Water Ways Consulting

Arrow River physical habitat assessments

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Cover photo: Cross Section 2, pool habitat, Arrow River

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1. INTRODUCTION

The Otago Regional Council is developing a new Regional Water and Land Regional Plan (WLRP) and as part of this process the Council is setting minimum flows for Otago rivers. To inform the minimum flow setting process physical habitat models can be made for selected river reaches and these can be used to model changes in physical habitat for fish, macroinverterbrates and periphyton taxa with change river flow.

Two physical habitat models have previously been developed for the Arrow River by NIWA in 2004 (Jowett 2004). One of the model reaches was in the upper Arrow River near Mace Town and the other downstream of State Highway 6 (Figure 1). However, there was some concern that neither of these models were appropriate for modelling habitat in the reach from Arrowtown to the State Highway 6. Therefore, an assessment of the habitat in this reach was required and the development of a physical habitat model for this reach of the river.

This report provides the physical habitat model details for three habitat models for the Arrow River.

Figure 1: The Arrow River habitat model reaches.

2. METHODS

2.1. Methods for New Model Reach

The field work and physical habitat modelling for the new reach of the Arrow River was conducted using the same methods as the original Arrow River models. For the habitat models the habitat preference curves (HSC) used are the most recently developed HSC available and many are updates on those available in 2003. Therefore, the habitat model outputs for the original NIWA (2003) reaches were updated by using the more recently developed HSCs.

The field work for the assessment of instream macrohabitat and the development of a physical habitat model was undertaken over two summers, 2022-2023 and 2023-2024.

In 2022-23 the Arrow River was walked from 1 km upstream of Arrowtown downstream to 500 m downstream of the State Highway 6 bridge. The proportions of run, riffle, and pool habitat along this reach was estimated during the river walk. Notes were kept on the nature of the runs and riffle habitat with, for instance fast and gentle runs and riffle noted. The habitat proportions and types within each general habitat unit were then used to determine the number of habitat model cross sections for each habitat type. For the SEFA model fifteen cross sections were selected and the number of pool, riffle and run cross sections reflected the proportion of the river reach that was these habitat types. For example, if 20% of the reach was classified as pool habitat, 60% run habitat and 20% riffle habitat, then three pool, three riffle and nine run cross sections were used for the model. When the cross sections were selected the variation in the nature of the habitat unit was considered, and cross sections were selected to incorporate the within habitat unit variation.

Fifteen cross sections for physical habitat models were selected 2022-2023 but the instream gauging could not be completed before high flows prevented flow measuring at some of the cross sections. In January 2024 fifteen new cross sections were selected in the study reach and the three sets of cross section gaugings and calibration gaugings and water level measurements were completed an allowed the development of a physical habitat model in SEFA. It was noted that the study reach of the Arrow River had not changed in the habitat proportions from 2022-2023 to 2023-2024 and some of the original cross sections were reselected in 2024.

To reduce the access time and any access difficulties cross section were located close together as long as the appropriate habitat proportions and types were present in the reach. However, care was taken to ensure the model would represent the longer reach for which the habitat units and proportion had been assessed.

At each cross section a main gauging was undertaken. This gauging gathered the measurements for a channel cross-section, the water depths and water velocities across the riverbed. Water velocities were measured using an Seba water velocity meter (calibrated by NIWA). For each cross section the dry riverbank profile was measured so the channel profile could be modelled at higher flows than those on the gauging day. At each site a temporary staff gauge was placed in the water on the cross-section line. The distance from the top of the staff gauge to the water surface was measured on the gauging visit to provide a water level reference for developing cross section rating curves. To ensure the water level was measured in the same manner on each subsequent visit the corner or side of the water level peg the measurement was taken from was marked on the peg. This avoided confounding the water level measurements, especially on sloping pegs, if people did not measure from the same place on the top of the peg.

When the cross-section was being gauged visual estimates of the riverbed substrate were made. The substrate was divided into eight categories:

- Bedrock
- Boulder
- Cobble
- Gravel
- Fine Gravel
- Sand
- Mud
- Vegetation

The percentages of the riverbed substrates around the location of the water depth and velocity measurement points were estimated. The area the substrate was estimated across depended on the spacing between water depth/velocity measurement locations and extended halfway to the adjacent measurement points.

Two additional visits were made on separate days with different river flows to measure the water level on the temporary staff gauges at each cross section and to measure flow at one cross section. The cross section selected for the flow gauging was always a run habitat with good laminar flow as these cross sections provide the best flow gauging opportunities.

2.1. Arrow River 2024 Habitat Model

The main set of cross section measurements and substrate assessment was conducted on a flow of low measurements for the cross sections in this reach were conducted on flows of 0.886 m^3/s on the 3 March 2024, the lowest flow day in the Arrow River during the 2023-2024 summer. Calibration flows for ratings curves were conducted on higher flows of 1.067 m^3/s and 1.326 m^3/s.

The analysis programme System for Environmental Analysis (SEFA) was used to develop the habitat models. The model produces two outputs, a reach area weighted suitability (RAWS m^2/m) and a combined suitability index (CSI).

Figure 2: A temporary staff gauge with orange top to aid relocating the peg.

Once completed the physical habitat model had fifteen cross sections with three flow gaugings and water levels to construct rating curves for each cross section.

One limitation of the cross-section selection process was that the work could only be conducted in wadable water. To allow the new model to incorporate deeper water habitat the main gauging run was conducted on a flow low enough to allow the full channel to be waded and measured. Then water level and flow data for rating curve calibrations was done on higher flow when the full channel on the deeper cross sections did not need to be waded.

There was a small percentage of habitat, less than 1% that still was too deep for wading so the new model may underestimate the changes in habitat for the small areas of very deep-water habitat.

The flow measuring work aimed to include flows from close to the 7dMALF (at Cornwall Road 1.41-1.43 m^3/s, Olsen et al 2017) down to the lowest flow available during the summer period. This allowed the 2024 model was calibrated to the river's low flow conditions. Therefore, this model does not provide good high flow habitat predictions, but as the models were intended to provide information on low habitat conditions this was an intentional outcome.

For each model reach a range of algal taxa, macroinvertebrates and fish were modelled (Table 1). The modelling was limited to taxa that are reported in the Arrow River and for taxa for which habitat suitability curves (HSCs). The New Zealand freshwater fish database (NZFFD) and the Otago Regional Council SOE monitoring data were used to provide fish, macroinvertebrate and algal taxa data for the Arrow River. The ORC conducts State of the Environment (SOE) monitoring in the Arrow River at the end of Morven Ferry Road. This provides macroinvertebrate and fish data from Surber samples and more recently eDNA sampling.

2.2. 2004 Habitat Models

Details of the model measurements are provided in Jowett (2004). The two models consist of 15 cross sections each. For the lower Arrow River model reach the habitat proportions were:

- Runs 40%
- Riffles 55 %
- Pools 5%.

The river here is lined with crack willows and often vertical schist cliffs (Figure 3).

Figure 3: Habitat from the lower Arrow River habitat model reach (from Jowett 2004).

For the upper Arrow River model reach the habitat proportions were:

- Runs 29 %
- Riffles 67 %
- Pools 4 %.

The river site also is lined with crack willow but the banks are more gently sloped and eroding in at least some areas (Figure 4).

Figure 4: Habitat from the upper Arrow River habitat model reach (from Jowett 2004)

Both models were based on habitat mapping for 1-2 km of rivers.

The model calibration flows for the lower Arrow River were:

- 1.12 m^3/s for main gauging run
- 2.06 m^3/s calibration 1
- 2.18 m^3/s calibration 2

The model calibration flows for the upper Arrow River were;

- 1.02 m^3/s for main gauging run;
- 1.35 m^3/s calibration 1; and
- 1.45 m^3/s calibration 2.

Therefore, the lower Arrow River model is calibrated over 1 m^3/s range and the upper Arrow River model over a 0.4 m^3/s flow range.

The upper Arrow site was not revisited to confirm the habitat remains the same. The upper parts of the lower Arrow River section were revisited, and the river remains a crack willow and schist cliff lined water course. No changes to the RHYHABSIM models were made for these reach and updated habitat preference curves were run in the models once the datafiles were imported in SEFA.

3. RESULTS

3.1. Mid Arrow Reach description

The fifteen cross sections were place along the Arrow River in the reach beside the Arrowtown golf course (Figure 5). This reach is characterised with a U-shaped channel often with near vertical banks of 0.5 to 1.0 high. The banks are well vegetated with a mix of trees, shrubs and grasses with little evidence of bank erosion (Figure 6). The streambed in sections is predominately bedrock and other areas a mix of cobble and gravel being the dominant substrate. Occasional boulder clusters also provide some habitat variability. Pool habitat was rare, and the reach was dominated by run and riffle habitats. The stream walk estimated the percentage of run, riffle and pool habitat in the Arrowtown to State Highway bridge were:

- Run 42 %
- Riffle 53 %
- Pool 5 %

During the 2023 habitat survey a suction dredge was working along the study reach. In some parts of the habitats assessment reach the mining had created mine holes 1-1.5 m deep and rock piles immediately downstream (Figure 7, Figure 8). When the reach was walked again in February 2024 the holes had been infilled and the rock piles redistributed indicating that the mining modifications was not leading to long term changes in the stream habitat.

Table 1: Habitat suitability curves used in instream habitat modelling.

Group	HSC name	HSC source
Periphyton	Cyanobacteria (*Phormidium*)	Ex Heath et al. (2013)
	Diatoms	NIWA Unpublished data
	Didymo (Waitaki)	Jowett unpublished data
	Long filamentous	NIWA Unpublished data
	Short filamentous	NIWA Unpublished data
Macro-invertebrates	Mayfly nymph *(Deleatidium*)	Jowett et al. (1991)
	Mayfly nymph (*Coloburicus*)	Jowett et al. (1991)
	Net-spinning caddis fly (*Hydropsyche*)	Jowett et al. (1991)[1]
	Free living caddis fly (Hydrobiosidae)	Jowett et al. (1991)
	Cased caddis fly (*Olinga*)	Jowett et al. (1991)
	Benthic invertebrate density	Jowett (2018)
	Food producing habitat	Waters (1976)
Fish	Brown trout spawning	Shirvell & Dungey (1983)
	Brown trout yearling	Raleigh et al (1986)
	Brown trout 40-65 cm	Hayes & Jowett (199)2
	Brown trout < 100 mm	Jowett & Richardson 2008
	Juvenile brown and rainbow trout	Wilding et al (2014)
	Adult brown and rainbow trout	Wilding et al (2014)
	Rainbow trout spawning (Tongariro River)	Jowett et al (1996)
	Rainbow trout < 100 mm	
	Rainbow trout fingerlings	

[1] Jowett et al (1991) use the previous genus name – *Aoteapsyche*.

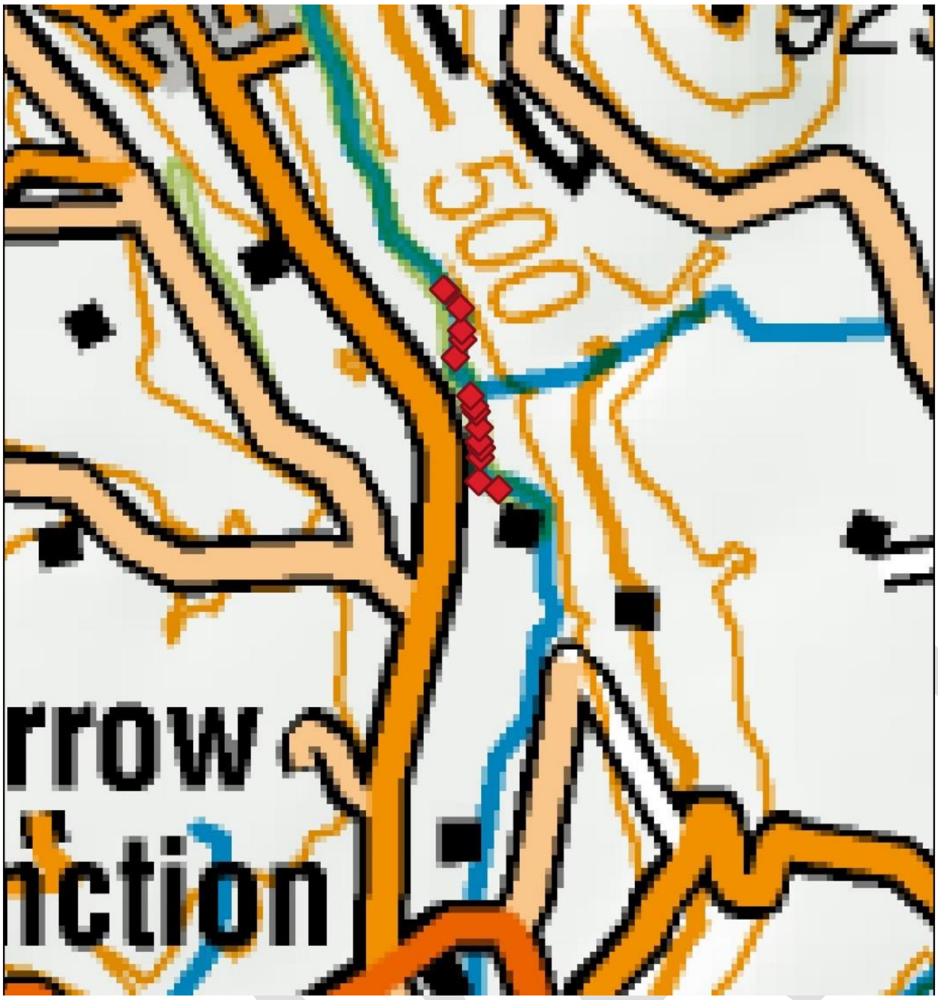

Figure 5: The location of cross section for the mid Arrow River habitat model.


Figure 6: A view of the mid-reach of model section of the Arrow River (Feb 2024).

Figure 7: Suction dredge working the Arrow River, operated by SCUBA diver (Jan 2023).

Figure 8: Suction dredge mine hole (Jan 2023).

3.1. Mid-Arrow Reach SEFA outputs

3.1.1 Periphyton

The periphyton response to changing flow varies with the periphyton type. Diatoms show an increase in available habitat (RAWS) and habitat quality (CSI) as flow increases (Figure 9, Figure 10). Didmyo and phomidium show an initial increase in CSI from 0.0 m^3/s to 0.1 m^3/s and them stabilises through the flow range of 0.1 m^3/s to 1.5 m^3/s. For the habitat available for Didmyo and phomidium it increases rapidly from 0.0 m^3/s to 0.1 m^3/s and then continues to increase more slowly up to 1.5 m^3/s. For long filamentous algae the habitat and suitability peak at low flows, 0.0 m^3/s to .2 m^3/s and both decrease as flow continuous to rise. Short filamentous algae habitat and suitability increases from 0.0 m^3/s to 1.0 m^3/s and then decreases as flow continues to increase.

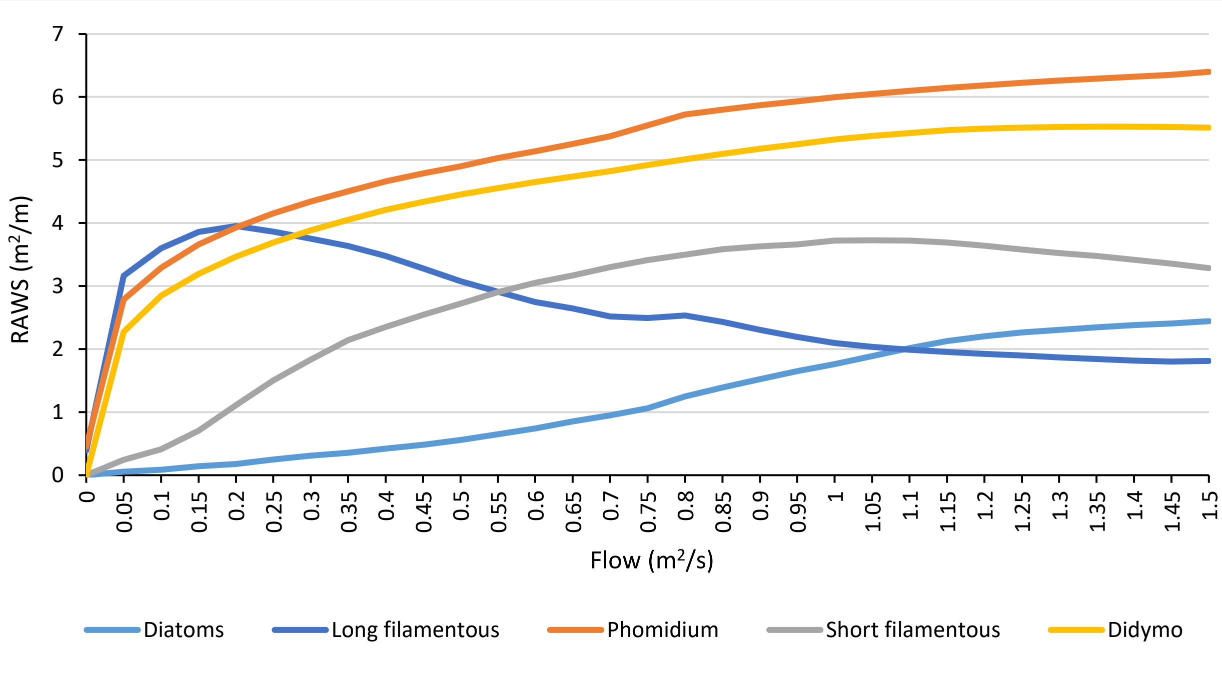

Figure 9: The mid-Arrow River reach habitat flow relationship for periphyton taxa.

3.1.2 Macroinvertebrates

The response of the five macroinvertebrate taxa and the two general macroinvertebrate habitat criteria all showed an increase in habitat available as flow increases from 0.0 m^3/s to 1.0 m^3/s. Habitat for *Olinga*, a caddisfly larva, stabilises at 1.0 whereas all the other taxa continue to increase to 1.5 m^3/s. There is no peak habitat for these taxa at flows below the 7dMALF of 1.4 m^3/s.

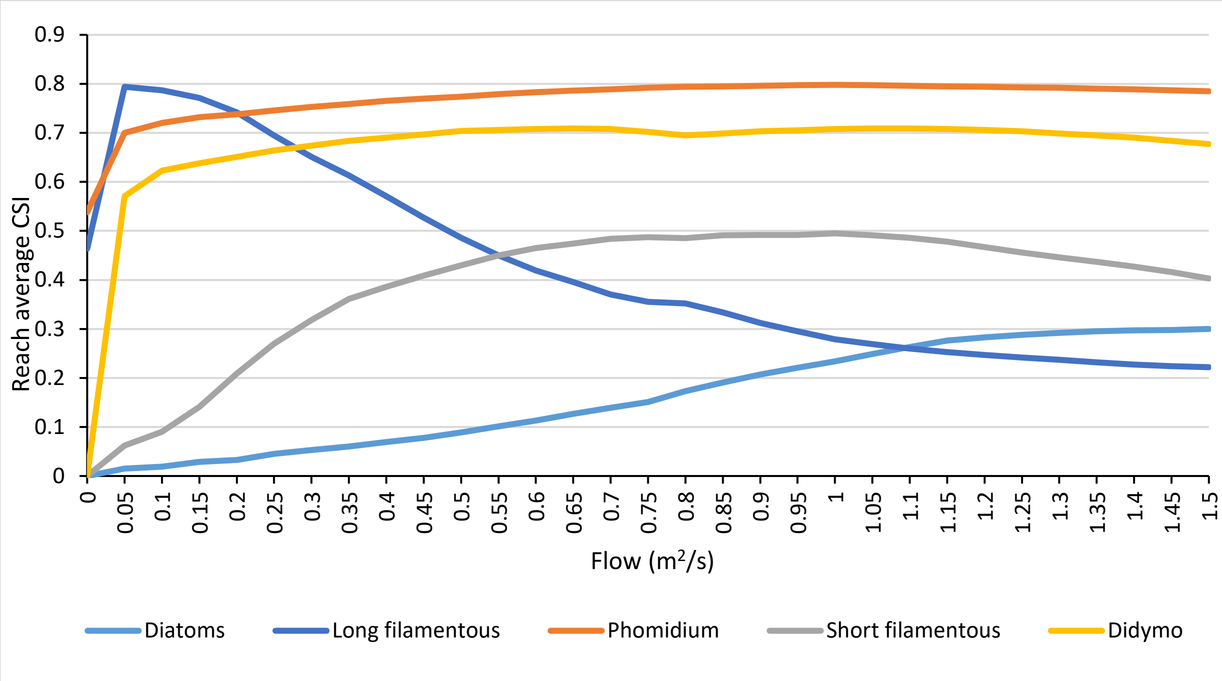

Figure 10:The mid-Arrow River reach habitat suitability flow relationship for periphyton taxa.

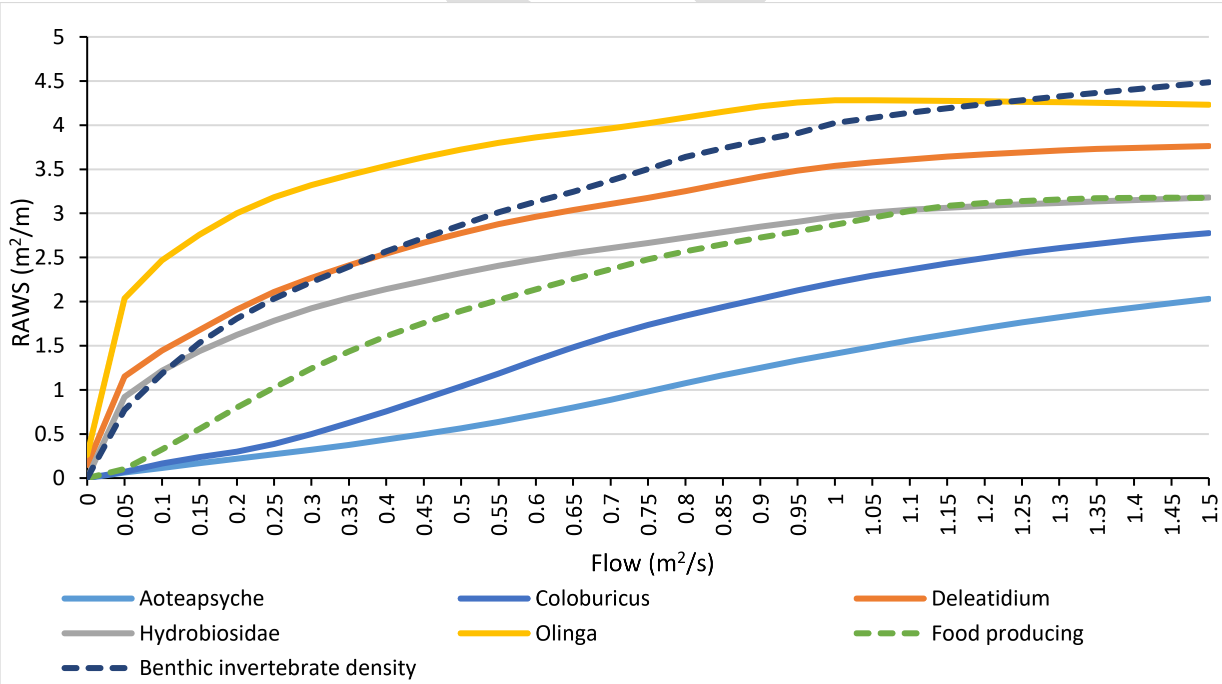

Figure 11: The mid-Arrow River reach habitat flow relationship for macroinvertebrate taxa.

3.1.3 Fish

The various brown and rainbow trout model outputs show varying responses to the changing flow (Figure 11, Figure 12). Spawning habitat for rainbow trout rises with flow from 0 m^3/s to 1 m^3/s and then stabilises. Brown trout spawning habitat peaks at 0.45 m^3/s and then slowly declines. The adult trout and large brown trout habitat increases slowly through the 1.5 m^3/s flow range, but the amount of habitat predicted remains relatively small. Juvenile rainbow and brown trout habitat show varying trends but all have an moderate to rapid increase from 0 m^3/s to 0.2 m^3/s or 0.45 m^3/s. For the smaller juvenile trout, the increase continues to 1.0 m^3/s or 1.5 m^3/s. For fry and small trout < 100 the habitat available is predicted to be relatively stable or slowly declining for flows above 0.5 m^3/s.

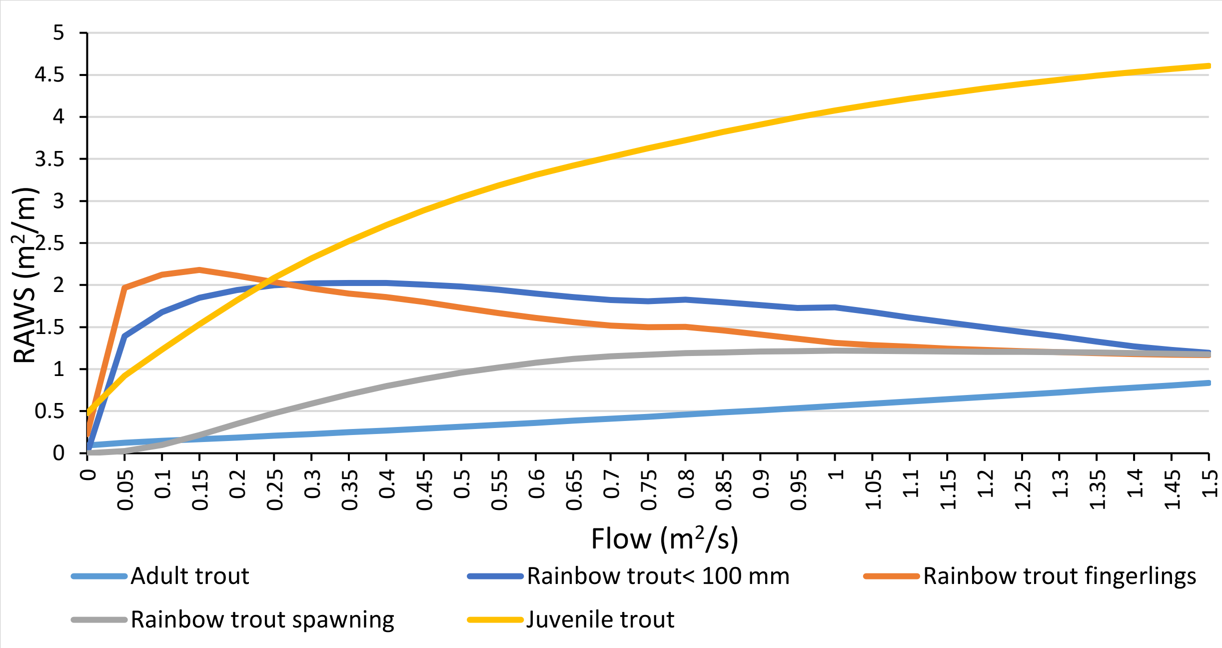

Figure 12: The mid-Arrow River reach habitat flow relationship for rainbow trout and general trout HSC.

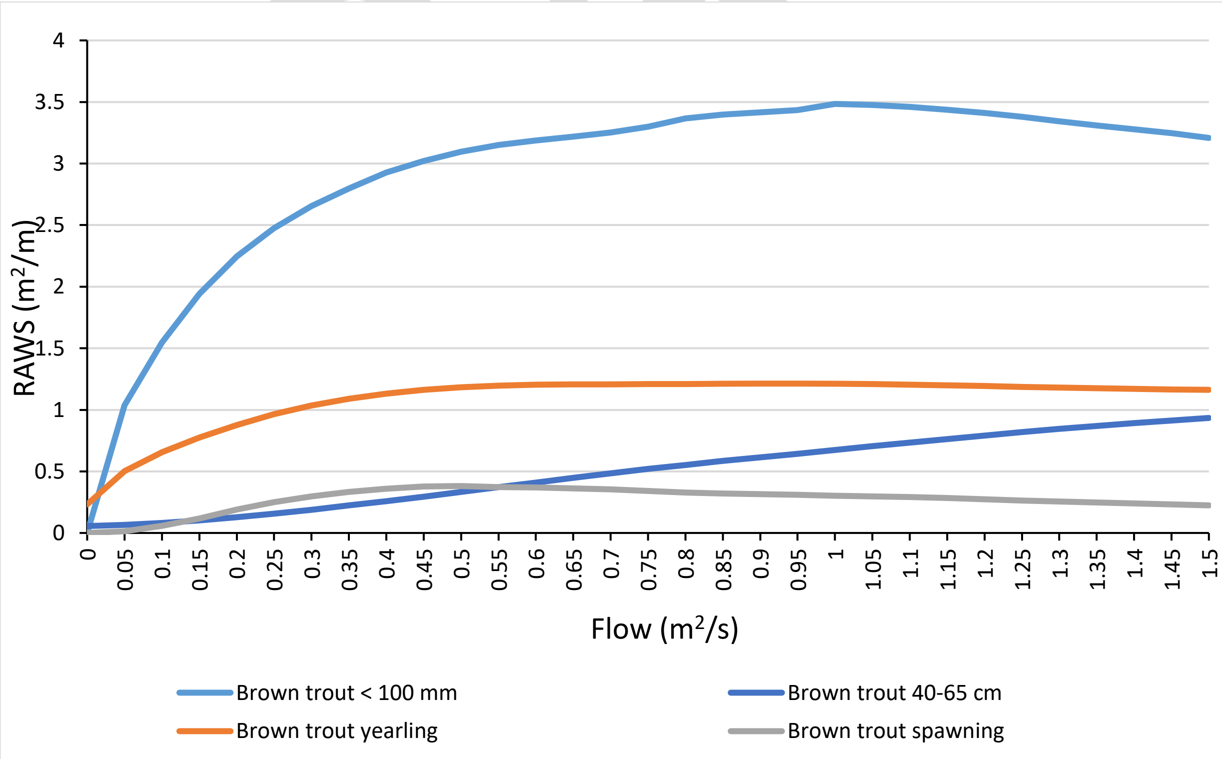

Figure 13: The mid-Arrow River reach habitat flow relationship for brown trout.

3.1.4 Habitat retention at flow increments below 7dMALF.

For each of the taxa and life history stages the habitat predicted to be present at 10% increments below the 7dMALF (1.41 m^3/s) (Table 2, Table 3, Table 4, Table 5) found only two taxa, diatoms and *Aoteopsyche* loose more that 50% of their habitat and only when the flow is below 50% of 7dMALF (0.705 m^3/s). A drop in flow to 70 % of the 7dMALF (0.987 m^3/s) results in less than a 20% drop in habitat for most taxa or life history stage.

Table 2: Habitat predictions for percentages of 7dMALF flow for periphyton in the mid-Arrow River reach.

% of 7dMALF	Flow (m^3/s)	Diatoms	Long filamentous	Phomidium	Short filamentous	Didymo
100	1.41	100	100	100	100	100
90	1.269	95.08	104.40	98.50	104.68	99.76
80	1.128	89.41	107.65	97.20	108.01	98.97
70	0.987	74.03	115.29	94.91	108.89	96.31
60	0.846	58.49	133.83	91.79	104.88	92.60
50	0.705	39.87	138.50	85.08	96.55	87.29

Table 3: Habitat predictions for percentages of 7dMALF flow for macroinvertebrates in the mid-Arrow River reach.

% of 7dMALF	Flow (m^3/s)	*Aoteapsyche*	*Coloburicus*	*Deleatidium*	Hydrobiosidae	Olinga	Benthic invertebrate density	Food producing
100	1.41	100.00	100.00	100.00	100.00	100.00	100.00	100.00
90	1.269	91.25	94.63	98.61	98.48	100.47	97.23	98.87
80	1.128	84.47	90.14	97.30	97.27	100.73	95.12	97.07
70	0.987	72.98	82.07	94.55	94.10	100.85	91.37	90.37
60	0.846	60.30	71.80	89.15	88.51	97.83	84.88	83.44
50	0.705	45.96	59.87	83.01	82.79	93.38	76.53	74.54

Table 4: Habitat predictions for percentages of 7dMALF flow for rainbow trout and general trout HSCs in the mid-Arrow River reach.

% of 7dMALF	Flow (m^3/s)	Rainbow trout< 100 mm	Rainbow trout fingerlings	Rainbow trout spawning	Juvenile trout	Adult trout
100	1.41	100.00	100.00	100.00	100	100.00
90	1.269	113.53	102.97	101.18	96.95431	89.36
80	1.128	122.34	105.60	101.43	94.43831	82.44
70	0.987	136.51	111.45	102.43	89.95807	72.18
60	0.846	141.23	123.83	100.76	84.28603	62.18
50	0.705	143.51	128.67	96.73	77.75326	52.44

Table 5: Habitat predictions for percentages of 7dMALF flow for brown trout in the mid-Arrow River reach.

% of 7dMALF	Flow (m^3/s)	Brown trout < 100 mm	Brown trout 40-65 cm	Brown trout yearling	Brown trout spawning
100	1.41	100.00	100.00	100.00	100
90	1.269	103.11	91.82	101.45	110
80	1.128	104.88	85.54	102.48	117.92
70	0.987	106.32	75.56	103.59	126.25
60	0.846	103.69	65.58	103.59	133.75
50	0.705	99.27	54.26	103.16	147.083

4. JOWETT (2004) MODEL REACHES

4.1. Lower Arrow River reach

4.1.1 Periphyton

The periphyton response to changing flow varies with the periphyton type (Figure 14, Figure 15). Diatoms show an increase in available habitat (RAWS) and habitat quality (CSI) as flow increases from 0.25 m^3/s (Figure 9, Figure 10). Didmyo shows an initial rapid increase in CSI and RAWS from 0.0 m^3/s to 0.1 m^3/s. Didymo RAWs then increase slowly to a peak at 0.8 m^3/s before slow declining. Didymo CSI is essentially stable through the flow range of 0.1 m^3/s to 0.6 m^3/s before declining slowly as flow increases further to 1.5 m^3/s. For the habitat available for Phomidium it increases rapidly from 0.0 m^3/s to 0.1 m^3/s and then continues to increase more slowly up to 1.5 m^3/s. The CSI for Phomidium can be considered to be stable across the whole flow range after a small increase for the flows between 0.0 m^3/s and 0.3 m^3/s. The habitat and suitability for long filamentous algae peak at low flows, 0.1 m^3/s to 0.0 m^3/s respectively and both decrease as flow continuous to rise. Short filamentous algae habitat and suitability increases from 0.0 m^3/s to 0.65 m^3/s and then decreases as flow continues to increase.

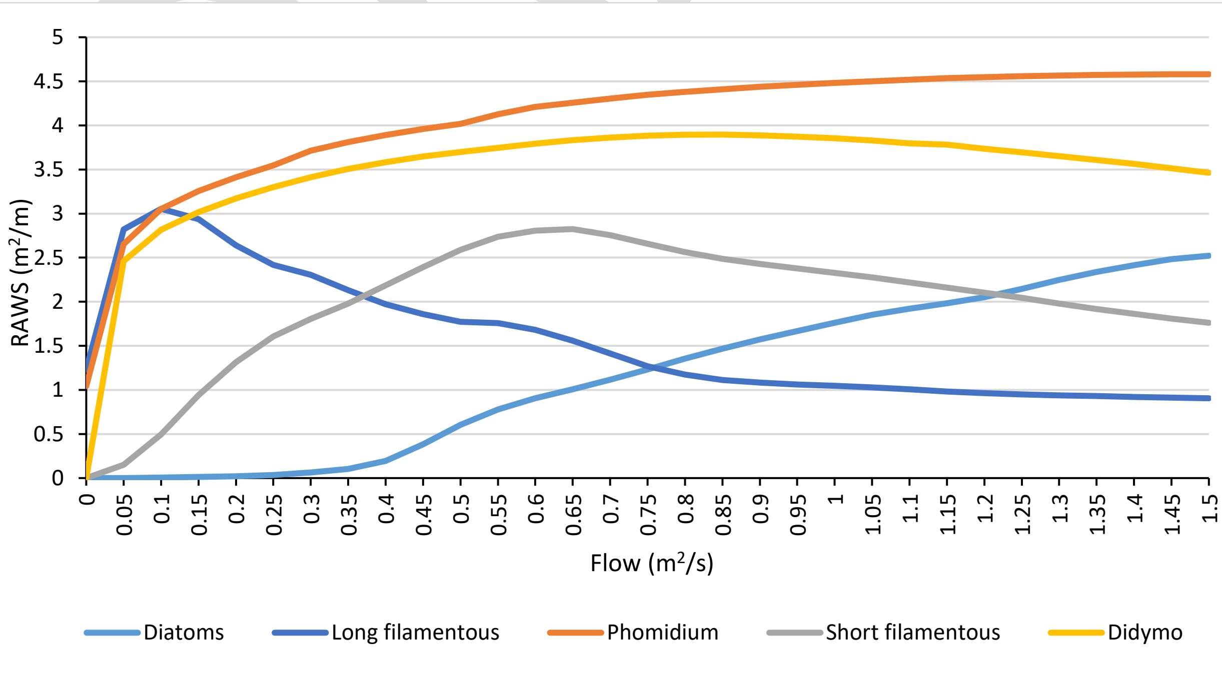

Figure 14: The lower Arrow River reach habitat flow relationship for periphyton taxa.

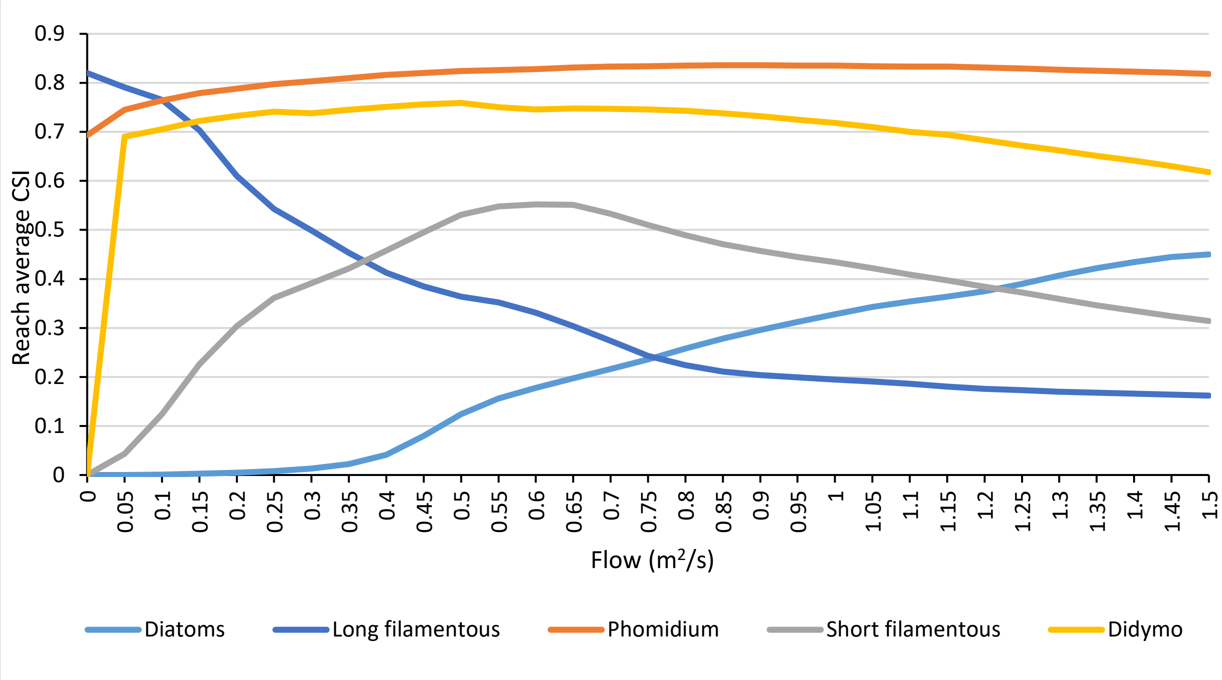

Figure 15: The lower Arrow River reach habitat suitability flow relationship for periphyton taxa.

4.1.2 Macroinvertebrates

The predicted habitat for macroinvertebrates all increases from 0.0 m^3/s to 0.45 m^3/s at which flow the habitat for *Olinga* begins to slowly decline (Figure 16). Food producing habitat also declines slowly once it reaches a peak at 0.85 m^3/s. Other taxa also show a decline in the rate of habitat increases as the flow increases over 0.8 m^3/s.

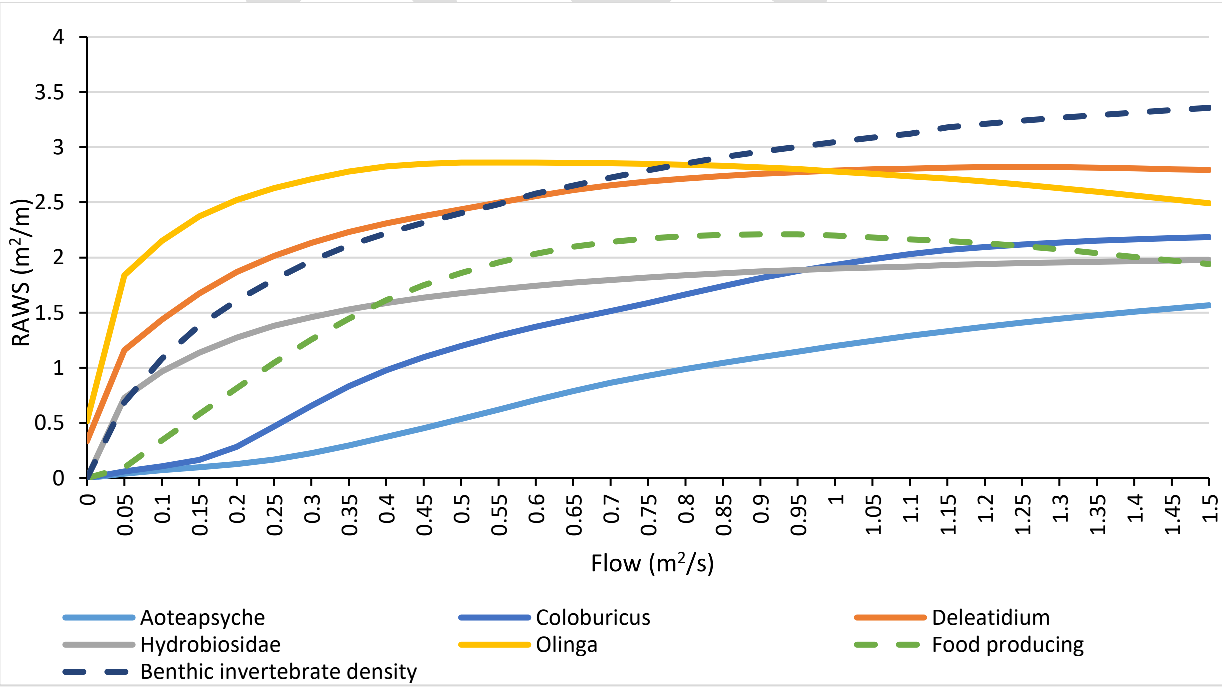

Figure 16: The lower Arrow River reach habitat flow relationship for macroinvertebrate taxa.

4.1.3 Fish

The brown and rainbow trout model outputs show varying responses to the changing flow (Figure 17, Figure 18). Spawning habitat for rainbow trout rises with flow from 0 m^3/s to 0.6 m^3/s and then declines. Brown trout spawning habitat peaks at 0.35 m^3/s and then declines. The adult trout habitat increases slowly through the 1.5 m^3/s flow range, but the amount of habitat predicted remains relatively small. The large brown trout habitat increases from 0.0 m^3/s to 0.7 m^3/s and then declines slowly as flow increases to 1.5 m^3/s. Juvenile rainbow and brown trout habitat show consistent trends, with a moderate to rapid increase from 0.0 m^3/s that levels off and then habitat declines. Maximum habitat for all the fry, and juvenile life history stages is at or below 0.75 m^3/s.

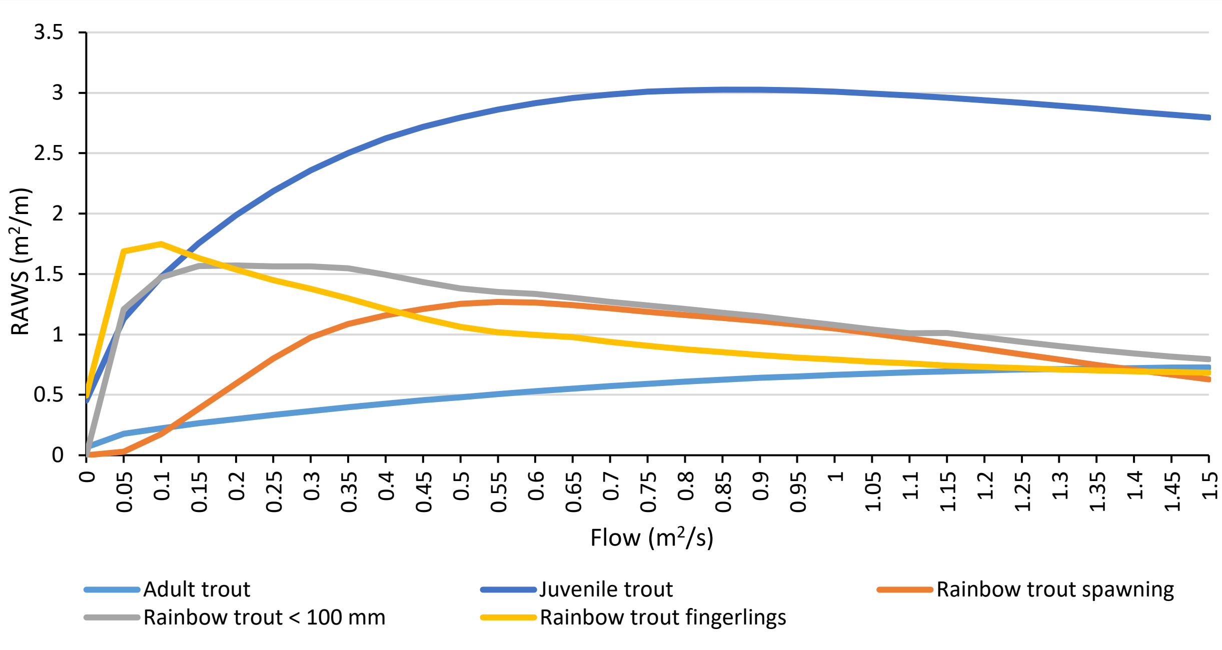

Figure 17: The lower Arrow River reach habitat flow relationship for rainbow trout and general trout HSCs.

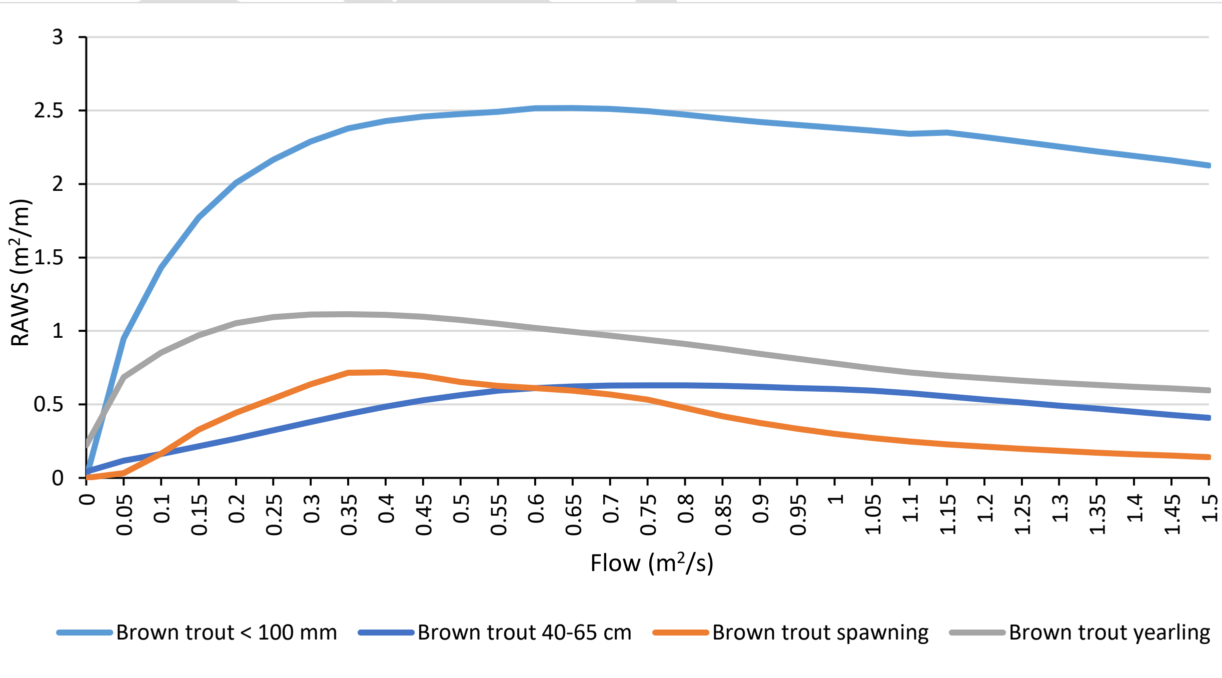

Figure 18: The upper Arrow River reach habitat flow relationship for brown trout.

4.1.1 Habitat retention at flow increments below 7dMALF.

For each of the taxa and life history stages the habitat predicted to be present at 10% increments below the 7dMALF (1.41 m^3/s) (Table 6, Table 7,

Table 8, Table 9) found only one taxa, diatoms loose more that 50% of their habitat and only when the flow is below 50% of 7dMALF (0.705 m^3/s). However, the predicted habitat for long filamentous does increase to over 150 % of that present at the 7dMALF indicate a potential for nuisance growths of long filamentous algae.

A drop in flow to 70 % of the 7dMALF (0.987 m^3/s) results in less than a 20% drop in habitat for most taxa or life history stage. For all the trout life history stages aside from the general adult trout HSC the peak habitat occurs at flows below the 7dMALF and for all these life history stages the declining flow leads to an increase in habitat. For adult trout a 50% drop in flow from 7dMALF only decreases habitat by 20.64 %.

Table 6: Habitat predictions for percentages of 7dMALF flow for periphyton in the lower Arrow River reach.

% of 7dMALF	Flow (m^3/s)	Diatoms	Long filamentous	Phomidium	Short filamentous	Didymo
100	1.41	100	100	100	100	100
90	1.269	88.86	103.26	99.61	109.77	103.68
80	1.128	82.10	106.74	99.15	116.11	106.09
70	0.987	72.99	113.70	97.95	125.08	108.14
60	0.846	60.85	120.87	96.37	133.51	109.32
50	0.705	46.23	153.70	94.06	148.07	108.39

Table 7: Habitat predictions for percentages of 7dMALF flow for macroinvertebrates in the lower Arrow River reach.

% of 7dMALF	Flow (m^3/s)	*Aoteapsyche*	*Coloburicus*	*Deleatidium*	Hydrobiosidae	Olinga	Benthic invertebrate density	Food producing
100	1.41	100	100	100	100	100	100	100
90	1.269	93.44	97.78	100.43	99.03	103.78	104.99	97.80
80	1.128	88.27	95.52	100.25	98.22	105.97	107.29	95.99
70	0.987	79.39	89.28	99.29	96.49	108.51	109.73	91.94
60	0.846	69.18	80.37	97.54	94.41	110.46	110.03	87.78
50	0.705	57.19	69.98	94.55	91.31	111.39	106.89	82.20

Table 8: Habitat predictions for percentages of 7dMALF flow for rainbow trout and general trout HSCs in the lower Arrow River reach.

% of 7dMALF	Flow (m^3/s)	Rainbow trout< 100 mm	Rainbow trout fingerlings	Rainbow trout spawning	Juvenile trout	Adult trout
100	1.41	100	100	100	100	100
90	1.269	111.52	103.74	118.10	102.57	98.20
80	1.128	120.31	106.91	130.83	104.08	96.26
70	0.987	128.03	113.81	148.37	105.84	92.24
60	0.846	140.14	122.59	160.68	106.44	86.57
50	0.705	150.83	135.11	171.85	105.03	79.36

Table 9: Habitat predictions for percentages of 7dMALF flow for brown trout in the lower Arrow River reach.

% of 7dMALF	Flow (m^3/s)	Brown trout < 100 mm	Brown trout 40-65 cm	Brown trout yearling	Brown trout spawning
100	1.41	100	100	100	100
90	1.269	104.38	114.00	106.60	122.36
80	1.128	107.25	123.33	112.24	142.24
70	0.987	108.71	134.22	125.28	186.34
60	0.846	111.59	139.33	141.38	260.87
50	0.705	114.55	139.56	155.88	352.80

4.2. Upper Arrow River reach

4.2.1 Periphyton

The didymo and Phomidium habitat predictions show a steep increase in habitat (RAWS, Figure 19) from 0.0 m^3/s to 0.05 m^3/s and then the rate of habitat increase slows but habitat continues to increase through the model flow range to 1.5 m^3/s. For long filamentous algae habitat peaks at 0.15 to 0.2 m^3/s and then steeply declines as flow increases to 0.55 m^3/s and then rate of decline slows but continues through to 1.5 m^3/s. Short filamentous algae habitat rises as flow rises from 0.0 m^3/s to 0.55 m^3/s and then is stable through to 1.15 m^3/s when it starts to decline as flow continues to increase. Diatoms have no habitat between 0.0 m^3/s and 0.2 m^3/s and then habitat rises as flow rises to 1.5 m^3/s.

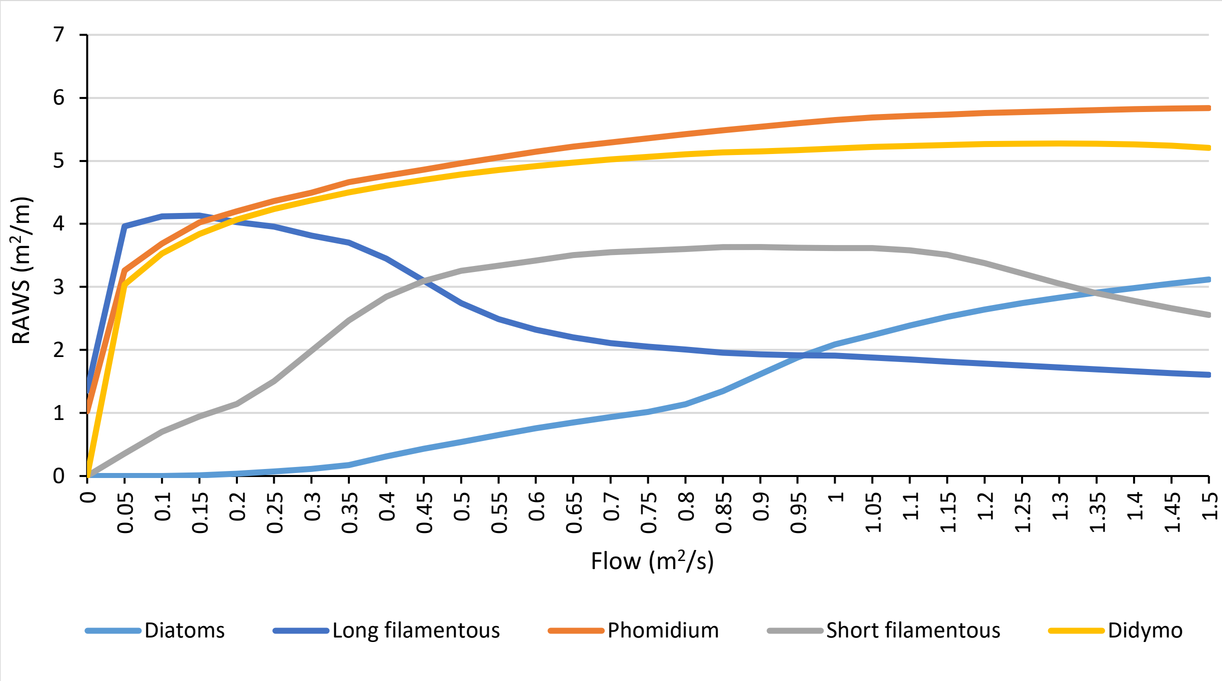

Figure 19: The upper Arrow River reach habitat flow relationship for periphyton taxa.

For the habitat suitability (CSI) this is stable for didymo and Phomidium as ide from didymo dropping to 0 suitability at 0.0 m^3/s flow (Figure 20). For long filamentous algae suitability peaks at 0.0 – 0.05 m^3/s and then steeply declines as flow increases to 0.55 m^3/s and then rate of decline slows but continues through to 1.5 m^3/s. Short filamentous algae habitat suitability rises as flow rises from 0.0 m^3/s to 0.5 m^3/s and then is stable through to 1.15 m^3/s when it starts to decline as flow continues to increase. The habitat is unsuitability (CSI = 0) for diatoms between 0.0 m^3/s and 0.15 m^3/s and then suitability rises as flow rises to 1.5 m^3/s.

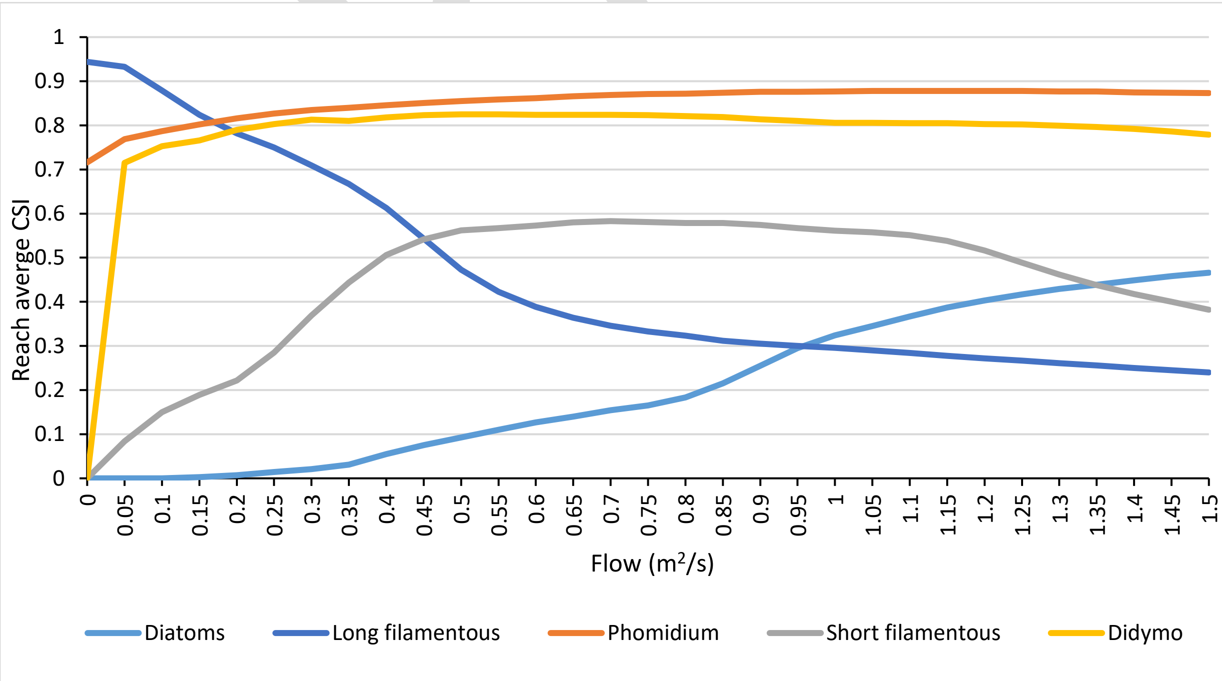

Figure 20: The upper Arrow River reach habitat suitability flow relationship for periphyton taxa.

4.2.2 Macroinvertebrates

The macroinvertebrate habitat is predicted to increase throughout the 0.0 m^3/s to 1.5 m^3/s flow range for all taxa aside from *Olinga* (Figure 21). The *Olinga habitat peaks at 0.75* m^3/s and slow declines as flow increases above this flow. For other macroinvertebrate taxa habitat increases most rapidly at lower flows and then the rate of increase slows above 0.4 m^3/s.

4.2.3 Fish

The various brown and rainbow trout model outputs show varying responses to the changing flow (Figure 22, Figure 23). Spawning habitat for rainbow trout rises with flow from 0 m^3/s to 0.7 m^3/s and then declines. Brown trout spawning habitat peaks at 0.45 m^3/s and then slowly declines. The adult trout habitat increases slowly through the 1.5 m^3/s flow range, but the amount of habitat predicted remains relatively small. The large brown trout habit increases from 0.0 m^3/s to 1.0 m^3/s and then declines slowly as flow increases to 1.5 m^3/s. Juvenile rainbow and brown trout habitat show varying trends, but all have a moderate to rapid increase from 0.0 m^3/s to 0.45 m^3/s. For the smaller juvenile trout, fry and trout < 100 mm, the increase continues to 0.75 m^3/s or 1.0 m^3/s.

4.2.4 Habitat retention at flow increments below 7dMALF.

No habitat retention estimates have been made for the upper Arrow River each as there is no flow monitoring in the upper Arrow to provide the 7dMALF flow statistic. In addition, this reach is upstream of any water abstractions, so the flow is at this time unmodified.

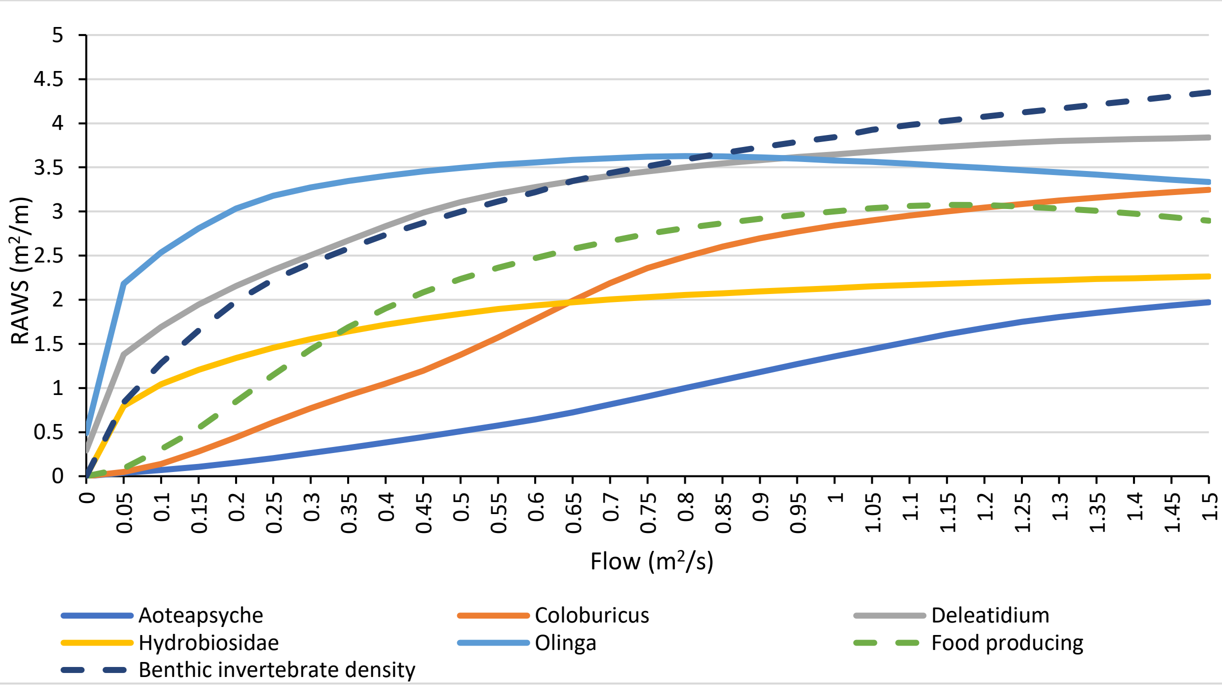

Figure 21: The upper Arrow River reach habitat flow relationship for macroinvertebrate taxa.

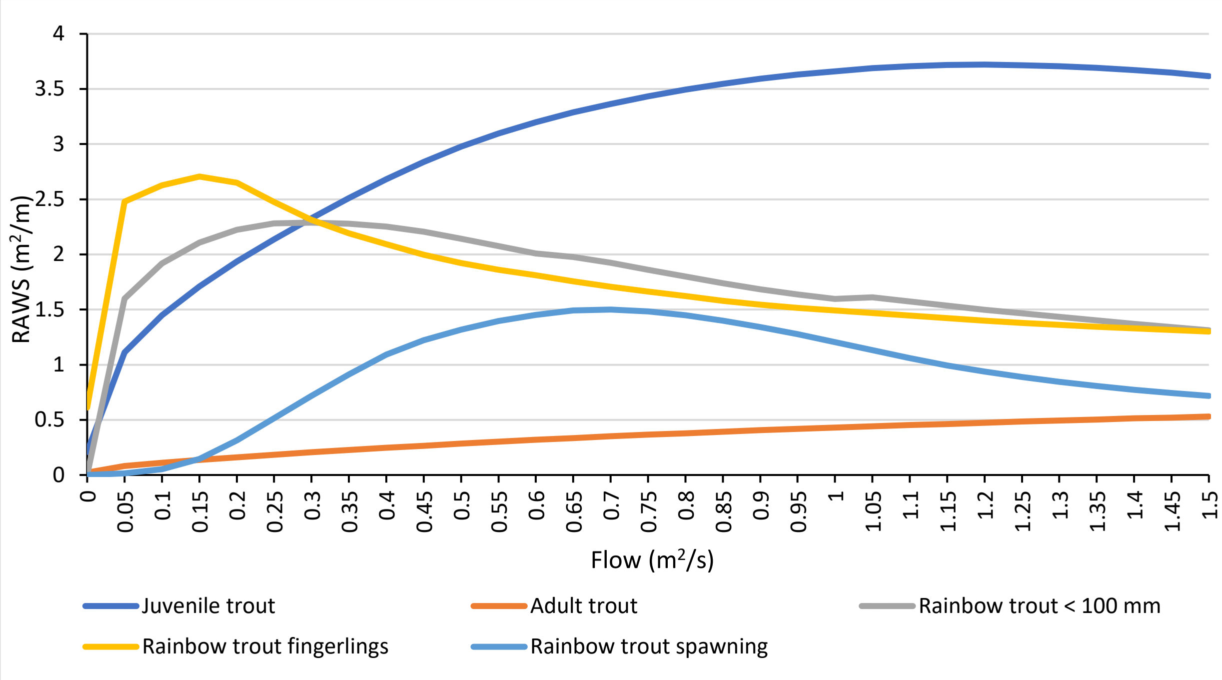

Figure 22: The upper Arrow River reach habitat flow relationship for rainbow trout and general trout HSCs.

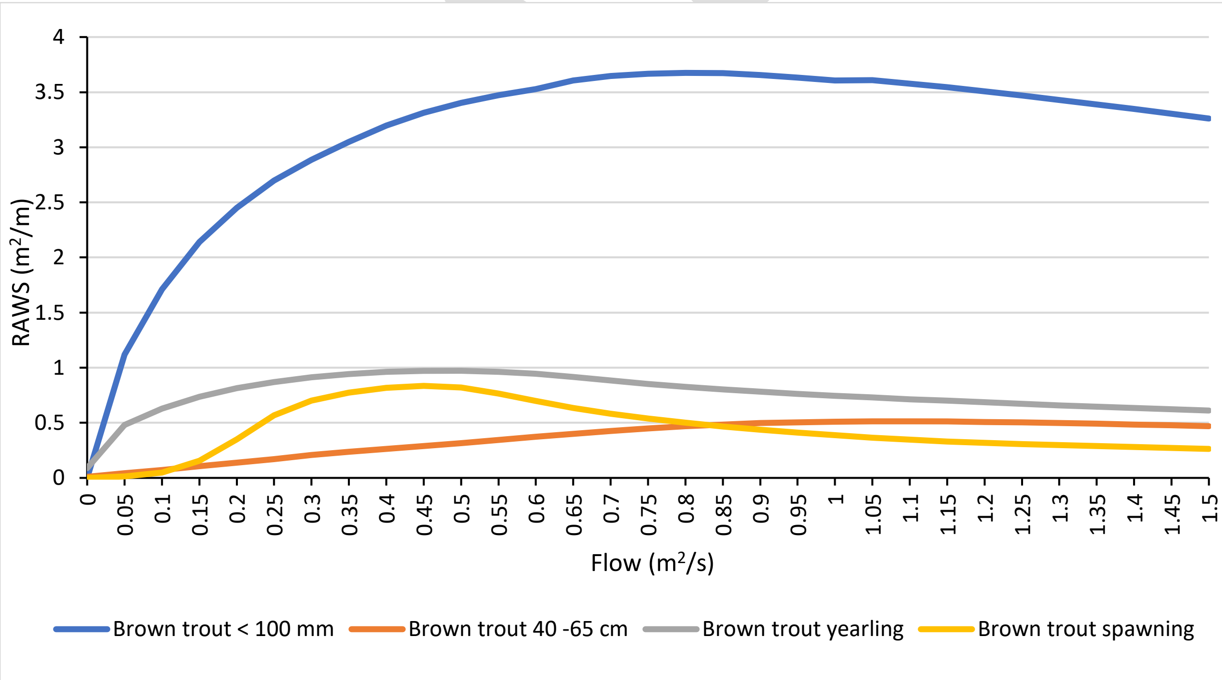

Figure 23: The upper Arrow River reach habitat flow relationship for brown trout.

5. DISCUSSION

Habitat for the two reaches modelled downstream of Arrowtown differs in the amount of habitat provided for various taxa modelled. However, the general trends are the same with macroinvertebrates and diatoms loosing habitat as flow declines. The declines are generally slow with decline flow so for most taxa 80 % of habitat is retained at 50% of the 7dMALF. The two species of trout model also show some differences between the two model reaches. At the lower Arrow River reach habitat increases for smaller life history stages as flow drops below the 7dMALF as peak habitat occurs at flows below the 7dMALF. In the mid-Arrow River reach adult trout loose habitat as flow declines below the 7dMALFand at 50% of the 7dMALF both adult trout habitat predicts are just over 50% of the habitat at the 7dMALF. For the fry and juvenile there is little habitat loss as flow declines.

During the habitat survey work trout fry were frequently observed along the river margins and a smaller number of yearling trout were observed in the pools (e.g. pool at cross section 2) and the deep run habitat. No large trout (30-60 cm long) were seen at any time during the January to March site visits. It is expected that large trout will be observed during the spawning seasons, but these fish do not reside year-round in the Arrow River.

The percentage of 7dMALF analysis indicates that a if a minimum flow of 70 % (0.987 m^3/s) or more of 7dMALF was set at Cornwall Road there would be limited impact on the habitat available for macroinvertebrates and fish in the Arrow River downstream of Arrowtown. Evena drop to 50% of 7dMALF (0.701 m^3/s) would only see adult trout and fast water macroinvertebrate habitat drop by more than 30%. However, the loss of habitat would be more noticeable in the mid-Arrow River reach between the State Highway bridge and Arrowtown where the habitat availability is more flow sensitive. The declining flow does also increase the risk of an increase in habitat for filamentous algae although these algae may be limited by the river shading and limited nutrients.

6. REFERENCES

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7. APPENDIX A– SITE PHOTOGRAPHS

7.1. Arrow River, new model reach

Figure 1A: Cross-section 1 – Riffle.

Figure 2A: Cross section 2 - Pool.

Figure 3A: Cross section 3 - Riffle

Figure 4A: Cross section 4 - Run

Figure 5A Cross section 5 – Run.

Figure 6A Cross section 6 – Run.

Figure 7A Cross section 7 – Riffle.

Figure 8A Cross section 8 – Riffle.

Figure 9A Cross section 9 Run.

Figure 10A Cross section 10 – Riffle.


Figure 11A Cross section 11 – Run, main gauging cross section


Figure 12A Cross section 12 – Pool.

Figure 13A Cross section 13 – Run.

Figure 14A Cross section 14 – Riffle.

Figure 15A Cross section 15 – Riffle.

Scientific name	Common name	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
Austroclima jollyae	Mayfly	94	107	133	212	133	98
Zelandobius truncus	Stonefly	94	64	33	42	16	44
Aoteapsyche colonica	NZ caddisfly	37	25	21	52	46	82
Deleatidium magnum	NZ mayfly	67	0	46	31	49	49
Coloburiscus humeralis	NZ spinygilled mayfly	0	0	16	23	20	46
Spaniocerca longicauda	Stonefly	0	0	50	11	0	39
Corynoneura scutellata	Non-biting midge	8	28	19	15	0	16
Pycnocentria evecta	NZ caddisfly	16	31	0	7	0	5
Psilochorema macroharpax	NZ caddisfly	14	36	0	0	0	0
Hydropsyche tipua	Netspinning caddisfly	0	28	0	8	0	0
Zelandobius auratus	Stonefly	0	15	0	7	0	12
Galaxias gollumoides	Gollum galaxid	0	0	0	0	25	0
Hydrobiosis chalcodes	Caddisfly	0	0	10	0	15	0
Costachorema callistum	Caddisfly	0	0	24	0	0	0
Olinga feredayi	Hornycased caddisfly	0	9	5	9	0	0
Hydrobiosella stenocerca	Caddisfly	15	0	6	0	0	0
Tanytarsus sp. EJD-2015	Non-biting midge	5	0	6	9	0	0
Deleatidium sp. Dl_S38_01	Single gill mayfly	0	0	0	15	0	5
Deleatidium sp. Dl_S38_02	Single gill mayfly	0	0	0	16	0	0
Costachorema xanthopterum	Caddisfly	0	0	0	8	7	0
Pseudoeconesus stramineus	Caddisfly	0	14	0	0	0	0

Deleatidium sp. G CRB-2017	Single gill mayfly	0	0	11	0	0	0
Hudsonema alienum	Cased caddisfly	0	9	0	0	0	0
Philorheithrus lacustris	Caddisfly	0	0	0	0	0	9
Hydrobiosella tonela	Caddisfly	0	0	6	0	0	0
Costachorema psaropterum	Caddisfly	0	5	0	0	0	0

8. APPENDIX B HABITAT PREFERENCE CURVES

8.1. Algal habitat preferences

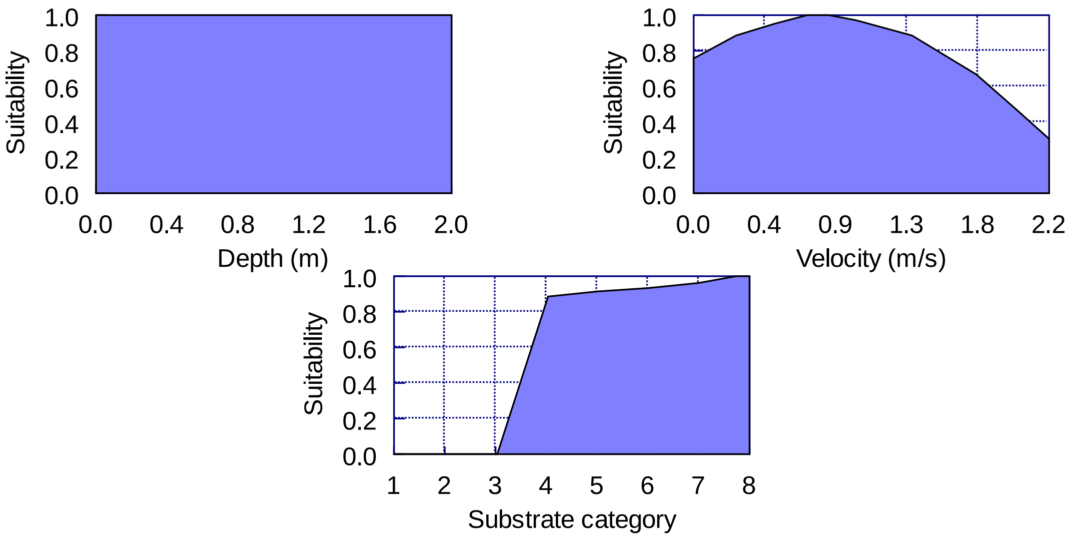

Figure B1: Habitat preferences for Phormidium.

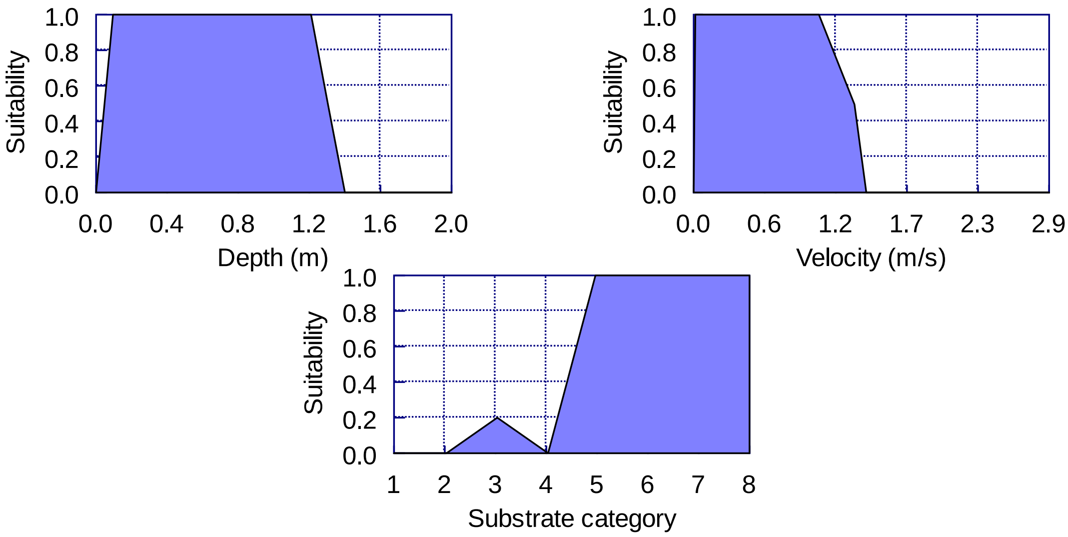

Figure B2: Habitat preferences for Didymo.

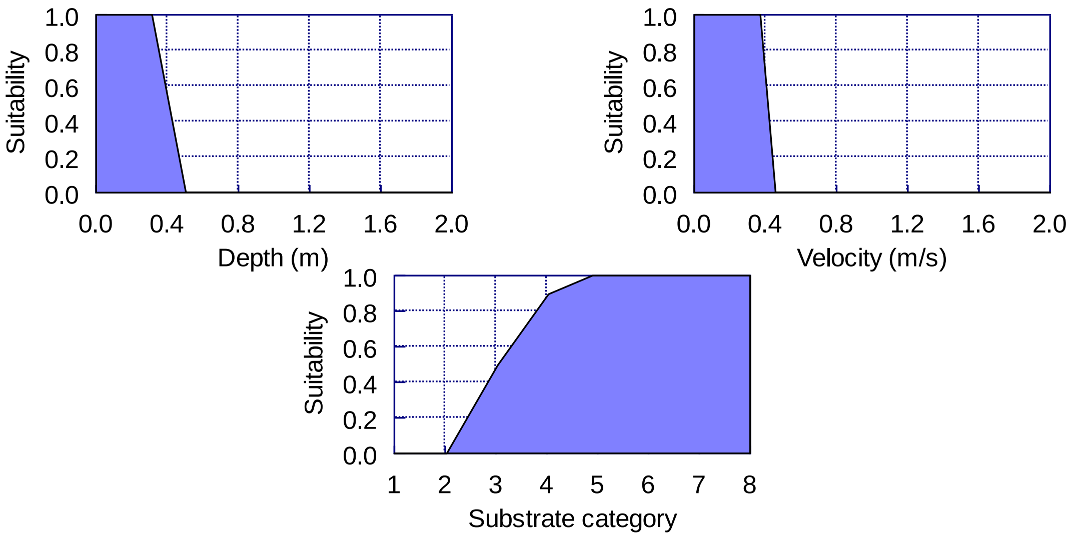

Figure B3: Habitat preferences for long filamentous algae.

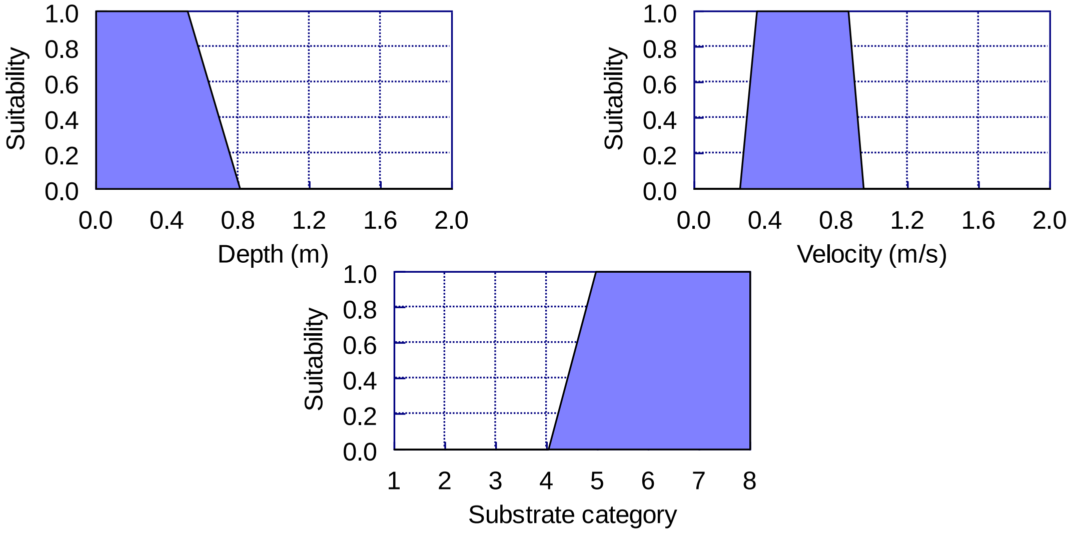

Figure B4: Habitat preferences for short filamentous algae.

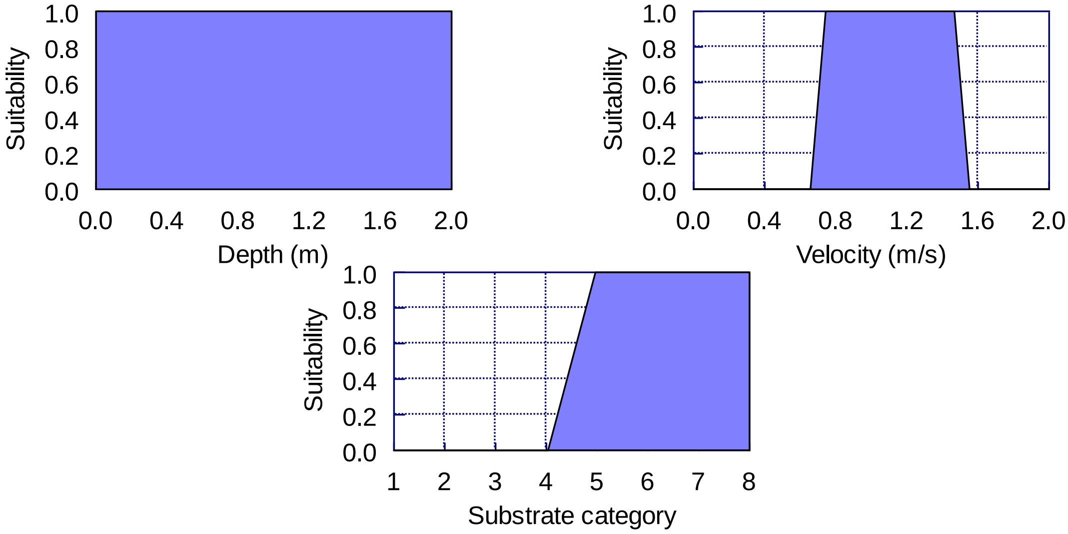

Figure B5: Habitat preferences for diatoms.

8.2. Macroinvertebrate habitat preference curves

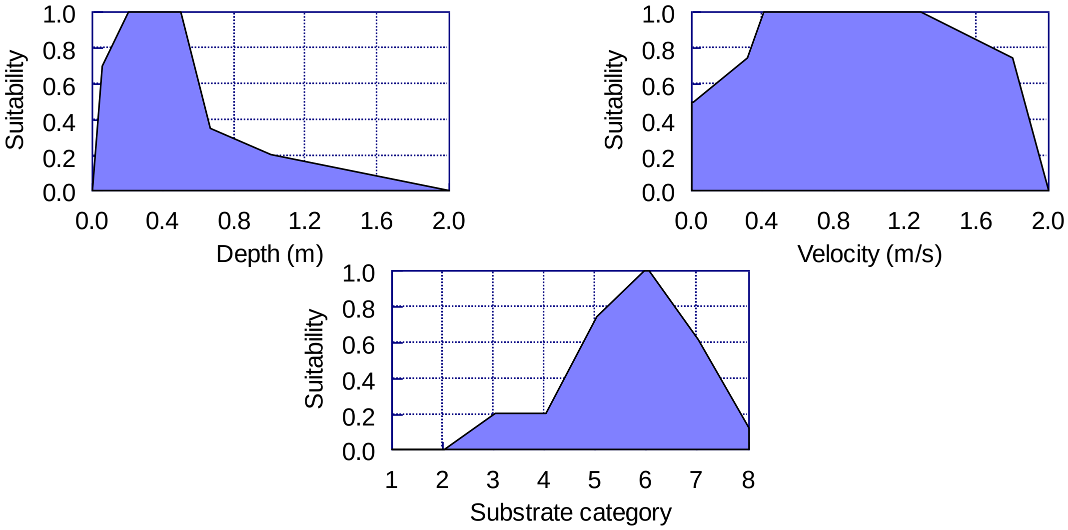

Figure B6: Habitat preferences for Deleatidium.

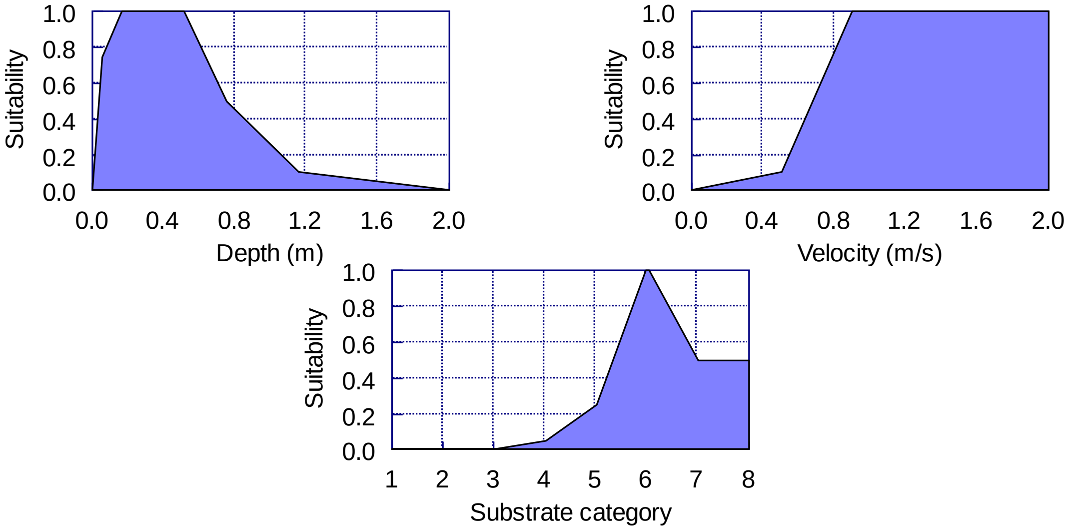

Figure B7: Habitat preferences for Hydropsyche.

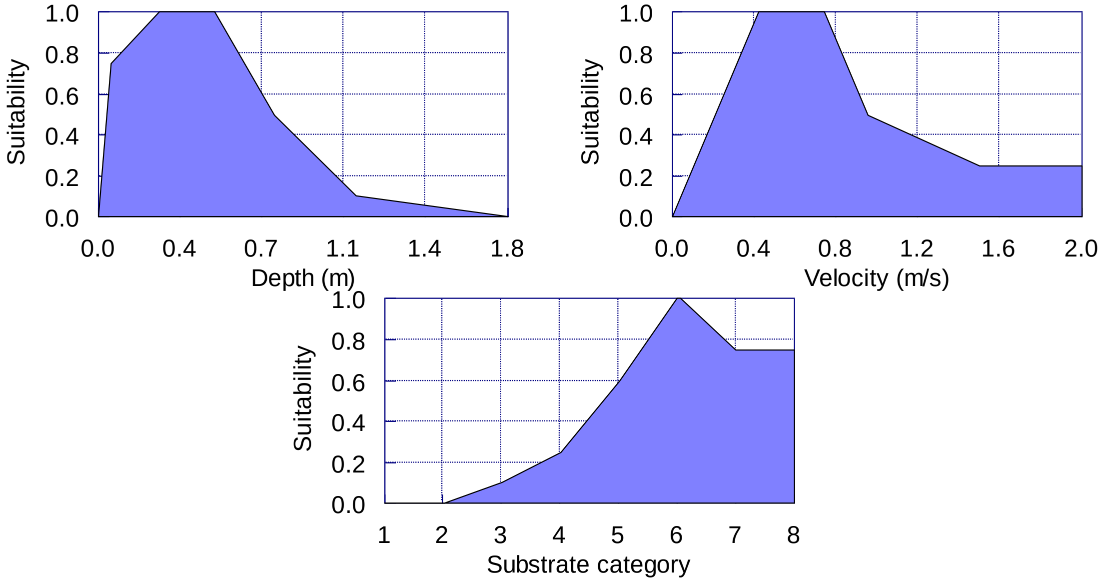

Figure B8: Habitat preferences for Pycnocentrodes.

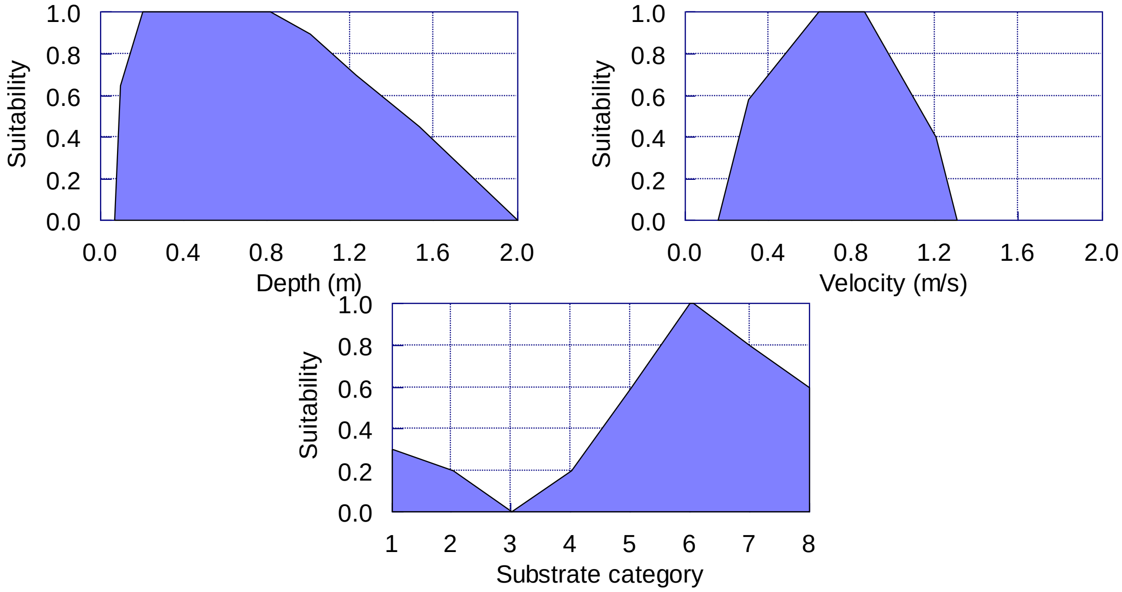

Figure B9: Habitat preferences for food producing habitat.

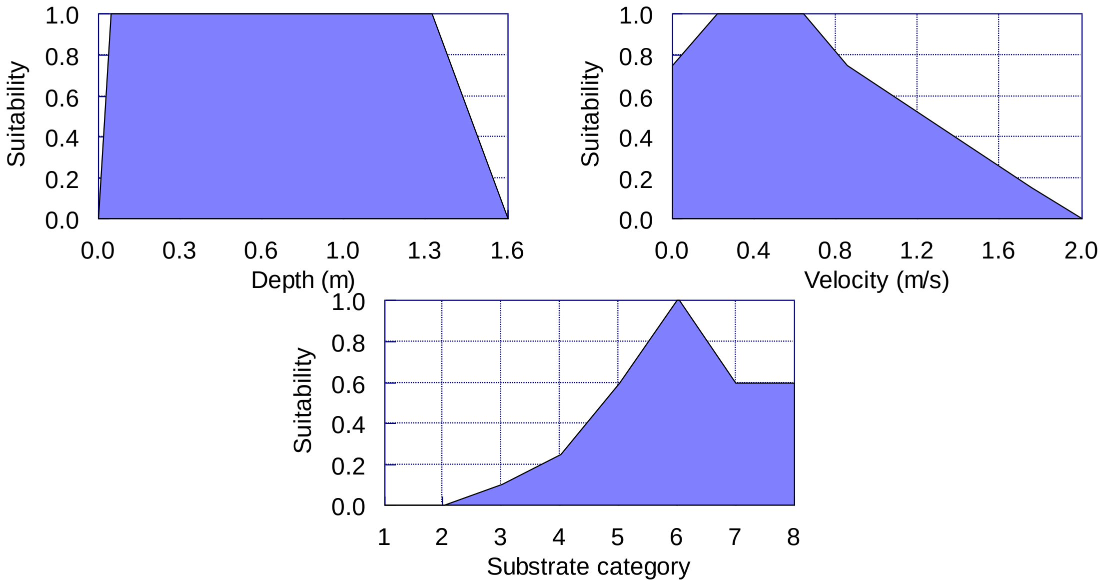

Figure B10: Habitat preferences for Olinga.

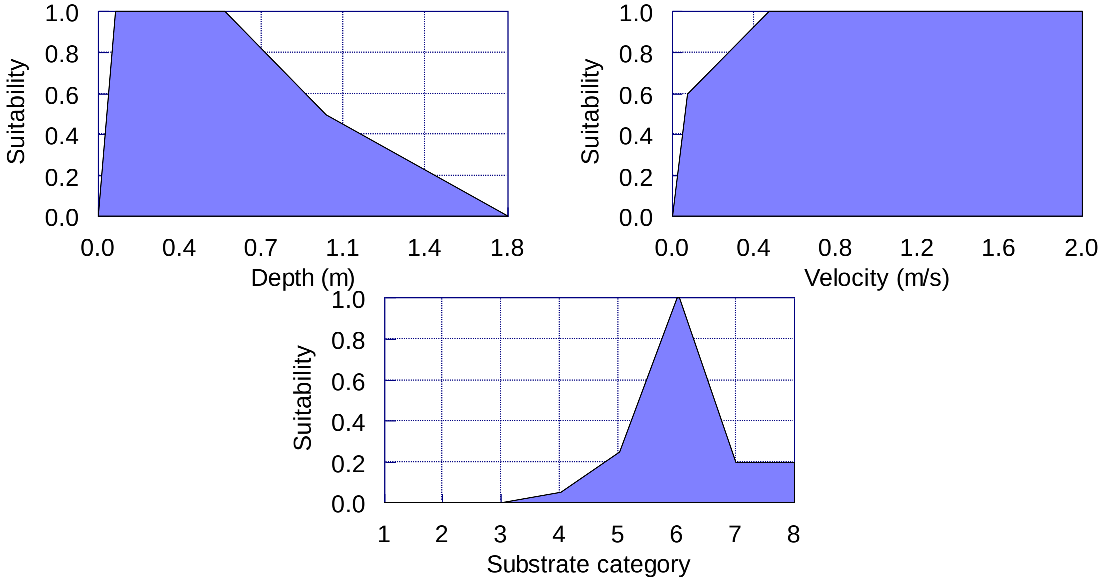

Figure B11: Habitat preferences for Hydrobiosidae.

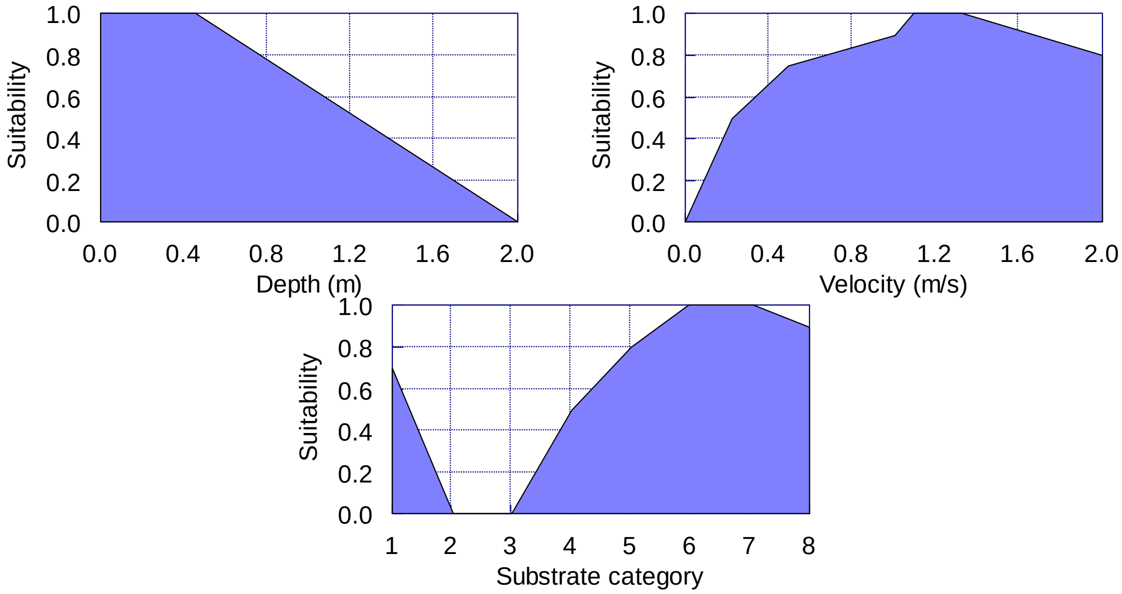

Figure B12: Habitat preferences for benthic invertebrate density.

8.3. Fish habitat preference curves

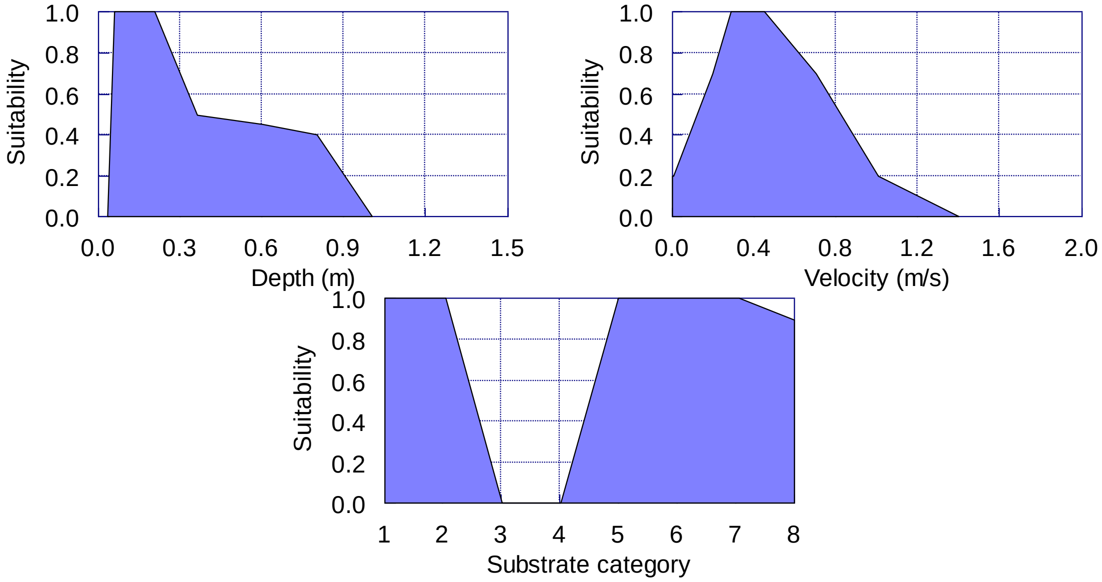

Figure B13: Habitat preferences for longfin eel < 300 mm.

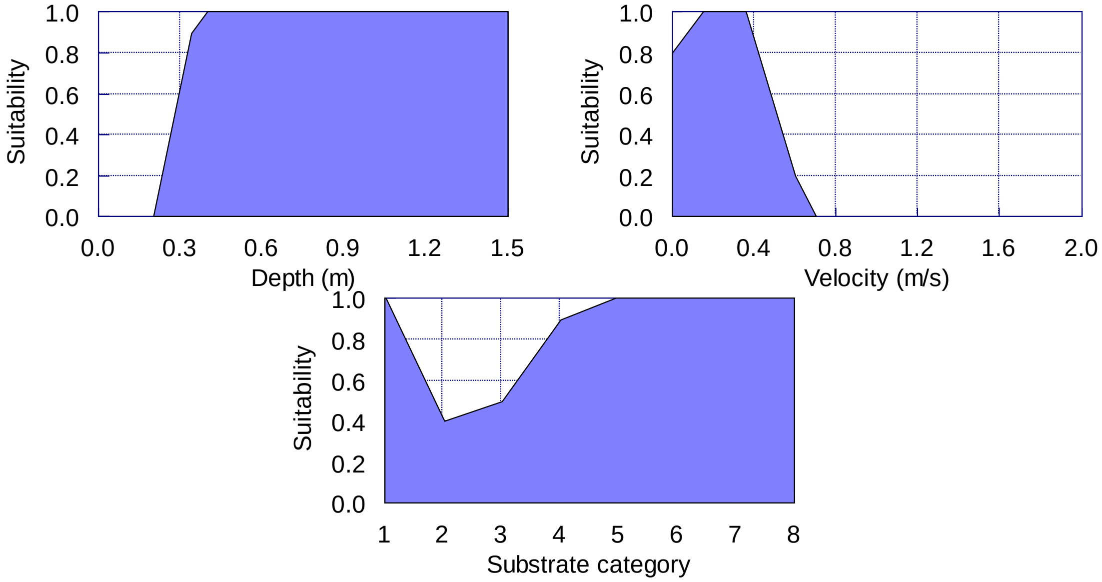

Figure B14: Habitat preferences for longfin eel > 300 mm.

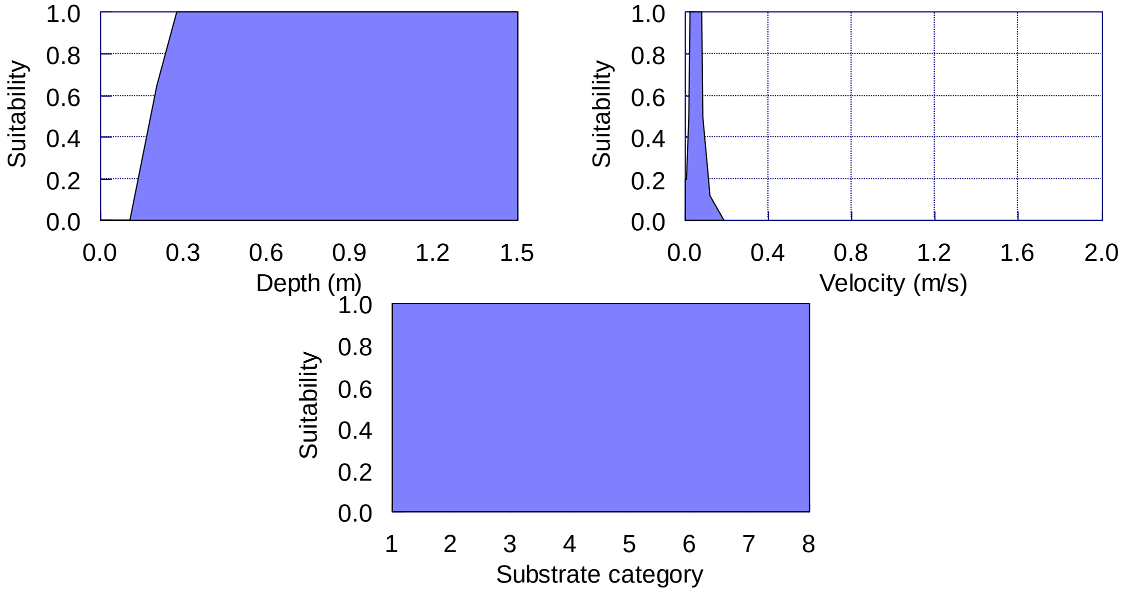

Figure B15: Habitat preferences for inanga feeding habitat.

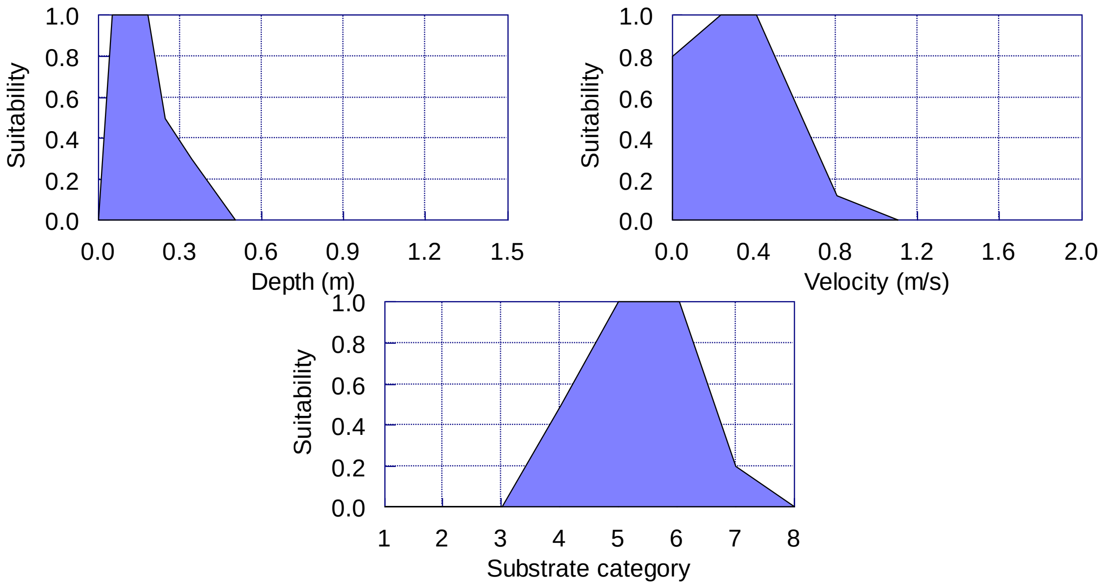

Figure B16: Habitat preferences for upland bully.

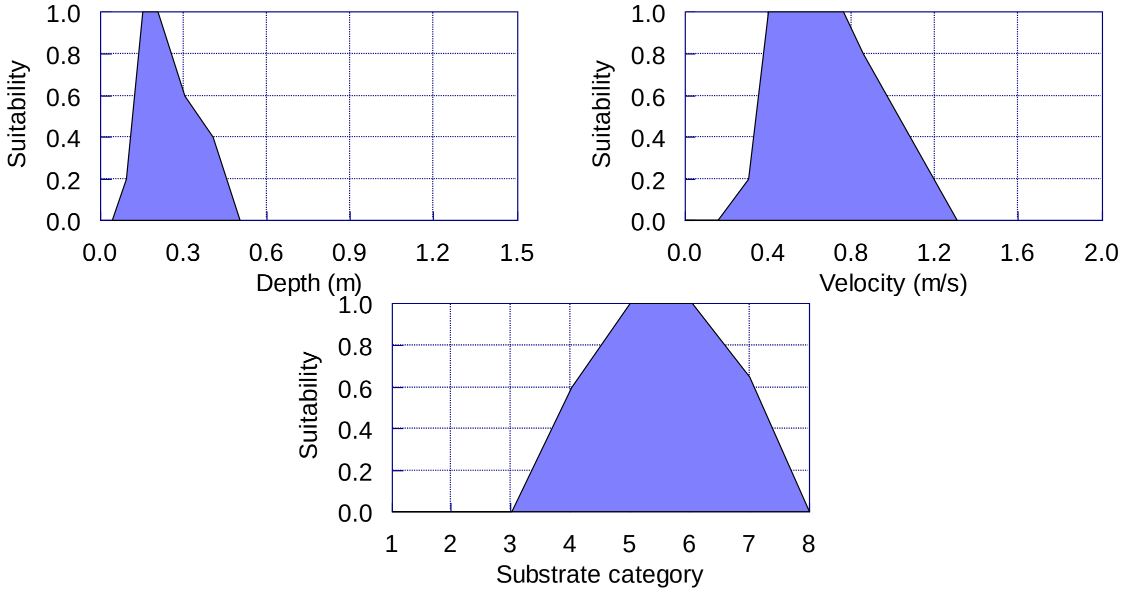

Figure B17: Habitat preferences for bluegill bully.

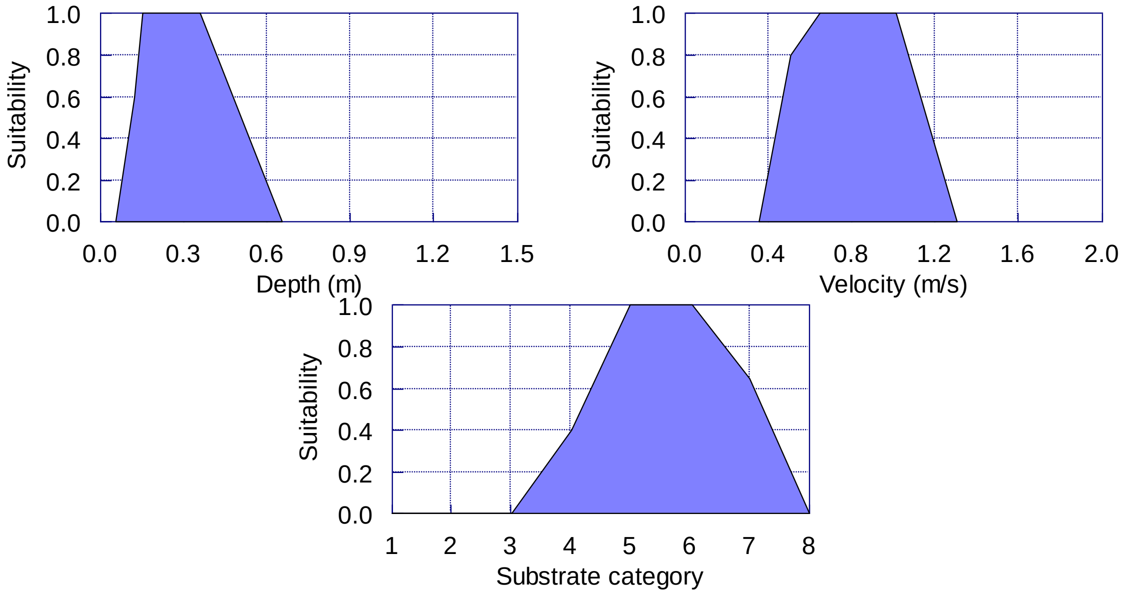

Figure B18: Habitat preferences for torrentfish.

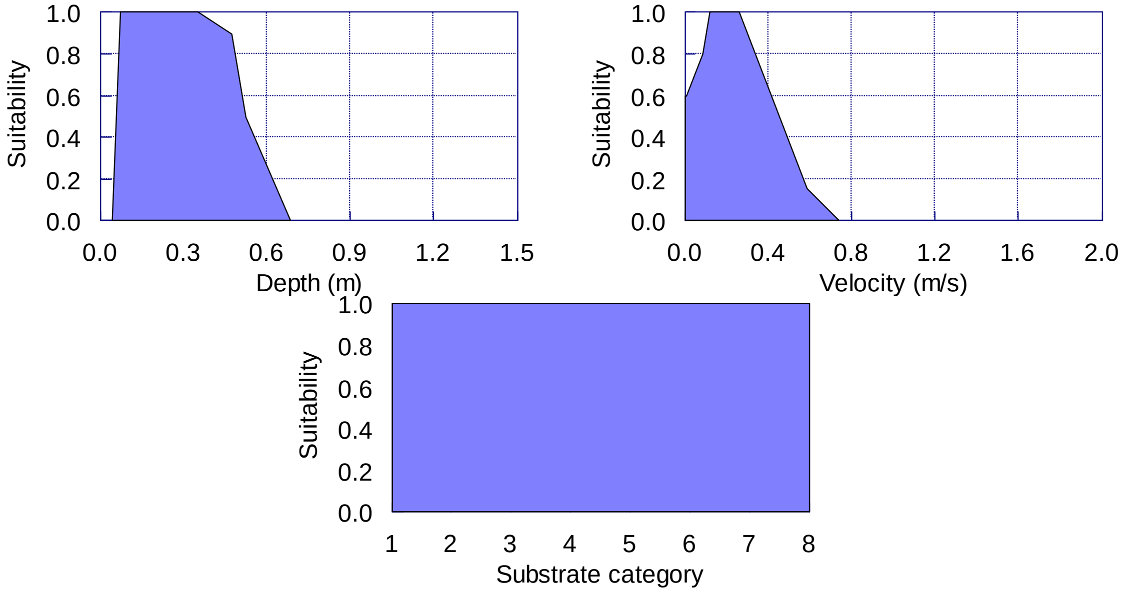

Figure B19: Habitat preferences for common bully.

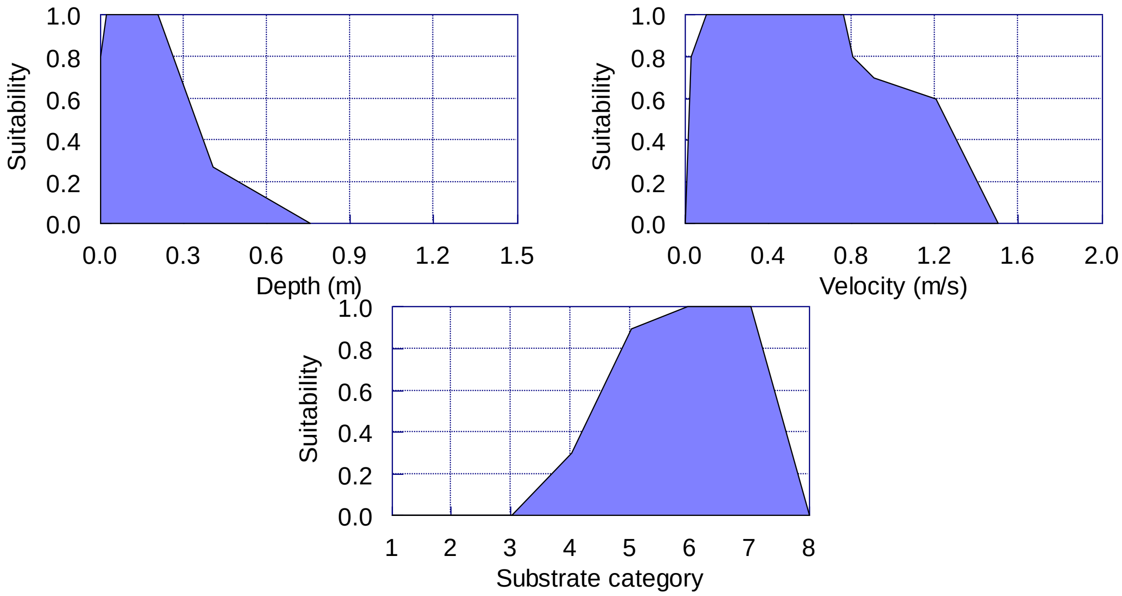

Figure B20: Habitat preferences for Canterbury galaxias.

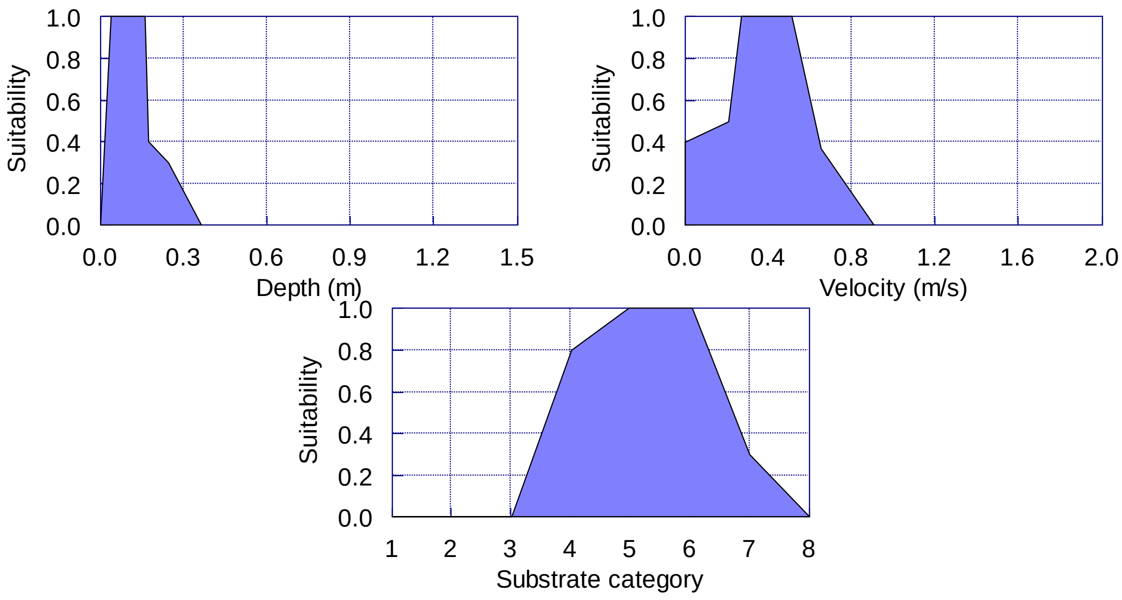

Figure B21: Habitat preferences for adult lowland longjaw galaxias.

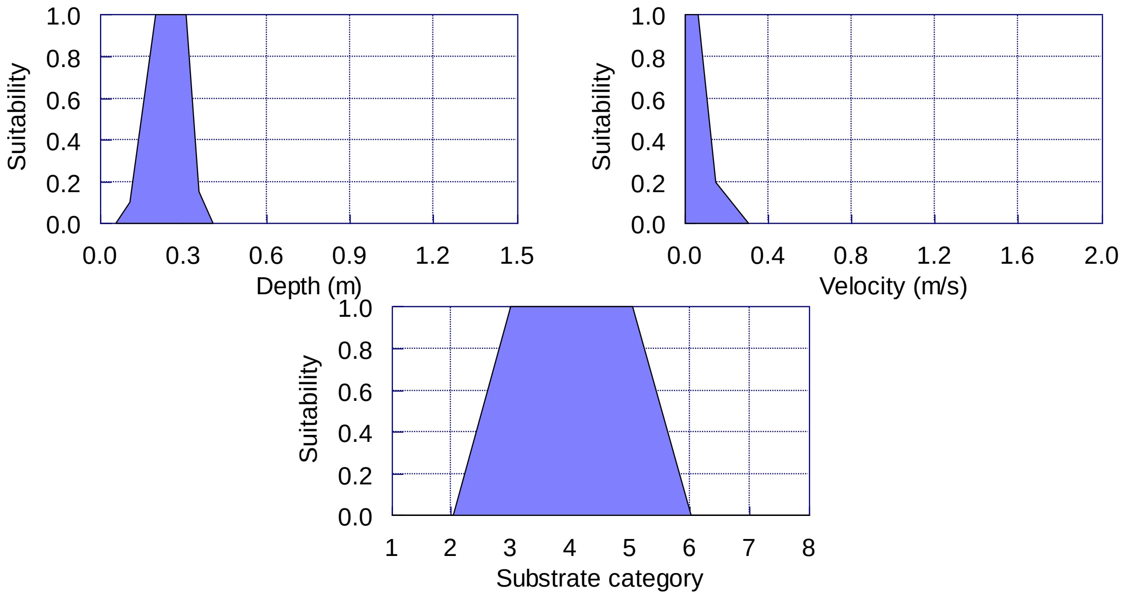

Figure B22: Habitat preferences for juvenile lowland longjaw galaxias.

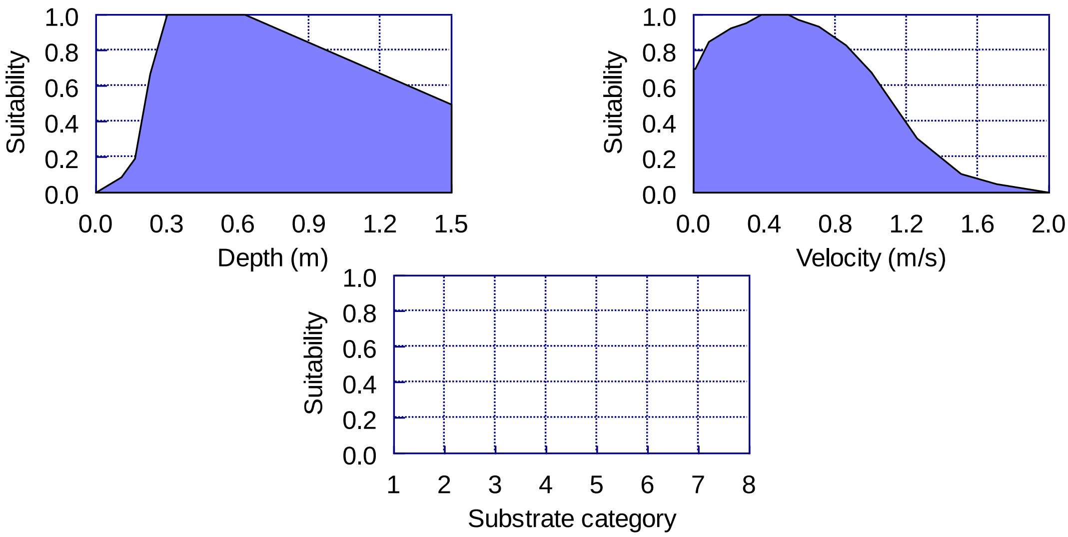

Figure B23: Habitat preferences for juvenile brown and rainbow trout.

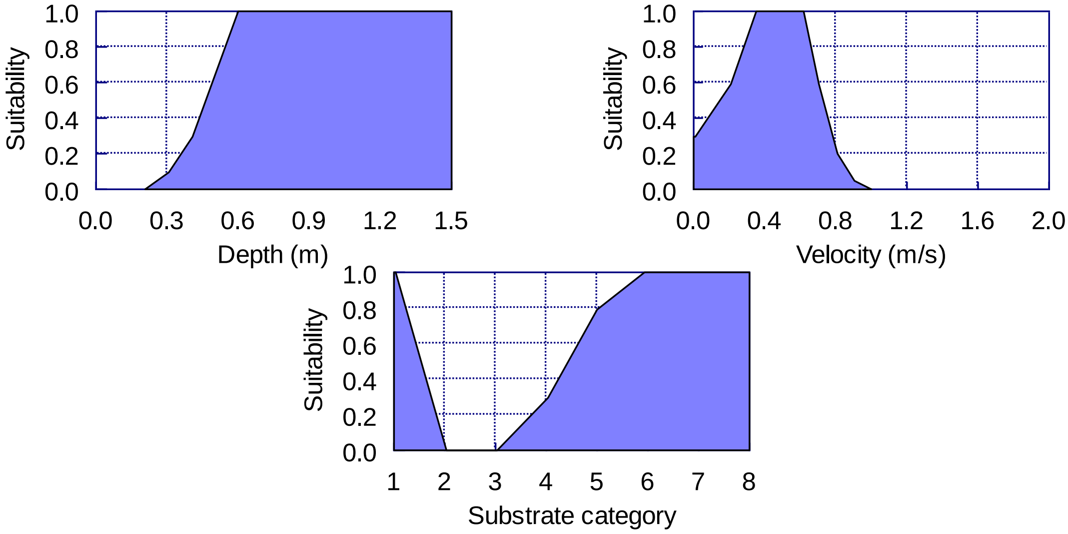

Figure B24: Habitat preferences for adult brown trout (40-65 cm).

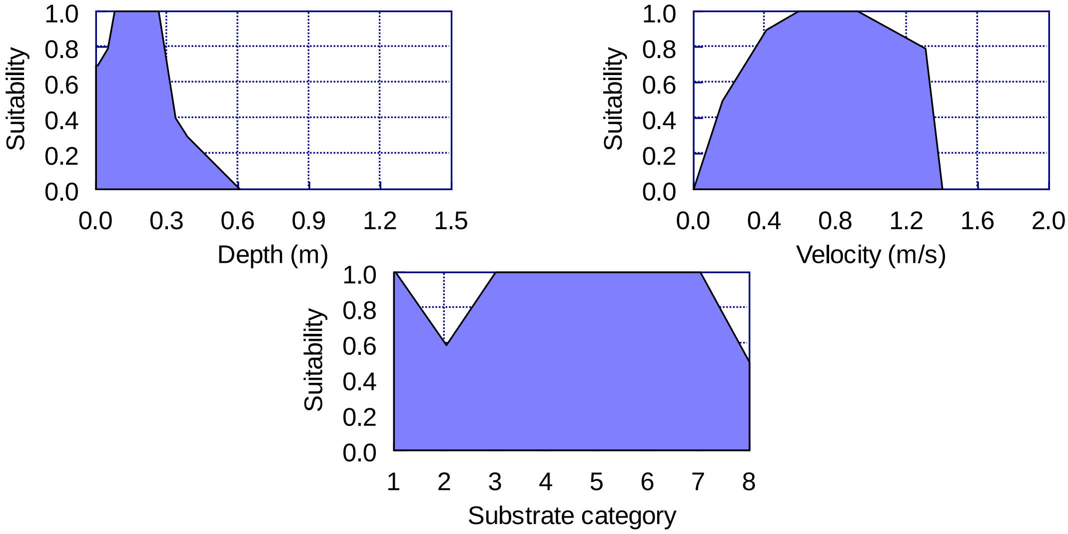

Figure B25: Habitat preferences for brown trout < 10 cm.

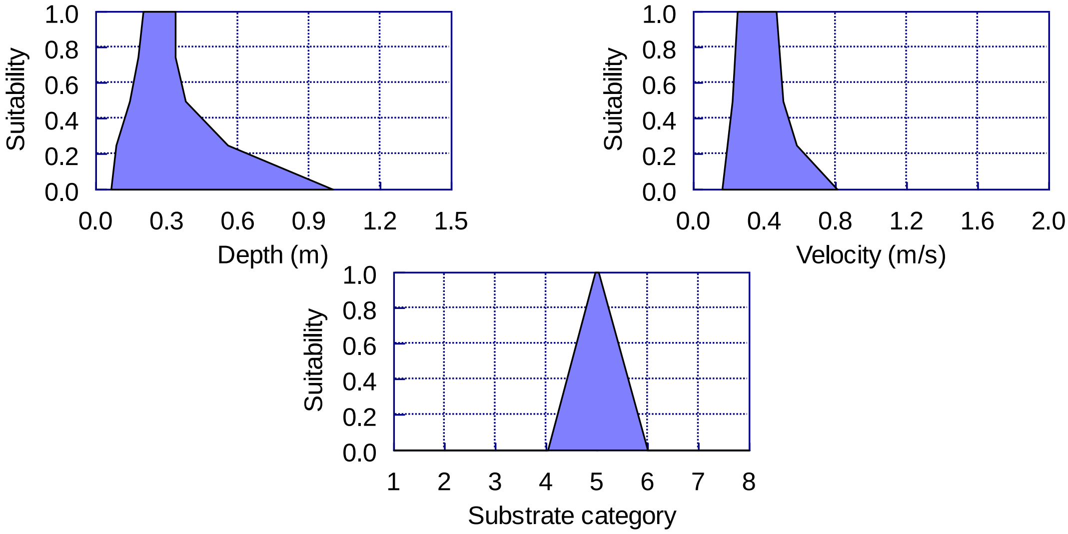

Figure B26: Habitat preferences for brown trout spawning.

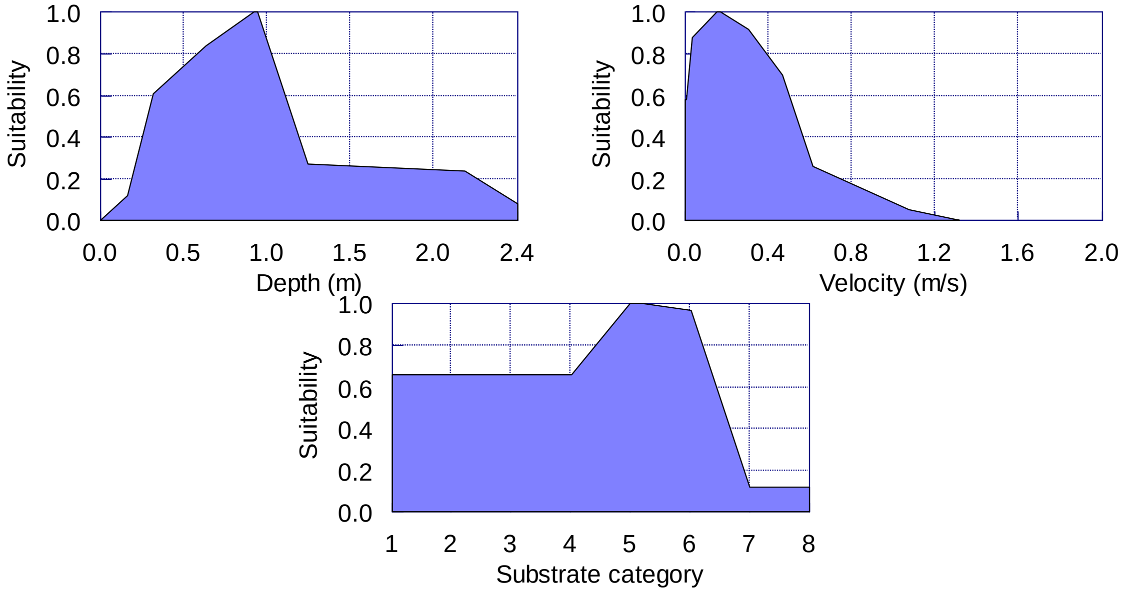

Figure B27: Habitat preferences for yearling brown trout.