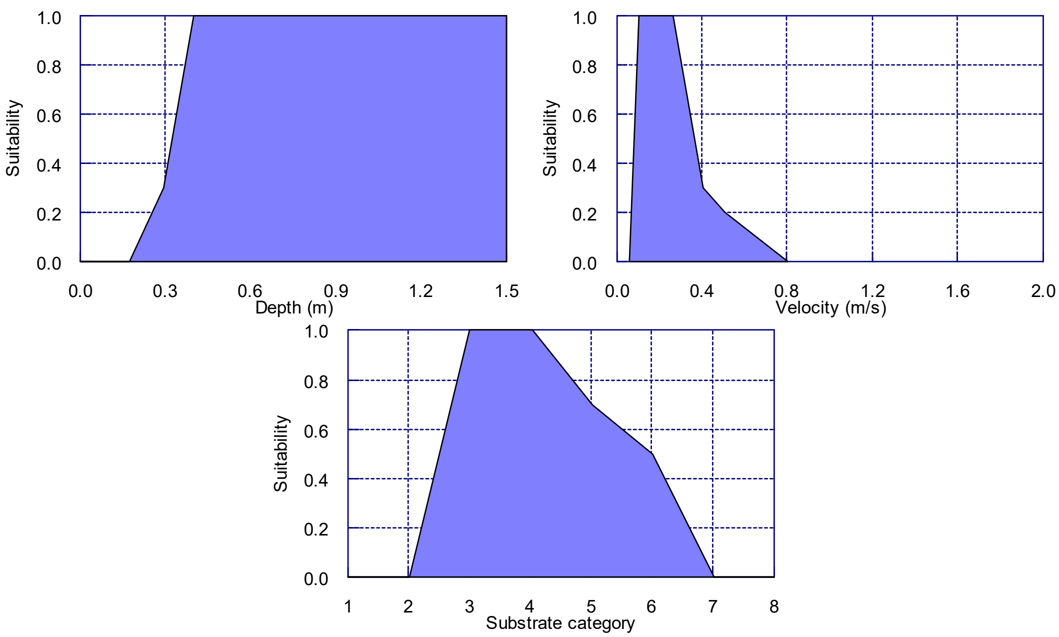




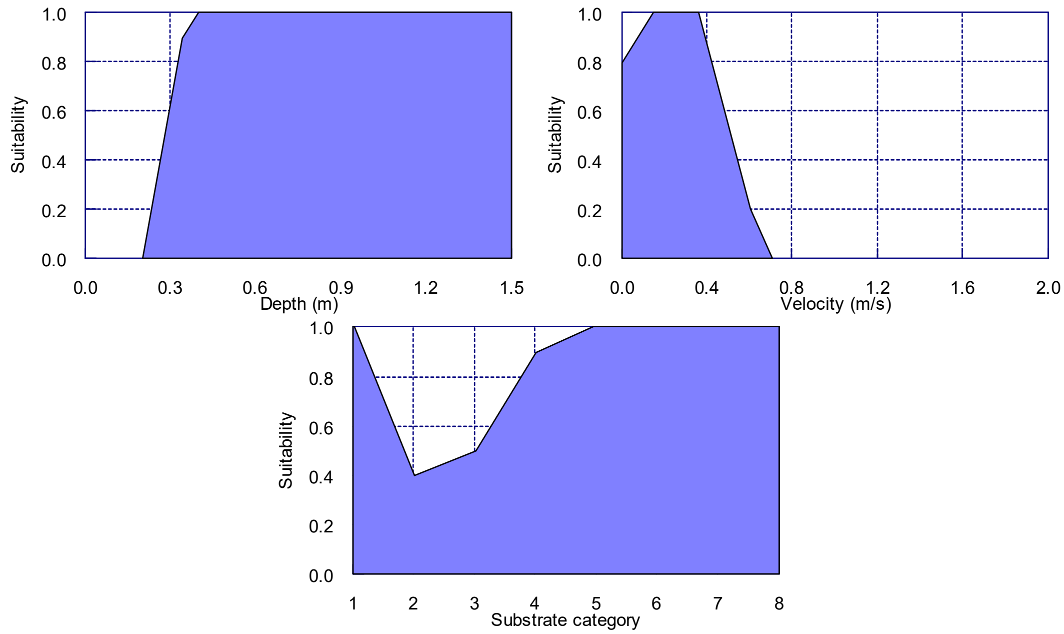
Common bully (Jowett & Richardson 2008)



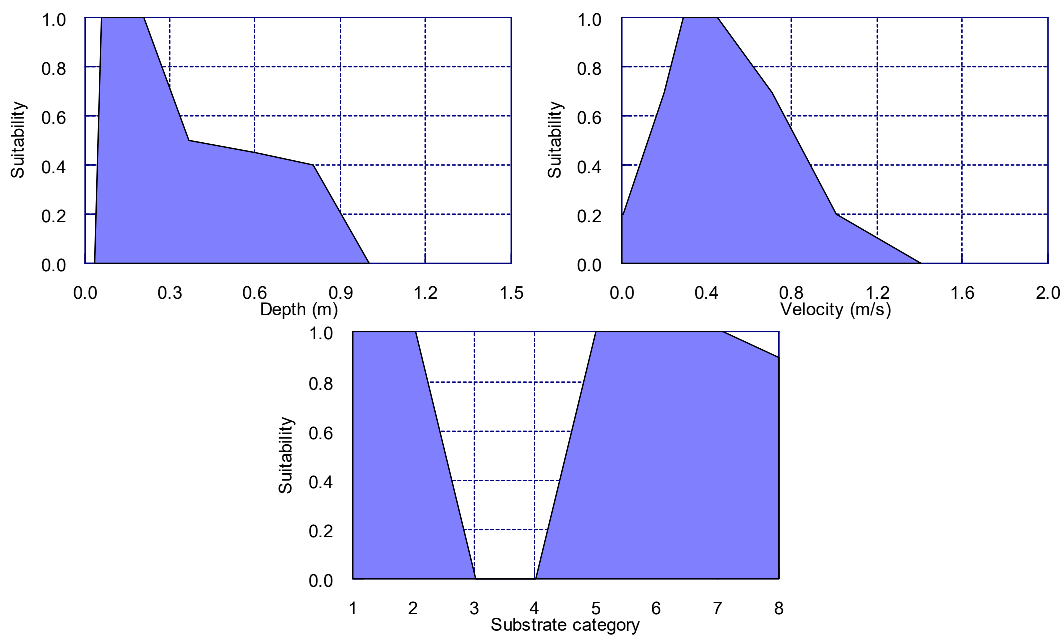
Smelt (Jowett & Richardson 2008)



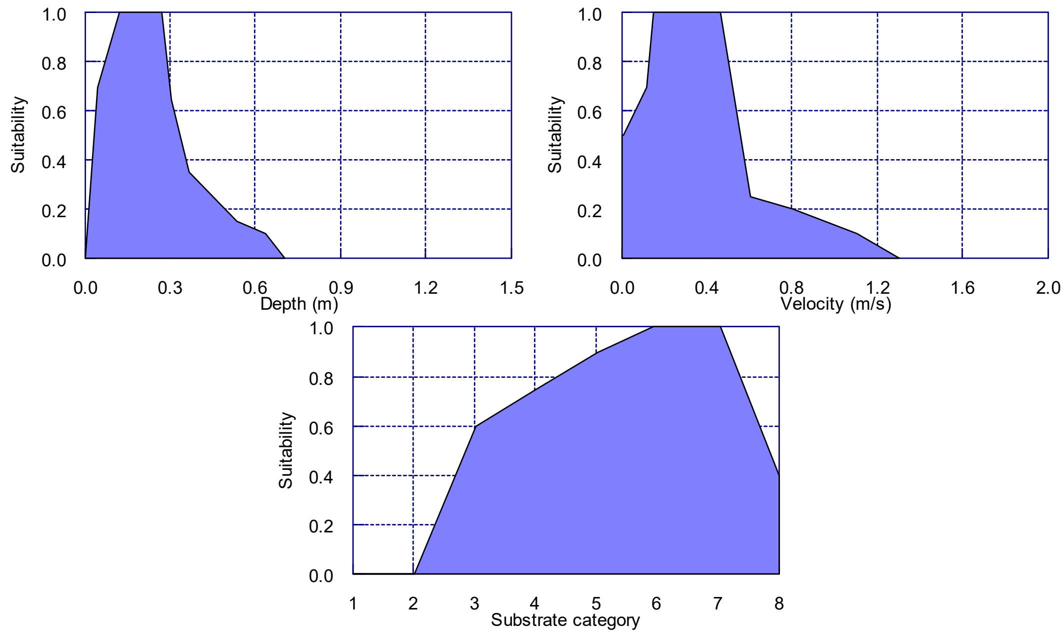
Longfin eel > 300mm (Jowett & Richardson 2008)



Longfin eel < 300mm (Jowett & Richardson 2008)



Redfin bully (Jowett & Richardson 2008)



Torrentfish (Jowett & Richardson 2008)