BASSLINK INTEGRATED IMPACT ASSESSMENT STATEMENT

POTENTIAL EFFECTS OF CHANGES TO HYDRO POWER GENERATION

APPENDIX 8:

GORDON RIVER FISH ASSESSMENT

M. Howland[1], P. Davies[2], D. Blühdorn[1] and D. Andrews[3]

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Hydro Tasmania
the renewable energy business

1. Hydro-Electric Corporation, GPO Box 355D, Hobart TAS 7001
2. Freshwater Systems, 82 Waimea Avenue, Sandy Bay, TAS 7005
3. Inland Fisheries Service, 6B Lampton Avenue, Derwent Park, TAS 7009

EXECUTIVE SUMMARY

The fish communities of the middle Gordon River, its tributaries and a number of out of catchment reference sites were sampled during 1999-2000 as part of the Basslink environmental impact assessment. Basslink consists of an undersea electricity cable across Bass Strait which will connect Tasmania to the National Electricity Market and therefore has the potential to affect the operational patterns of the Tasmanian electricity generating system, including the Gordon Power Station. This study is one of a series of studies that forms the Integrated Impact Assessment Statement for the Basslink proposal.

The aims of the study were to:

- document the present fish populations of the Gordon River downstream of the power station;
- identify the major factors controlling fish distribution within the Gordon River;
- identify an existing 'zone of impact' associated with the power station with reference to tributaries and out-of-catchment control sites;
- predict the likely response of the Gordon River fish fauna to changed power station operations under Basslink;
- identify potential measures that may be employed to ameliorate negative impacts;
- identify opportunities or potential benefits that Basslink may provide; and
- detail a monitoring program that would properly document the impacts of Basslink and assess the effectiveness of any mitigation that may be undertaken.

The surveys showed that the Gordon River, particularly between the Olga River and the Gordon Dam, is substantially modified with respect to fish fauna. The regulated flow regime, largely due to the operations of the Gordon Power Station, is a major factor controlling the fish community structure in the middle Gordon River. The mechanisms by which the existing flow regime affect fish are:

- habitat availability and quality are reduced through high flows (habitat availability for native fish is much lower at high flows) and regular dewatering. The utilisation of these habitats depends on colonisation rates for both fish and their invertebrate food supply;
- reduced food supply due to lowered macroinvertebrate abundance, and access by fish to the food resource at periods of high flow.
- reduced fish migration opportunities affect not only the Gordon River channel, but have a great influence on the fish fauna of adjoining tributaries, particularly those upstream of Ewarts Gorge, including the Denison River;
- rapid dewatering of the hydro-peaking zone leads to the potential for fish stranding. The present rates of dewatering are far in excess of those which would occur under natural flow conditions and to which the fish would be adapted
- the reversed seasonality of flows, due to the majority of power station discharges occurring during the naturally driest months of the year (summer-autumn). This produces high flow velocities at gorge sites and may limit fish migration opportunities during important migratory periods. The effect of reversed seasonality on spawning and migration cues is undocumented but suspected to be significant; and
- brown trout appear to be less sensitive to the altered flow regime of the Gordon River. This, combined with the fact that they have direct access to spawning areas in tributaries without needing to migrate to the sea, leads to domination of the upper sections of the middle Gordon River by this species. Brown trout have adverse effects on the native fish fauna through direct predation and competition for resources.

In comparison to present operations, Basslink is predicted to increase short-term hydro-peaking, resulting in more frequent fluctuations over the full range of power station operation. The proportion of time at high flows (ie. 3 turbines) is expected to increase, as will the proportion of time at very low flows. Basslink is expected to lead to regular shutdowns of the power station, particularly on weekends. These changes are expected to result in several impacts:

- reduced habitat availability/quality in the Gordon River channel through more frequent flow fluctuations and dewatering;
- reduced utilisation by fish of new habitats that may become available during the hydro-peaking cycle as there is less time to do so;
- increased potential for fish stranding in areas subject to dewatering as the frequency of such events is increased; and
- reduction in invertebrate food supply for fish.

These effects are likely to result in a further, but possibly unmeasurable, reduction of an already depauperate fish fauna in the upper middle Gordon.

Importantly, Basslink may improve opportunities for upstream migration of native diadromous fish species to both the middle Gordon River and its upper tributaries. This is seen as a potentially important positive effect of Basslink as the present operations of the power station appear to be precluding galaxiid recruitment to many of the middle Gordon River tributaries. To have a flow regime that is conducive to regular recruitment success in these waterways through more regular low flow periods would provide a highly valuable offset to the negative influences of Basslink. Ironically, increased fish migration would also lead to temporarily increased fish stocks in the main channel of the Gordon River and would increase the potential for fish stranding in some areas. It is envisaged therefore that Basslink will lead to negative impacts on the fish communities in the Gordon River itself, but may offer an improvement to the wider catchment through increased fish migration opportunities to tributaries.

Mitigation of the negative influences is possible to some degree. However, it unlikely that the negative effects of increased flow fluctuation can be completely ameliorated. The most promising mitigation is to reduce the potential for stranding through stepped decreases or partial ramping of flows during shutdown events. This would provide cues to fish that would enable them to evacuate the hydro-peaking zone before full dewatering of these habitats. The full ramping down of flows over long time periods is not recommended due to the potential for prolonged high baseflows, the consequent reduction in useable habitat area and negation of the fish migration benefits offered by low-flow events. Similarly, a minimum environmental flow would need to be very low (ie. less than ~10 cumecs) in order to maximise the probability of fish passage past gorge sections. A minimum environmental flow may have benefits, particularly in maintaining a healthier macroinvertebrate population (and hence food supply for fish) and may possibly offer greater areas for fish refugia. A minimum environmental flow, however, would not be expected to fully mitigate the effects of increased hydro-peaking.

Monitoring of the effects of Basslink and the effectiveness of any mitigation put in place will be essential. A substantial baseline has been established as part of the 1999-2000 surveys. Follow-up electrofishing surveys over a three-year period would establish the degree of inter-annual variation in fish stocks prior to the introduction of Basslink. Repeat surveys should be taken at numerous sites on the Gordon River as well as reference sites during December and April for each of these years. Surveys should record at a minimum, the catch per unit effort for each fish species and the lengths of each individual. A further 3 years of monitoring is recommended post-Basslink to fully evaluate these impacts and to confirm the conclusions of this report. Collection of such data would allow for thorough Before-After-Control-Impact statistical analyses.

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1 INTRODUCTION

This report is one of a series of reports dealing with the potential impacts of the proposed electricity inter-connector cable (Basslink) between Tasmania and Victoria. The Basslink cable itself does not have a direct impact on the Gordon River. However, the connection of the Tasmanian electricity grid to the National Electricity Market (NEM) is expected to alter the way in which Tasmanian hydro-electric power stations are operated. Appendix 1 of this report series – Scoping Report: Basslink Aquatic Environmental Project (Hydro Environmental Services, 2000) deals with the modelling of these new operating practices and highlights the Gordon River downstream from the Gordon Power Station as an area susceptible to environmental impact which may result from changes to operational practices.

The Gordon Power Station presently operates to satisfy both base-load and peak power demand and is integral to maintaining a secure supply of electricity in Tasmania. This station is operated more during the drier months of the year in order to supply power that may not be available from smaller hydro-electric storages in other parts of the state. Consequently, the middle Gordon River is highly regulated and has a hydrology typified by reversed flow seasonality, with frequent, often diurnal, peaks in discharge. The river is also subject to higher median flows than natural produced by prolonged periods of high flows. Conversely, the power station discharge shuts down regularly, hence dropping the flow below natural minima for extended periods of time. The power station discharge currently fluctuates between these extremes at far greater frequency than is natural and at a rate which is several orders of magnitude greater than natural. It is clear that the hydrology of the river has been highly modified and that the instream biota will be similarly affected.

The connection to the NEM via Basslink is expected to result in more cycling of power stations flows between zero (shutdown) and maximum capacity (‘full gate’). Additionally, it is expected that there will be a higher frequency of both startup and shutdown events over shorter time-scales than present. This represents a shift towards a more typical operation of a hydro-electric power station in a mixed generator environment.

The types of impacts expected on fish under hydro-peaking conditions are well studied and relate to:

- reduction in habitat quality and availability
- reduction in food supply (particularly macroinvertebrates)
- rapid dewatering of habitats leading to stranding; and
- potential reduction in migration and recruitment opportunities due to a less suitable flow regime.

These types of impacts may lead to reduced abundance and diversity of fish species, either through direct or indirect mortality, changes in the population structure of these communities, particularly due to recruitment failure, and to altered behavioural responses including changes in predator-prey relationships. For the fish fauna of the Gordon River, the introduction of a more variable flow regime has the potential for further negative impacts and it has therefore been identified as requiring investigation under the Integrated Impact Assessment Statement, which forms part of the Basslink approvals process.

1.1 Objectives

The aims of this study were to provide a sufficient understanding of the Gordon River fish fauna, with particular reference to the present impacts of the Gordon Power Station such that a prediction of the likely effects of Basslink can be made. Specifically, the study aims to:

- document the present fish populations of the Gordon River downstream of the power station;
- identify the major factors controlling fish distribution within the Gordon River;

- identify an existing 'zone of impact' associated with the power station with reference to tributaries and out-of-catchment control sites;
- predict the likely response of the Gordon River fish fauna to changed power station operations under Basslink;
- identify potential measures that may be employed to ameliorate negative impacts;
- identify opportunities or potential benefits that Basslink may provide; and
- detail a monitoring program that should be undertaken to properly document the impacts of Basslink and assess the effectiveness of any mitigation that may be undertaken.

2 METHODOLOGY

2.1 Site selection

Fish surveys were conducted at numerous sites within the Gordon River itself, in tributaries of the Gordon River and in three catchments believed to be outside of the influence of the Gordon River. The study area within the Gordon River extended from the Gordon Dam wall to the mouth of the Franklin River. A full list of sites sampled is detailed in Attachment 8.1. Locations of sites are shown in Figure 1.

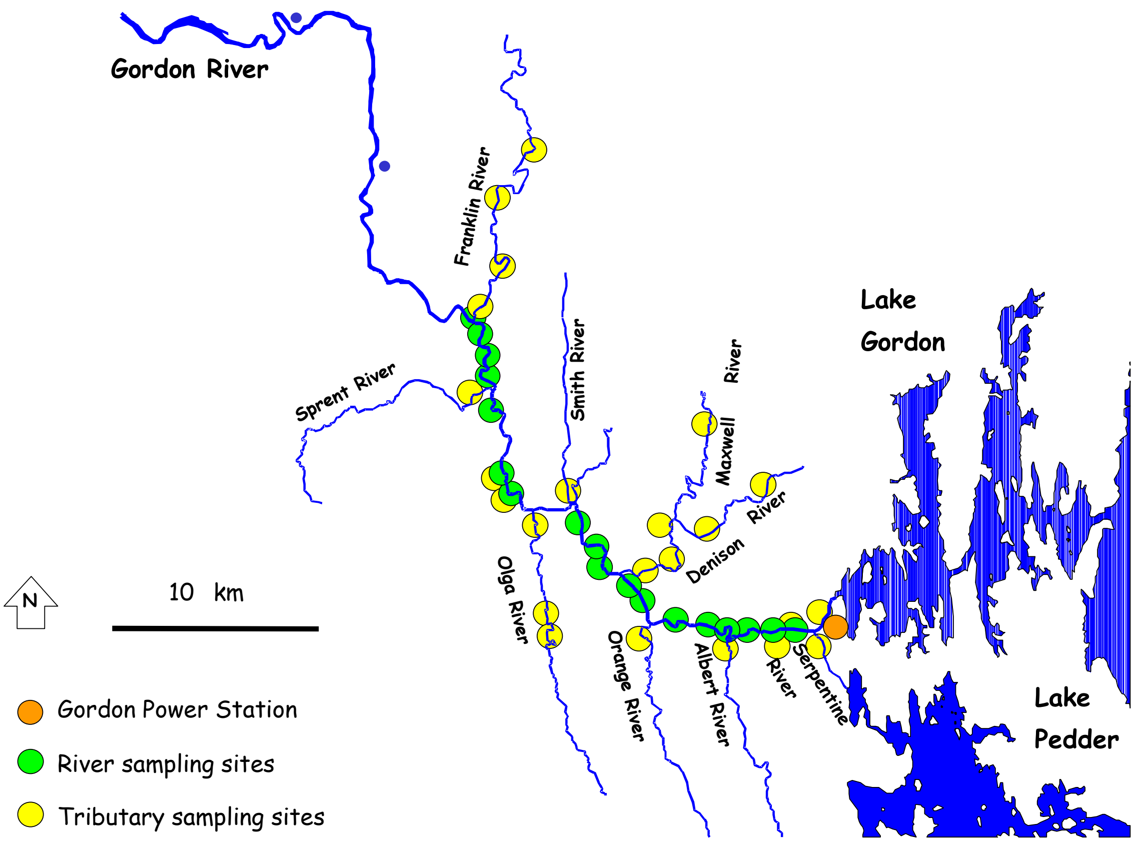


Figure 1. Fish sampling site locations in the Gordon and tributary streams.

Sites were selected on the basis of:

- zone as defined primarily by fish migration barriers (discussed in Section 3.1);
- concordance with other multi-disciplinary studies;
- accessibility. The only access to most of the study area was via helicopter and necessitated landing on dewatered cobble bars during power station shutdowns. Sites that could be accessed easily from such areas by wading or small boat were targeted to ensure maximum coverage of sites during field trips; and
- diversity of accessible habitat. (Where numerous sites within a zone were accessible, sites were prioritised in accordance with the diversity of habitats available for sampling to increase the probability of recording all species present).

Three out-of-catchment river systems were investigated to establish the various factors affecting fish distributions in west coast rivers and to provide a baseline for a future monitoring program. Three catchments were selected:

- Birchs Inlet catchment, comprising the Sorrell River and a major tributary, Pocacker River. These waterways drain into the southern end of Macquarie Harbour approximately 15 km from the mouth of the Gordon River. Although not strictly 'out-of-catchment' and therefore possibly influenced by changes in the Gordon fish fauna, it is expected that the Birchs Inlet waterways would be subject to the same timing and abundance of galaxiid migrating stock and would act as a reference to compare recruitment success over time. Two sites were selected in this catchment downstream of any major fish migration barriers;
- Port Davey catchment, comprising the Hardwood, Crossing and Davey Rivers. The headwaters of the Hardwood River originate in the same valley as the Olga River but flows southwards instead of north into the Gordon River. The Davey River catchment is completely unregulated and is the largest such river in south-west Tasmania. This entire catchment is trout-free and hence allows the impact of trout in other catchments to be isolated through comparison with the Davey catchment. A variety of sites were selected to encompass lower reaches as well as areas above potential fish migration barriers; and
- Henty River. This river was selected as its flow is influenced by minor dams in the upper catchment and by the Lake Margaret Power Station that is unlikely to change operational patterns as a result of Basslink. This power station, on the tributary Yolande River, operates as a run-of-river station that essentially mimics natural flows. Sites on the Henty River were selected both upstream and downstream of the power station influence.

2.2 Fish surveys

Backpack electrofishing was undertaken at all sites and formed the basis of the survey methodology. Electrofishing is widely used as a standard method for conducting fish surveys in Tasmanian waters and has the advantage of retaining a reasonable catch through a rapid survey methodology whilst producing minimal mortality rates in the captured fish.

The biases of electrofishing are well known and whilst no gear type is ideal for all situations, this method has the most potential for obtaining a representative sample for the sites surveyed. The method is limited in the effective area fished and the depth of water that can be effectively fished. The effective area is dependent on the electrical conductivity of the water, the species' physiology and the size of the fish. Generally, larger fish are more susceptible to electrofishing than smaller ones. The zone of galvanotaxis (attraction of the fish) is usually less than 2m from the centre of the electrofisher anode.

The main limitation with backpack electrofishing is the depth that can be fished. This is limited by the freeboard of the operator's waders and is typically around 1m. Effective fishing depth is also influenced by the operator's ability to see fish that are stunned at depth. In all of the sites sampled, the water was tannin stained, which limited visibility to less than 1.5m. In limited cases fish were drawn up from deeper waters by following drop-offs and logs accessed from shallower water or from the bank.

Boat-based electrofishing was not undertaken due to the logistical difficulties in deploying such a unit in the river and the problems with comparing catch per unit effort (CPUE) between sites that could and could not be accessed by a boat-based unit.

Electrofishing effort was standardised by shocking time as counted by the backpack electrofisher's battery timer. Shocking time is not continuous at a site as ambush type techniques are used to maximise catch rate, increase the diversity of fish species captured and to ensure a representative sample was taken. An effort was made to ensure that at least 1200 seconds (20 minutes) of actual shocking time had elapsed at each site. This typically equated to between 1 and 2 hours of on-site fishing. An effort was also made to ensure that all the habitats fishable by this method at a site were included in the survey.

Initially, trials using gill nets, fyke nets and baited traps in addition to electrofishing were conducted. A very small number of fish were caught by any of these additional methods which proved largely unsuccessful even in areas where electrofishing was productive. The only exception to this was the capture of a single brown trout at Site 75 in a gill net where electrofishing did not return a result. Due to the difficulties in comparing CPUE for different sampling methods, catches made with this additional gear are not reported in the CPUE summaries, however they are included in presence/absence analyses.

Captured fish were anaesthetised using appropriately diluted Aqui-S solution, identified, measured for length to the nearest mm and released. Type specimens for unidentifiable species were retained and later identified by the Inland Fisheries Service.

All catch and effort data were recorded on site (see proforma – attachment 8.2) and later entered into a Microsoft Access database. Table 2-5, in section 3.1, list the species sampled, the sampling locations and the numbers caught.

2.3 Catch data analysis

Specialised queries were written in Microsoft Access to allow catch per unit effort (CPUE) summaries to be produced for a variety of different site groupings. All CPUE figures are calculated as the total catch (each species treated separately) for a site (or group of sites) divided by the total electrofishing battery time and standardised to 1200 seconds (20 minutes) shock time. ie:

$$CPUE_{(spp1,site1)} = \frac{\text{Pooled number of individuals}_{spp1}}{\text{Pooled electrofisher shock time (s)}_{site1}} \times 1200$$

Hence, all CPUE figures presented in this report are the expected numbers of fish that would be caught if all electrofishing shots were of 1200 seconds fishing time. The mean shocking time was 1328 secs per site, per visit.

Ordination of site fish community data, ANOVA and other statistical analyses were conducted using PRIMER and Microsoft Excel using CPUE data produced in this manner.

2.4 Habitat availability

An Instream Flow Incremental Methodology (IFIM) study was undertaken to determine the likely changes in habitat availability for those fish species whose habitat requirements were known.

The core element of this methodology is an estimation of physical aquatic habitat available within the river at specific discharges, which can then be used to develop relationships between a measure of the habitat availability for key species (weighted useable area, WUA) and total river (including power station) discharge (Q). The WUA for a given discharge is determined through a combination of hydraulic modelling and the combination of habitat preference curves with empirical and/or simulated site hydraulic and substrate data. These preference curves are species-specific and relate water velocity, substrate composition, water depth and instream cover to the relative suitability for those species. Hydraulic modelling is used to assess hydraulic and substrate conditions at discharges for which empirical data could not be collected. Davies and Cook (2001) describe the methods for this process in detail in Appendix 7 of this report series – Gordon River Macroinvertebrate and Aquatic Mammal Assessment.

For this study, the habitat preference curves for the species listed in Table 1 were utilised and predictions of WUA were made using flow time-series derived from the outputs of the Gordon River hydrological model (Appendix 2 of this report series – Gordon River Hydrology Assessment (Palmer *et al*, 2001)) and the outputs of the TEMSIM power system modelling software (Appendix 29 of this report series (Connarty, 2001)). This allowed analysis of habitat availability time-series for each of the species for the predicted Basslink-driven flow regime.

Table 1. Data source(s) for habitat preference curves used in this study.

Species	**Data Source(s)**
Climbing galaxias (*Galaxias brevipinnis*)	Jowett 1992 and unpub. data
Spotted galaxias (*Galaxias truttaceus*)	Modified after Jowett, Davies unpub. data
Common jollytail (*Galaxias maculatus*)	Jowett 1992 and unpub. data
Ammocoetes (lamprey juveniles of *Geotria australis* and *Mordacia mordax*)	Modified after Jowett, Davies unpub. data
Short-finned eels (*Anguilla australis*)	Jowett 1992 and unpub. data
Brown trout (*Salmo trutta*)	Raleigh *et al.* 1986

The habitat preference curves for those species listed in Table 1 are presented in Attachment 8.4 of this report.

3 PRESENT CONDITIONS

3.1 Overview of the Gordon River fish fauna

Prior to this study, there was a paucity of information relating to the fish fauna of the Gordon River. A reasonably extensive series of invertebrate samples was collected as part of the lower Gordon scientific surveys in the mid-1970s (Christian and Sharp-Paul 1979). Despite this, minimal fish surveys were conducted during this time, and were concentrated in the lowest reaches of the river (IFC 1974; Fulton 1976, 1977). No targeted biological sampling of the area has been conducted at any other time, with the exception of the invertebrate work undertaken by Davies *et al.* (1999) which did not include fish.

Limited data on whitebait and trout catches were available from surveys conducted in the lower Gordon during the late 1980's by IFS staff. Whitebait runs are upstream migrations of juvenile galaxias and other fish species which occur in the lower reaches of Tasmanian rivers during late winter to early summer. The IFS data showed that whitebait runs include juvenile *Galaxias maculatus* (the common jollytail), *G. brevipinnis* (climbing galaxias) and *G. truttaceus* (spotted galaxias) and *Neochanna cleaveri* (Tasmanian mudfish). It was inferred therefore, that these species were resident as adults in the middle Gordon and Franklin catchments. All of these species are common and abundant in rivers of the West Coast. Trout catches indicate a significant population of the introduced brown trout (*Salmo trutta*), with occasional catches of other exotic salmonid species, including rainbow trout (*Oncorhynchus mykiss*) and Atlantic salmon (*Salmo salar*). The latter are likely to have originated as escapees from aquaculture facilities in Macquarie Harbour. The Gordon River Fishing Association operates a shack at Boom Camp in the tidal reaches of the Gordon River. The shack has a log book in which users are encouraged to record catch details such as species count and size estimates, however, the quality of these data are unknown and have not been analysed for this report.

Observations made in other Tasmanian rivers (eg. Davies 1989, Howland and Davies pers. obs., IFS unpub. data), indicate that deeper pool-run habitats tend to be dominated by larger brown trout and/or eels (*A. australis*). Greater abundances of native fish and juvenile brown trout tend to be found in channel margin habitat in pool-runs or shallower habitat in riffles, often associated with snag or cobble-boulder substrates. Fish abundance is probably highest at the channel margins, particularly for native fish, associated with snag shelter and/or bar habitats adjacent to areas of higher water velocity.

Davies (1989) observed a negative correlation between distance from the sea and fish diversity in Tasmanian rivers, due to the higher abundance of migratory native fish closer to tidal waters, and greater abundance of the exotic brown trout upstream. This was also observed in NSW rivers by Gehrke and Harris (2000). Thus, Tasmanian rivers tend to have higher diversity and abundance of native fish (galaxiids etc.) closer to the sea, but become dominated by brown trout and eels in the middle to upper reaches.

Surveys for the present study were conducted between October 1999 and September 2000. Sites were sampled in the Gordon River downstream of the Gordon Dam and associated tributaries; in the Franklin River and associated tributaries; and in out-of-catchment rivers, including the Davey River, Birchs Inlet and Henty River catchments. A total of eight fish species were regularly captured at these sites. The tables below give the locations, as well as the species and numbers captured during this study for:

a) the Gordon River (Table 2);
b) tributaries of the Gordon River (Table 3);
c) the Franklin River and tributaries (Table 4); and
d) the out-of-catchment rivers (Table 5).

Table 2. Sites, species and numbers of fish caught in the Gordon River during the 1999-2000 Gordon fish sampling. Zone definitions are given in Section 3.3.1.

Gordon River sites	*Anguilla australis*	*Geotria australis*	*Galaxias brevipinnis*	*Galaxias. maculatus*	*Galaxias truttaceus*	*Mordacia mordax*	*Pseudaphritis urvillii*	*Salmo trutta*
Zone 1								
G3								3
G4								1
Zone 2								
G5								33
G5a								3
G6								4
Zone 3								
G7	7							16
G9		2						10
at Grotto Creek								6
G16								4
Zone 4								
at Howards Creek								2
at Platypus Creek	21	2			6			3
Zone 5								
at Franklin Eddy					5			
G14	20	13		1	8	2	9	2
G15		1	1		7		5	
d/s Sprent River	16				2		4	1

Table 3. Sites, species and numbers of fish caught in the Gordon River tributaries (excluding the Franklin River) during the 1999-2000 Gordon fish sampling.

Gordon Tributary Sites	*Anguilla australis*	*Geotria australis*	*Galaxias brevipinnis*	*Galaxias maculatus*	*Galaxias truttaceus*	*Mordacia mordax*	*Pseudaphritis urvillii*	*Salmo trutta*
Zone 1								
Serpentine River	1		2					
Indigo Creek			3					
Piguenit Rivulet								1
Zone 2								
Albert River						1		4
Mudback Creek								9
Splits Creek								2
Zone 3								
Orange River	1							11
Maxwell River @ Boundary	1							6
Denison u/s Gorge	1							23
Denison u/s Maxwell River	3	1						2
Denison @ Maxwell River		2						19
Denison d/s Maxwell River								28
Denison u/s TNR	2							14
Denison @ D1								12
Denison @ Denison Camp								1
Harrison Creek					2			10
Smith River								8
Zone 4								
Olga @ Fly Creek								5
Olga @ Riffles								13
Olga @ Gordon	2					1		9
Howards Creek	2				2			7
Platypus Creek	5				8			23
Sprent @ Division					1		1	1
Trutt Creek					5			1
Sprent River	2				4			1

Table 4. Sites, species and numbers of fish caught in the Franklin River and tributaries during the 1999-2000 Gordon fish sampling.

Site	*Anguilla australis*	*Geotria australis*	*Galaxias brevipinnis*	*Galaxias maculatus*	*Galaxias truttaceus*	*Mordacia mordax*	*Pseudaphritis urvillii*	*Salmo trutta*
Jane u/s J1								9
Wattle Camp Creek	3				1			9
Franklin @ Wattle Camp Ck	7							8
Franklin @ Flat Island								2
Forester Creek			1		4			11
Franklin @ Forester Creek	3							5
Flummox Creek					2			7
Franklin @ Canoe Bar	3							2
Ari Creek			2		8			1
Franklin d/s Big Fall	3				11		11	2
Franklin @ Third Island	1	1		1	1		3	2
Franklin @ Shingle Island	6			1	8		4	2
Franklin @ Pyramid Island	6			9	3		9	3

Table 5. Sites, species and numbers of fish caught in the out-of-catchment sites, including Birchs Inlet, the Davey River catchment and the Henty River during the 1999-2000 Gordon fish sampling.

Site	*Anguilla australis*	*Geotria australis*	*Galaxias brevipinnis*	*Galaxias maculatus*	*Galaxias truttaceus*	*Mordacia mordax*	*Pseudaphritis urvillii*	*Salmo trutta*
Birchs Inlet rivers								
Pocacker River	12	1			18		42	
Sorell River	11	4			18		49	
Davey River catchment								
Crossing d/s Dodds River	1		19					
Crossing @ Clover Corner	1		18					
Crossing @ Gorge	3		12					
Crossing d/s Gorge	2		2		15		2	
Crossing @ Bent Strut					7		2	
Hardwood @ Turner Creek	3	1	1		3	1	15	
Davey d/s Hardwood River		1			2		7	
Davey u/s Crossing River		1	1	2	9		9	
Davey @ Crossing River					1			
Davey Creek		1			33		5	
Hut Creek u/s waterfall	1		2		10			
Hut Creek d/s waterfall	2		1		10		2	
Davey @ Hut Creek					8		4	
Henty River								
Henty @ Zeehan Hwy					4			9
Henty @ Sisters	2	2			3		6	24
Henty @ West Sister	2	2			10	2	1	6
Henty @ Yolande	2	6					1	9
Henty u/s Bottle Creek		7	5	8	12	2	9	

3.2 Conservation status of fish

All fish species found in the middle and lower Gordon River are common and abundant in Tasmanian rivers, and none are listed under the *Threatened Species Protection Act* (1995) with the exception of the Australian grayling (*Prototroctes maraena*). The grayling is listed as vulnerable under the Act but is considered widespread in Tasmania, though low in abundance. This species was not captured during the 1999-2000 surveys, although it is still likely that this species inhabits the lower reaches of the Gordon River. There is no evidence that the population in the lower Gordon is abundant nor is there any evidence of any trends or threats to that population.

The Gordon River fish populations therefore do not have a high conservation status. In addition, the presence of the exotic brown trout throughout the middle Gordon and its major tributaries indicates a potential and ongoing threat to native fish and macroinvertebrate populations within the catchment. These impacts are discussed in more detail in section 3.5 of this report.

3.3 Community structure and zonation

3.3.1 Gordon River

The fish community structure of the Gordon River varies longitudinally for a variety of reasons. The natural longitudinal gradient in fish populations as described in section 3.1 is a factor expected to reduce both diversity and numbers of fish with distance upstream. Fundamental to this winnowing out process is the role of fish migration barriers along the river channel and the ability of individual fish to negotiate these at various flow stages.

Four main physical barriers were identified downstream of the Gordon Dam during the field-work for this project. Moving in order downstream from the Gordon Power Station, these are:

1. Abel Gorge – This area is relatively steep, and is characterised by large boulder accumulations separated by rocky pool sections. The boulder fields may form temporary barriers during extremely low flows and the constrained sections of the gorges would have high water velocities at peak power station discharges. Areas of this nature are more likely to winnow out species (and numbers of individuals) gradually.
2. 1st and 2nd Splits – these narrow gorges have high water velocities, increasing with discharge. These gorges are the most substantial fish migration barriers downstream of the dam. At low flows the Splits have small drops and waterfalls that would act as barriers to some species, however other species such as *G. brevipinnis* and *A. australis* would easily be able to negotiate these. The presence of other species upstream indicates that the two Splits do not act as total barriers to fish migration.
3. Ewarts Gorge – this is a gorge site with moderate water velocities at high flows, it is fairly long and may therefore act as a partial fish barrier. At low flows a small step exists across the river adjacent to Sunshine Falls (which are on a tributary). This step would only be impassable for some species during very low flows (ie. PS off and no rainfall) but would be negotiable at other times.
4. Sprent River Delta – essentially a low flow barrier resulting from high velocities through a narrow slot between the delta and the limestone cliffs on the eastern bank. At high flows, the river overtops the boulder field of which the delta is comprised, resulting in increased opportunities for fish passage. There are low velocity refuges through this area at all flows, and it is unlikely to form an impassable barrier to any species. It may however, act as a significant deterrent to migratory fish and therefore represent a behavioural barrier to some species.

A fifth barrier is located at the bottom of the study reach and is represented by the rapids at Big Eddy that separate the tidal sections of the river from those that are purely fluvial in nature.

Table 2 lists the sampling locations and zones, the species sampled and the numbers caught at each site in the Gordon River.

Sampling of Gordon River and tributaries revealed species compositions that equated reasonably well with the zones defined by these barriers, which were adopted for use in this study. The Gordon River zones are:

Zone 1: Gordon Power Station tailrace to the bottom of Abel Gorge;
Zone 2: Below Abel Gorge to the bottom of the 1st Split;
Zone 3: Below the 1st Split to Ewarts Gorge;
Zone 4: Below Ewarts Gorge to the Sprent River delta; and
Zone 5: Below the Sprent River delta to the tidal extent.

These zones are shown in Figure 2 and, with respect to altitude, in Figure 3.

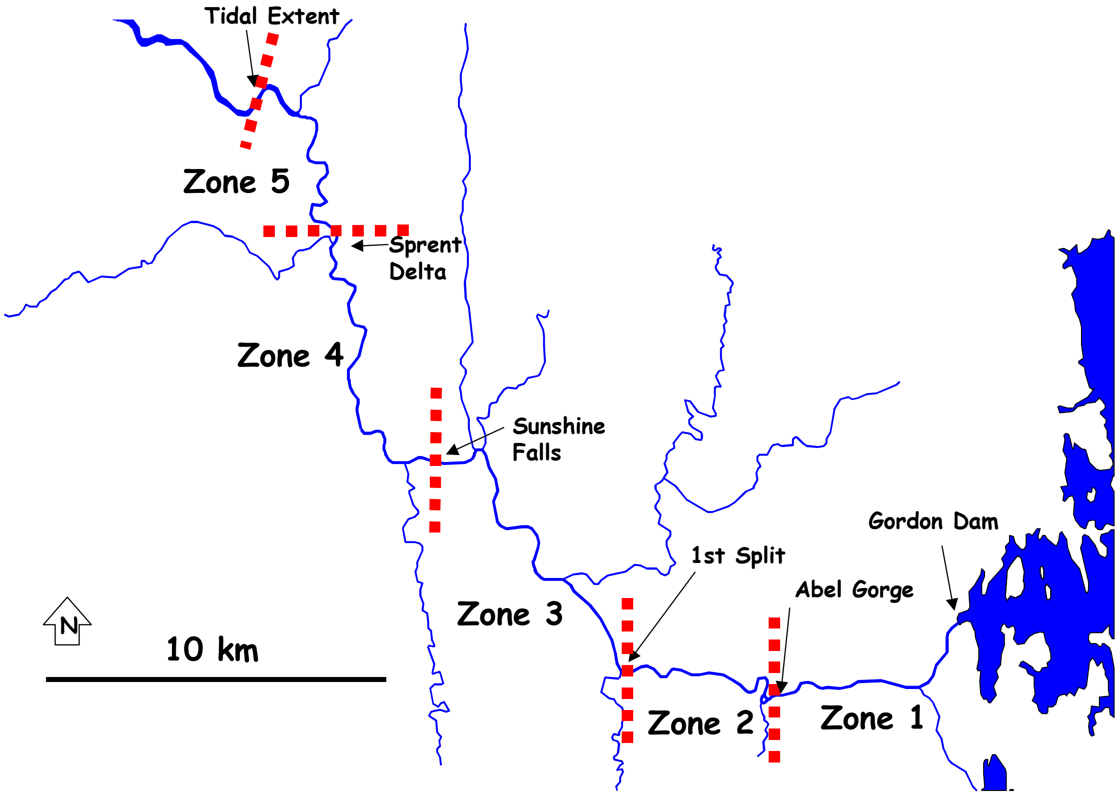


Figure 2. Zonation of fish communities in the Gordon River

The fish migration barriers identified correspond with major drops in altitude (Figure 3). Between these drops, the river is characterised by sequences of pools, runs and riffles. Even at the tailrace, there is some natural flow pickup from the catchment downstream of the Gordon dam and similarly in the Serpentine River downstream of the Serpentine Dam. Hence, along the continuum of the river, there are no sections that are completely dewatered, and it is likely that fish passage would be possible in all sections of the river within (but not necessarily between) the major zones during power station shutdown. Some flow would be required for fish passage past some of the cascades in the river and at the barriers between zones, however, this flow would need to be low to ensure passable velocities, and would often be provided by natural catchment pickup.

While instream velocities within the barrier features were not measured during this study, primarily for safety reasons, simulation of instream velocities was conducted by Davies and Cook (2001), for bar and pool-run habitats at a variety of locations. They found that mid-channel velocities were consistently higher than the maximum of 0.3 – 0.4 m/s water velocity against which *G. truttaceus*, *G. maculatus* and *S. trutta* from Tasmanian streams could swim at 'burst speed' (as measured by Walker 1999). Thus even in 'non-barrier' sections of the Gordon, discharges associated with efficiently load or full gate power station operations pose a significant limitation on fish movement. It is likely that this is true of the barriers described above for a wide range of flows

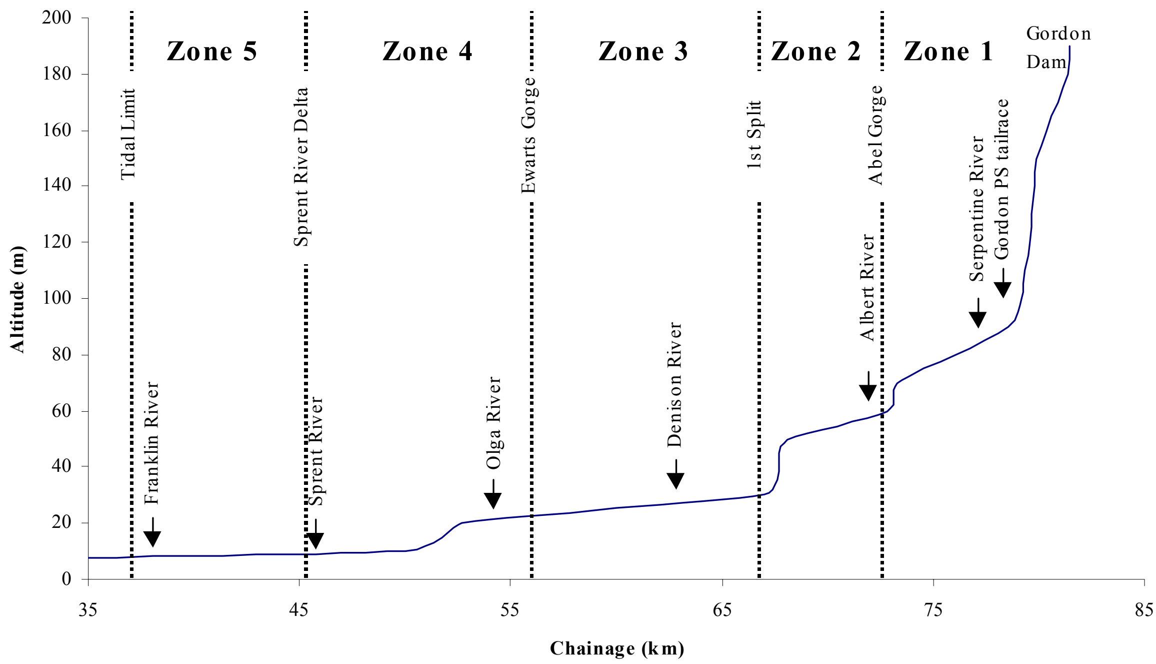


Figure 3. Gordon River longitudinal-section and fish zones.

There are some notable tributary in-flows into some of these zones – the Albert River enters at the upstream end of Zone 2, the Denison River into the middle of Zone 3 and the Olga River at the upstream end of Zone 4 and the Sprent River at the downstream end of this zone. The Franklin River enters near the lower boundary of the study area and represents a tributary that appears to be minimally impacted by the Gordon Power Scheme. As such, it provides a useful reference river for comparing present impacts of the Gordon power scheme.

Within each zone a range of sites within the Gordon River were sampled repeatedly over the study period. Clustering of similarities based on pooled (ie. total) CPUE indicated (with one exception) two major groups – those sites downstream of the Ewarts Gorge (ie. Zones 4 & 5) and those upstream of the 1st and 2nd Splits (Zones 1 and 2). The community composition of these zones is shown in Figure 4 and the catch rates for abundant fish species is given in Figure 5 and for all species in Table 6 (river sites).

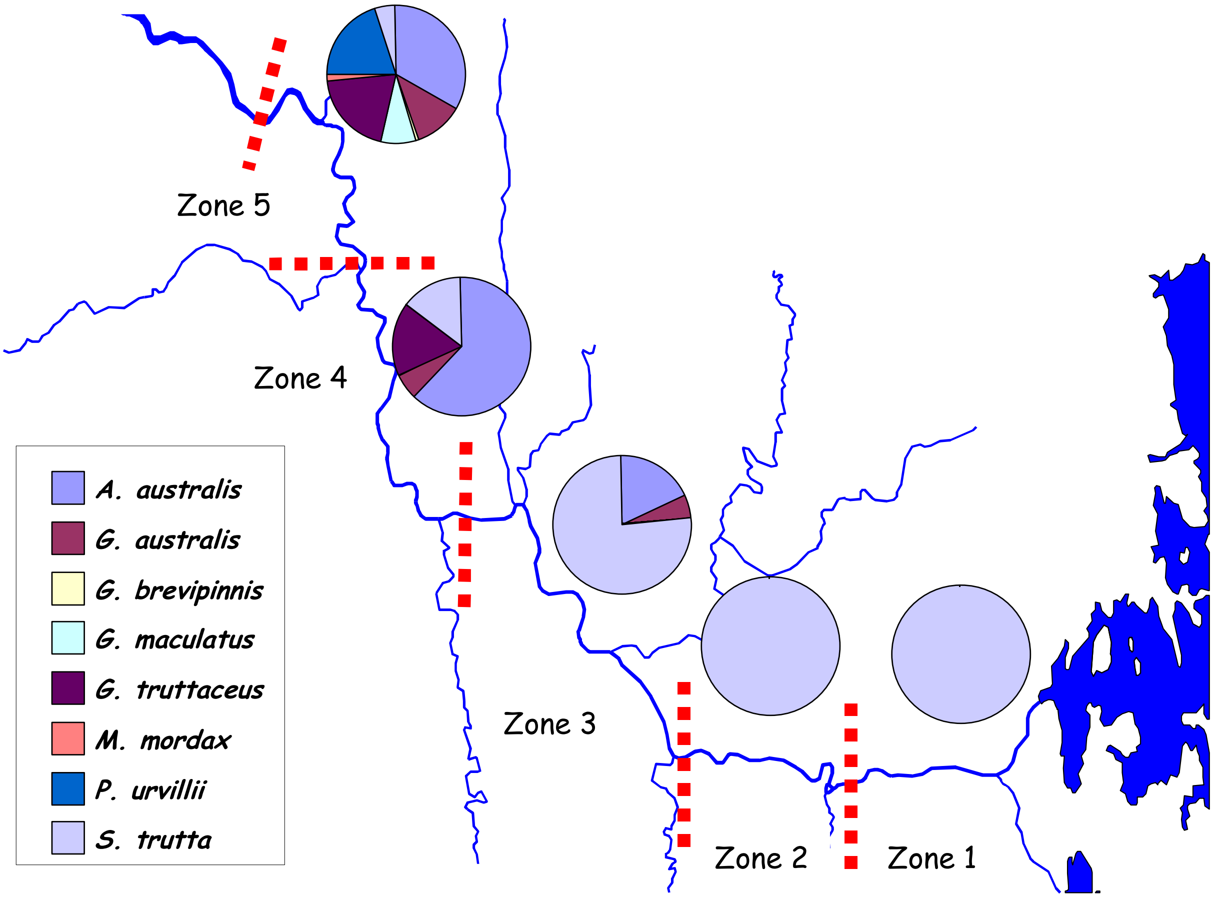


Figure 4. Fish community composition for the Gordon River zones

Three species were restricted to the lower reaches of the study zone, namely, *G. maculatus, M. mordax* and *P. urvillii*. The capture of a single adult *G. brevipinnis* at Site 42 in Zone 5 (Table 6) was regarded as extremely unusual for the Gordon River, as this species is more often associated with headwater streams. It was found in a shallow backwater environment.

Table 6. CPUE summary for Gordon River zones (pooled samples – river sites).

Zone	*A. australis*	*G. australis*	*G. brevipinnis*	*G. maculatus*	*G. truttaceus*	*M. mordax*	*P. urvillii*	*S. trutta*
1								0.35
2								3.22
3	1.07	0.30						4.42
4	6.85	0.65			1.96			1.63
5	4.15	1.61	0.12	0.12	2.53	0.23	2.07	0.35

The results showed that there is a trend of reducing abundance of fish for all species from Zone 3 upstream for river sites.

Short-finned eels (*A. australis*) were reasonably abundant in Zones 4 and 5, but declined rapidly above Ewarts Gorge (Zone 3). No eels were found upstream of the Splits (Zone 2), however the presence of one adult eel in the Serpentine River indicates that this species has been able to migrate upstream past the splits at some time in the past. It is possible that this eel was released into the Serpentine River via releases from Serpentine Dam. However, the presence of eels in Lake Gordon, and unsubstantiated anecdotal reports of eels in the tailrace of the Gordon PS after long shutdowns, indicates that eels are able to negotiate the Splits and Abel Gorge at times. The flow conditions that enable them to do so are unknown and it was interesting to note that no eels were found at the tailrace during the 1999-2000 surveys. The absence of these fish in the upper zones of the Gordon River itself is indicative of the present impacts of hydro-peaking and the lack of velocity refuges in these zones during high flows. There is a general increase in the size of captured eels with distance upstream, indicating ageing populations in the upper zones, which are probably not regularly supplied by juvenile recruitment from downstream. Most eels captured in zones 4 and 5 were juveniles.

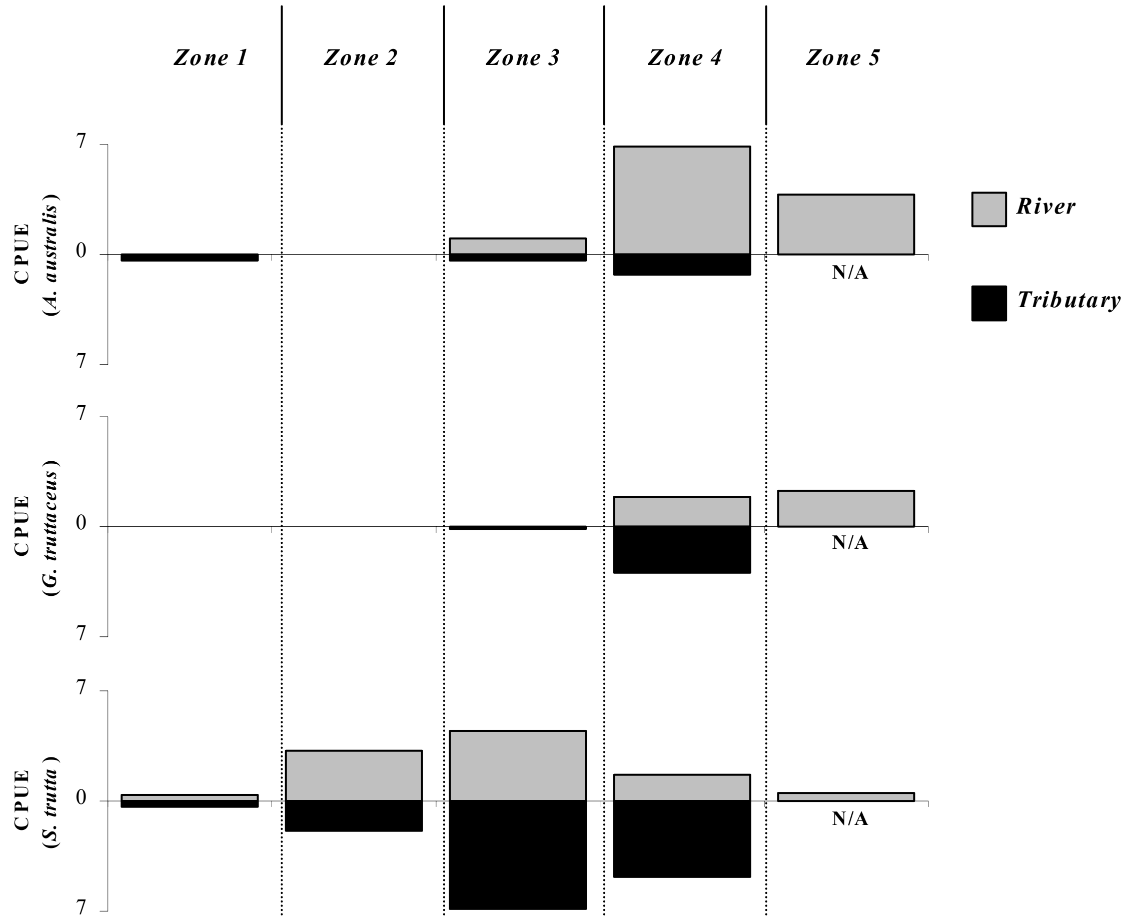


Figure 5. Zone CPUE summary for abundant species.

Galaxias truttaceus exhibits similar distributional patterns, with abundant juveniles schooling in the lower reaches of the river, leading to larger fish upstream and in the tributaries. The absence of this fish in Zones 1 or 2 in either the river or tributaries suggests an inability for this fish to negotiate the Splits. This inability is probably less a function of its swimming ability, which is similar to other galaxiids (Section 3.4.4), but rather its inability to climb wet surfaces in the way that *G. brevipinnis* or *A. australis* are able to.

Brown trout were by far the most abundant fish in the upper reaches of the Gordon River and its tributaries. This is primarily due to the fact that freshwater brown trout populations are self-sustaining through local recruitment from tributary streams, whereas all the native fish populations are only sustained by migration of adults and juveniles from downstream.

The decreasing abundance of brown trout upstream of Zone 3 is probably linked to the increasing influence of the power station and the associated regular dewatering of habitat and reduced food supply in the river. The size of the river was variable and did not appear to influence catch rates. The large catches of trout in the Zone 3 tributaries (Figure 5) were primarily associated with surveys of the Denison River, which was dominated by trout. The decrease in CPUE for tributaries of upper zones in comparison to downstream areas is more likely to be associated with the decreasing size (hence habitat limitations) of the tributaries and possibly the lack of food resource in the form of native migratory galaxiids.

The low catches of trout in the most downstream reach (Zone 5) may be a function of river size, although similar habitats were sampled upstream and the survey methods are therefore considered comparable. The decreased dominance of trout over natives in these areas reflects a combination of the naturally higher numbers of native fish in downstream reaches and a proportional reduction in the influence of the power station on river hydrology. This latter effect helps to define a zone of influence for the power station.

The longitudinal distribution of species within the Gordon River (Figure 6) highlights the wide distribution of brown trout (*S. trutta*) throughout the river, with the exception of the upper sites in Zone 1 (chainage of >75 km). No fish were captured by any method in the Gordon River upstream of Site 75 despite the presence of a number of species in adjoining tributaries.

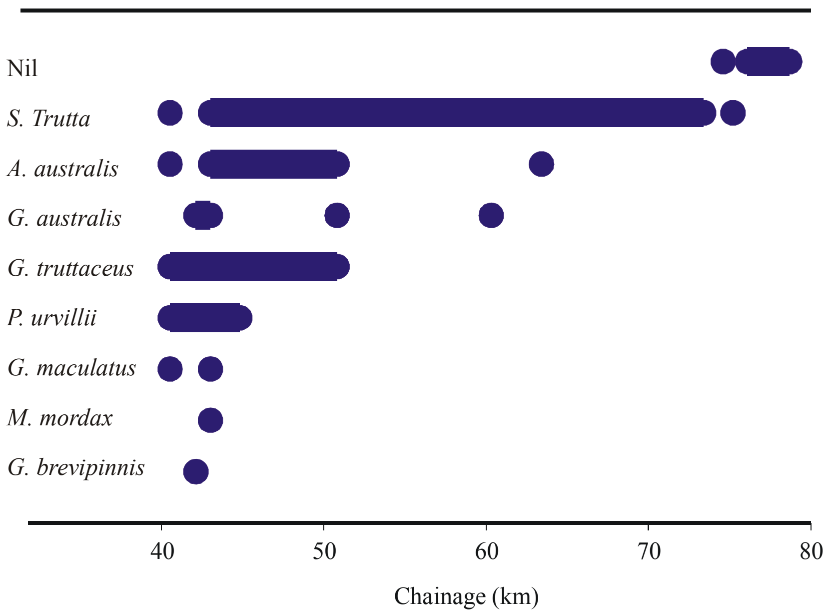


Figure 6. Longitudinal distribution (presence/absence) of all fish species captured in the Gordon River using all gear types. Chainage represents the distance upstream from the mouth of the Gordon River. Distribution of species found in adjoining tributaries is not shown.

The Gordon River fish communities therefore appear to be heavily influenced by the natural trends in diversity and abundance of natives upstream, the location of the fish migration barriers, the regulated hydrology and the presence of brown trout. The zonation found in the Gordon River was far less pronounced in the out-of-catchment reference streams surveyed (see section 3.3.4) and was attributed largely to the competition and predation effects from brown trout (section 3.5).

3.3.2 Gordon River tributaries (excluding Franklin River)

The tributaries of the Gordon River, particularly those upstream of Ewarts Gorge (Zone 3 and upstream) were generally depauperate, contained brown trout and, where natives were present, were typified by a lack of juvenile galaxiids.

Table 3 lists the sampling locations and associated Gordon River zones, the species sampled and the numbers caught at each site in the tributaries of the Gordon River. Figure 7 shows the change in fish community composition over tributaries of the four upper zones of the Gordon River.

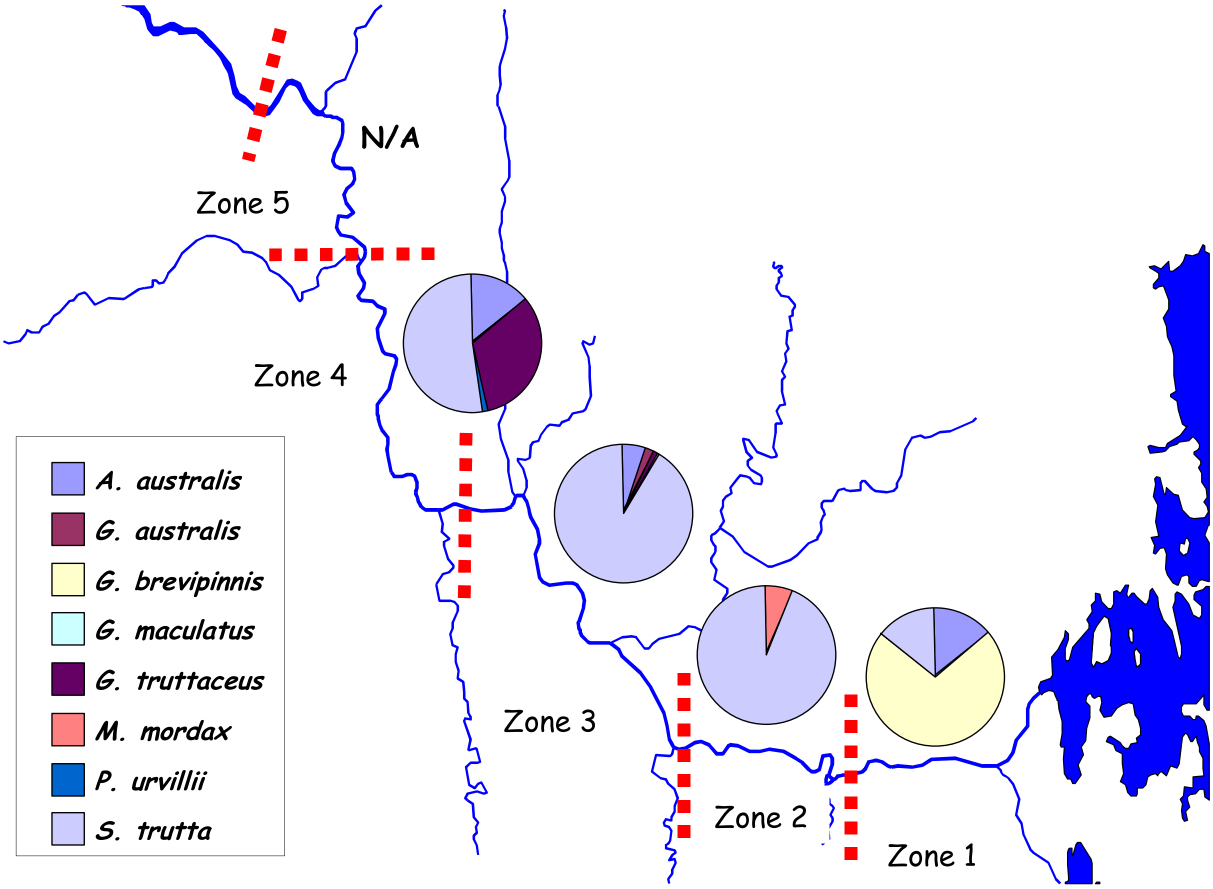


Figure 7. Community composition of Gordon River tributaries. Note: no tributaries of Zone 5, except the Franklin River, were sampled during this study.

With the exception of the Franklin River, no tributaries of Zone 5 were sampled during the 1999/2000 surveys due mainly to the lack of tributaries that would be comparable in size and nature to those upstream. The Franklin River fish fauna is discussed in section 3.3.3. Similarly, no substantial tributaries were located on the lower Franklin (downstream of Big Fall), so there is a lack of information about the fish communities of the smaller streams in these areas. However, it is expected that they would be similar to Zone 4 tributary communities and be dominated by *G. truttaceus* and *S. trutta*. Davies *et al.* (1996) electrofished a number of small tributary streams (e.g. Eagle Creek) in the tidal reaches of the Gordon and found that they were dominated by *G. truttaceus*.

The only tributaries to contain *G. brevipinnis* were those in Zone 1 (Table 7). This is consistent with this species' migratory abilities and the effects of preferential habitat use in the lower sections of the river. Such habitat partitioning did not appear to take place in unregulated waterways such as in tributaries, the Davey catchment and the Henty River, yet apart from one *G. brevipinnis* at Site 42 (G15), was always observed in the Gordon River. Davies (unpub. data) also maintains that the distribution of *G. brevipinnis* is heavily influenced by the presence of brown trout, as the galaxiid is restricted to river sections upstream of the limit of trout when they are present in a catchment, and distributed to sea level when trout are absent.

Table 7. CPUE summary for tributary sites, ordered by Gordon River zones (pooled samples – tributary sites). Note: no tributaries were sampled in Zone 5.

Zone	*A. australis*	*G. australis*	*G. brevipinnis*	*G. truttaceus*	*M. mordax*	*P. urvillii*	*S. trutta*
1	0.34		1.72				0.34
2					0.12		1.87
3	0.43	0.13		0.09	0.04		6.81
4	1.31			2.91		0.15	4.80
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A

The size of *G. brevipinnis* in Zone 1 tributaries was significantly greater than populations of this species elsewhere (Figure 8). Those in the Serpentine River were particularly large and, although not retained for proper ageing, it was apparent that these fish were of advanced age and represented a population that received very little, if any, juvenile recruitment. A similar phenomenon was observed by Davies *et al.* (1996) in tributaries of the King River in which *G. brevipinnis* had been isolated due to pollution in the main stem, reaching ages up to 28 years.

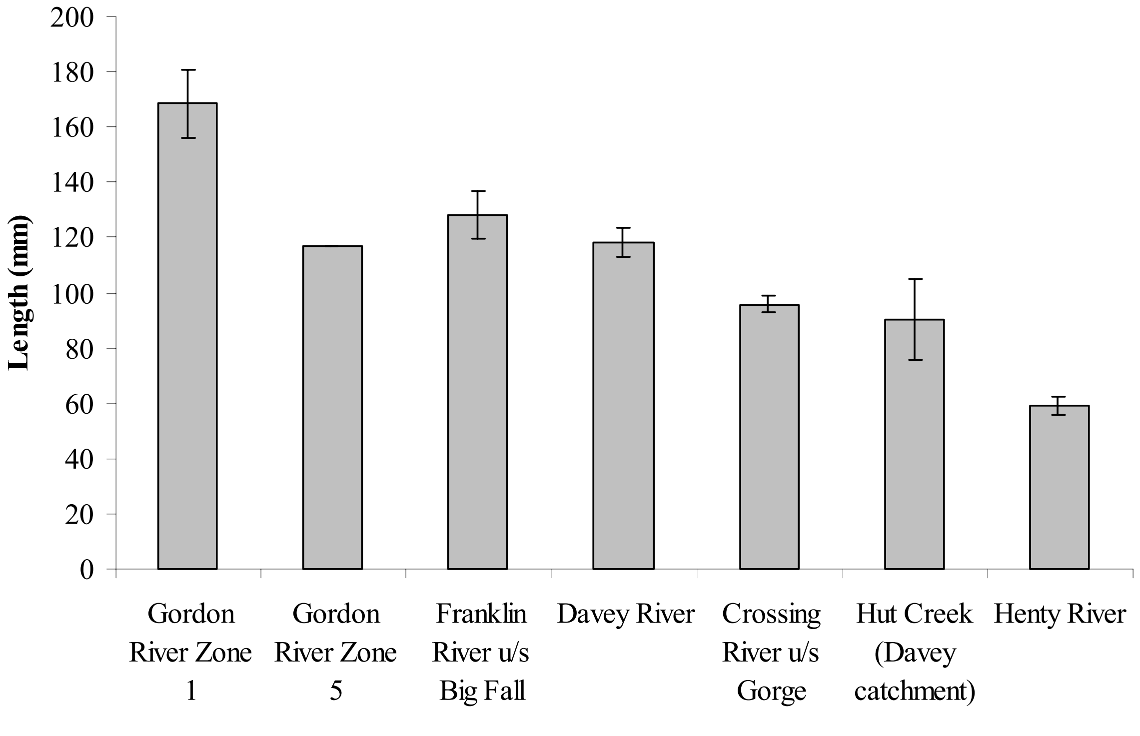


Figure 8. Length variation in *G. brevipinnis* (mm ± standard error).

The tributaries of Zone 4, which is further downstream, were richer, particularly with respect to *G. truttaceus*. The only exception to this was the Olga River, which enters the Gordon downstream of Ewarts Gorge. This river was typified by low catch rates and contained mainly brown trout, with only two eels and an ammocete captured over the study period. No immediate explanation could be found for this and it was interesting that the Hardwood River, which shares the Olga valley but drains southward to Port Davey, had a diverse range of species (section 3.3.4). Sharks Mouth rapids, in the Gordon River, are located just over 1 km downstream of the Olga river confluence and may form a partial fish migration barrier. To investigate this, the fish populations of Howards Creek which are also upstream of the rapids was investigated, but was found to be more typical of other Zone 4 tributaries. The IFC (1997) reported from a limited survey of the area that the Olga River had notable populations of lamprey ammocoetes and also provided good nursery areas for brown trout, but give no details on other fish species. Hence, the factors shaping the Olga River fish populations are not fully understood but may relate to a particular suitability to trout at the expense of native species.

3.3.3 Franklin River

The Franklin River is believed to be outside of the Gordon Power Station's major zone of influence in terms of fish populations, with the possible exception that the Macquarie Harbour pool of galaxiid recruits may be influenced by any decline in King River and Gordon River populations. This may affect lower Franklin populations to a certain extent. The Gordon River at the Franklin confluence is still significantly affected by the power station (~60% of the average flow above the Franklin confluence is controlled by the power station). Despite this, the zonation displayed in the Gordon River communities (section 3.3.1) would tend to indicate that the negative effects of the power station diminish considerably, and that the Franklin River upstream of Big Fall provides a suitable reference site for the fish in the Gordon River.

Table 4 lists the sampling locations, the species sampled and the numbers caught at each site in the Franklin River and tributaries.

The fish communities in the Franklin River are influenced greatly by Big Fall, which is the most downstream fish migration barrier in this river. The fish communities in the Franklin River downstream of this barrier are similar in both composition and abundance to those in the lower reaches of Zone 5 (Figure 9). The surveys indicate the number of native fish species is greater in the Gordon River and in the case of the eels and ammocoetes, the abundance in the Gordon is also far greater. Interestingly, the catch rates for brown trout in Zone 5 of the Gordon River is lower than the adjoining section of the Franklin River, so in terms of the fish populations of these lower reaches, the Gordon River could be considered more diverse and to contain fewer of the exotic brown trout than the unregulated Franklin.

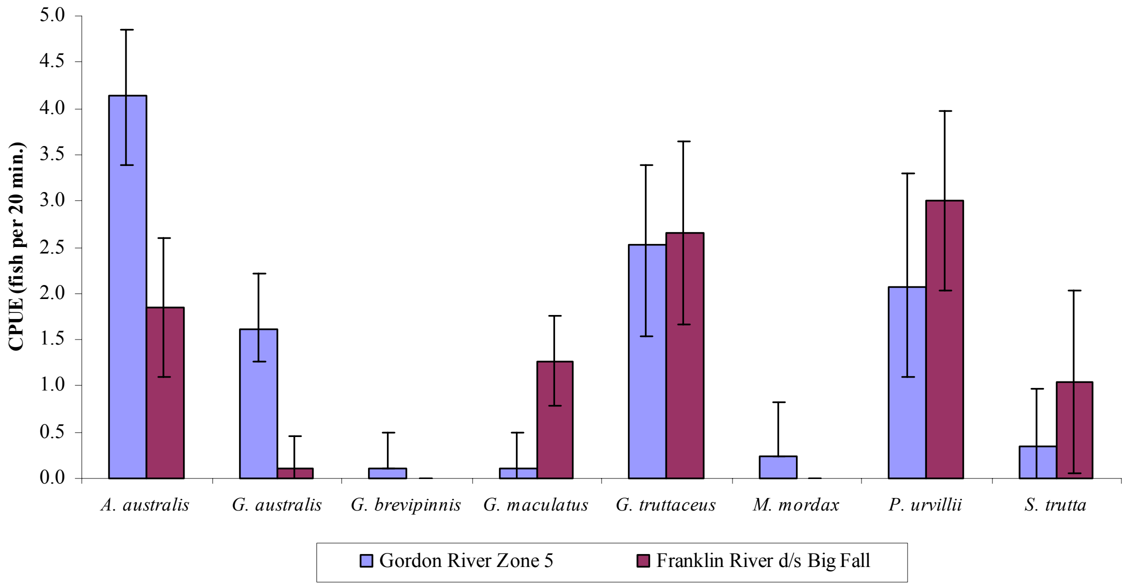


Figure 9. CPUE (±S.E.) comparison of the lower Franklin and Gordon River study reaches.

Upstream of Big Fall, the Franklin River contained far fewer fish species (Figure 10), indicating that this small waterfall is a major barrier to the upstream migration of a number of species. The tributaries entering the Franklin River upstream of Big Fall contained *G. brevipinnis* and this species has been observed in higher altitude tributaries of the Franklin River (Howland and Davies pers. obs.). Lack of *G. brevipinnis* appears, as in the Gordon and the Henty Rivers, to be related to the presence of brown trout.

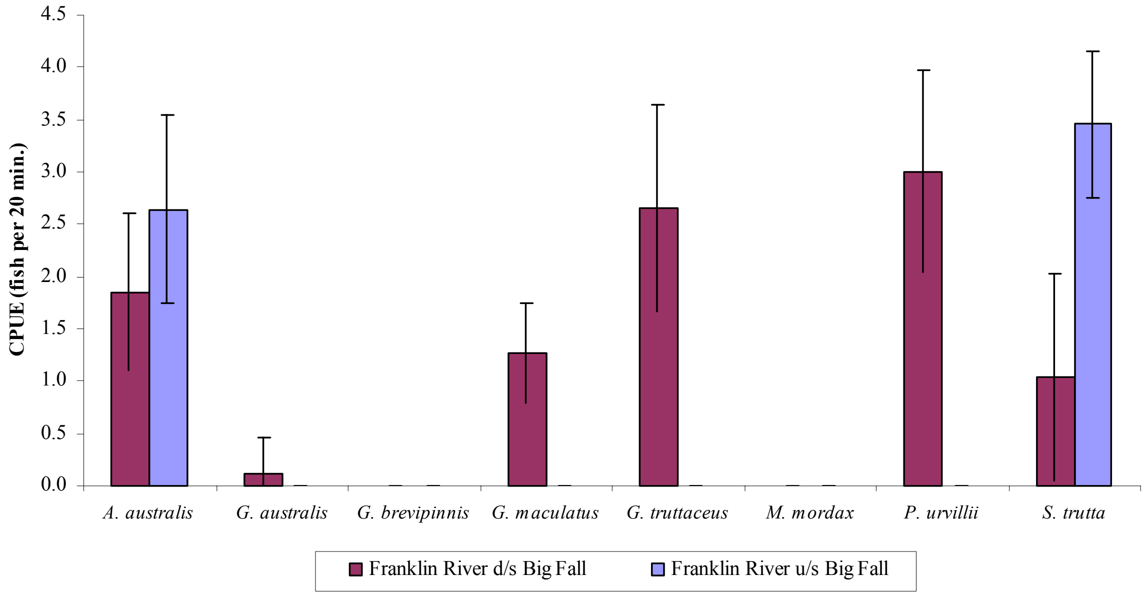


Figure 10. CPUE (±S.E.) comparison of the Franklin River downstream and upstream of Big Fall.

3.3.4 Out-of-catchment rivers

Three main river systems apart from the Gordon catchment were sampled. The rationale behind the selection of these waterways is given in section 2.1. Table 5 lists the catchments, sampling locations, the species sampled and the numbers caught at each site in the out-of-catchment rivers.

3.3.4.1 Davey River catchment

The fish community of the Davey River downstream of any fish migration barriers was very diverse, with high abundances of *G. brevipinnis*, *G. truttaceus* and *P. urvillii*. No brown trout were recorded during the survey which reinforced anecdotal evidence that this exotic species had not managed to colonise these areas. The CPUE for *G. brevipinnis* upstream of the Crossing Gorge was the highest recorded in this study (Figure 11). The Crossing Gorge was the most significant fish migration barrier with the study zone on this catchment, and was considered to be a good analogy of the barrier effects of the 1st and 2nd Splits in the Gordon River.

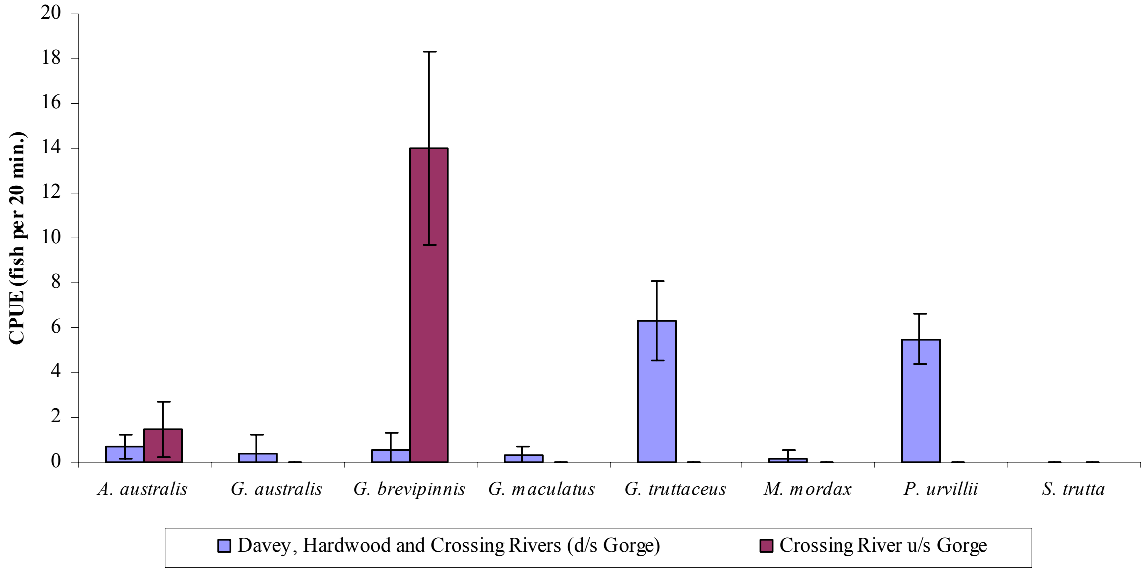


Figure 11. CPUE (±S.E.) comparison for the Davey River catchment.

3.3.4.2 Henty River

The Henty River was the only out-of-catchment river that did contain trout. This river is known to support large numbers of 'sea-run' trout and has recognised value as an estuarine trout fishery. The CPUE for brown trout in the Henty River upstream of the Yolande River was the highest of any region during the 1999-2000 surveys. Downstream of the Yolande, this catch rate was markedly lower, however, the catches for *G. truttaceus* and *P. urvillii* were reasonably consistent (Figure 12). The absence of *G. maculatus* from the areas upstream of the Yolande River was expected due to its lowland nature and consistent with its previously described distribution (Davies 1989). *G. brevipinnis* were caught as juveniles (Figure 8) at the most downstream site (upstream of Bottle Creek), but were absent in the rest of the river. This is presumed to be due to the presence of trout. Interestingly, trout were absent from the only site in the Henty River where *G. brevipinnis* were recorded.

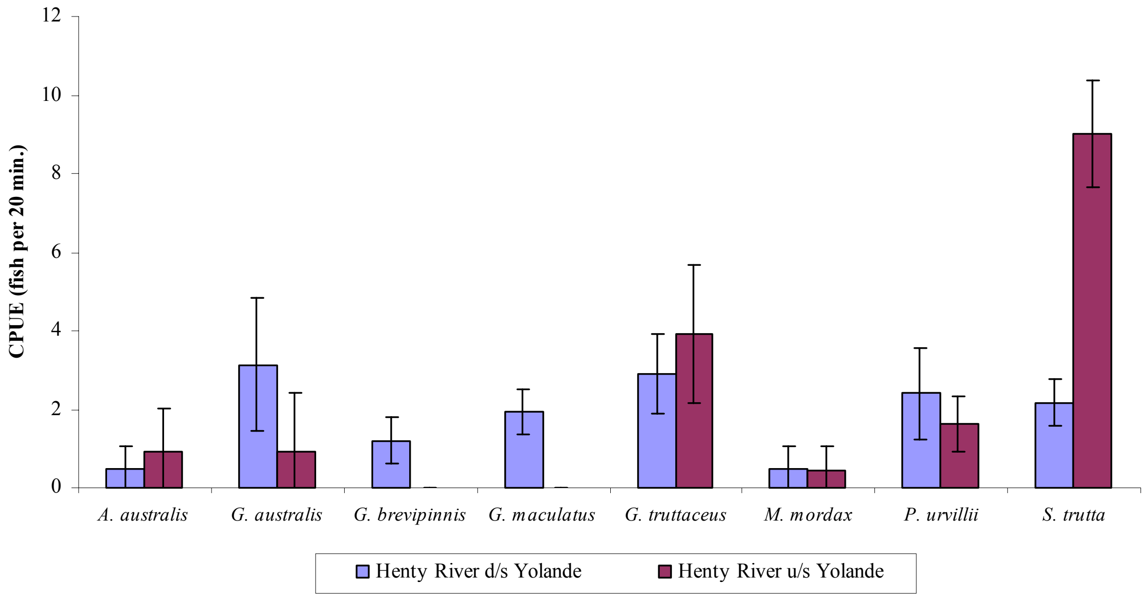


Figure 12. Mean CPUE (±S.E.) comparison for the Henty River sites upstream and downstream of Yolande river.

3.3.4.3 Birchs Inlet catchment

Similar to the Davey River catchment, sampling in the Birchs Inlet streams did not produce any trout. This was unexpected, as sea-run trout certainly would have had access to these creeks and there were no significant fish migration barriers downstream (as indicated by the presence of native lowland and migratory species in the locations sampled).

In these waterways, the diversity of native species was high and the abundance of *G. truttaceus*, in particular, was far higher than at sites elsewhere that contained trout. The influence of trout on fish community structure is discussed more fully in section 3.5.

3.4 Impact of present power station operations

Impacts from the present, altered flow regime are likely to include: changes in fish habitat availability and quality; changes in food production and/or availability; and decreased fish survival and recruitment. In addition to flow related effects, the physical barriers created by the Gordon and Serpentine Dams greatly reduce upstream and downstream movement of biota and surface waters between the upper catchments and the middle Gordon River. All of these impacts have been observed elsewhere downstream of hydro-electric and hydro-peaking power stations (Hunter 1992, Stanford and Hauer 1992, Hvidsten 1985, Moog 1993, Garcia De Jalon *et al.* 1994, Baran *et al.* 1995, Bradford *et al.* 1995, Ojutkangas *et al.* 1995, Valentin *et al.* 1995, Englund and Malmqvist 1996, Bradford 1997, Liebig *et al.* 1999) and are related to the various aspects of the altered flow regime.

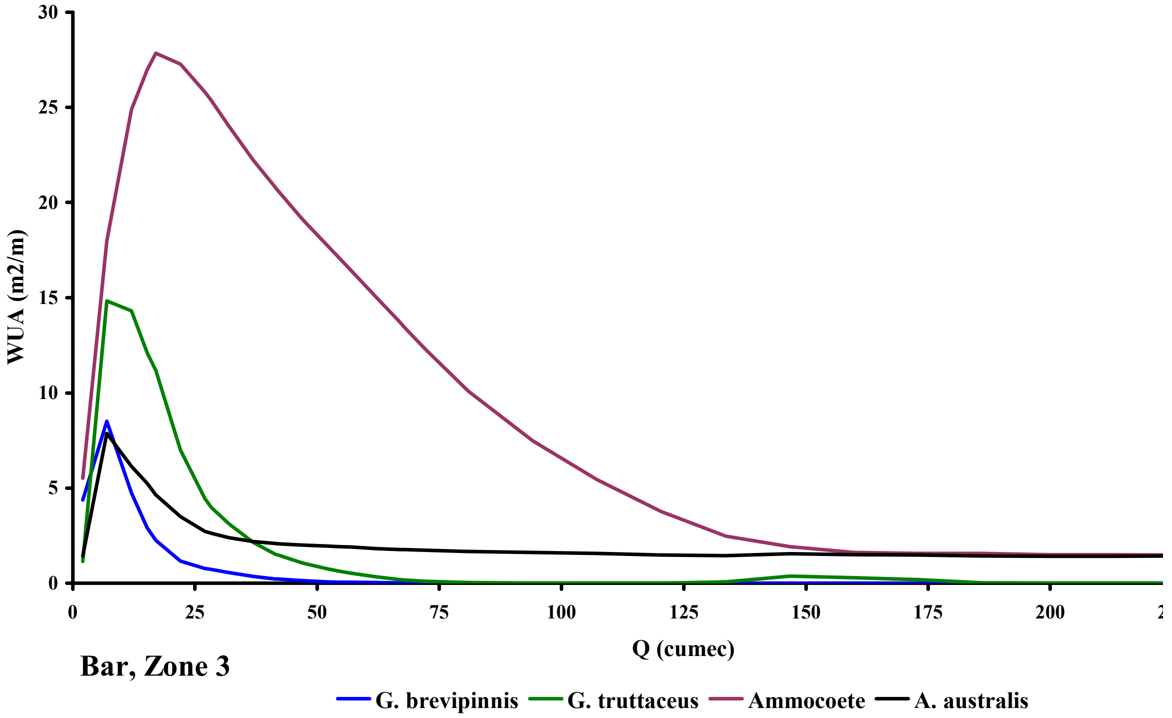
3.4.1 Habitat availability

No comparisons were made between fish utilisation of deep and shallow water habitats due to practical limitations such as the inability to electrofish in waters beyond depths that could be waded safely. There are no published data available to indicate whether adult galaxiids have different habitat preferences in large rivers such as the Gordon. Species richness may be reduced in the middle Gordon if adults of one or more species have preferences for habitats which are vulnerable to dewatering, such as snag or marginal (edge-associated) habitats. Native fish, especially galaxiids are known to be abundant in these habitats in the lower reaches of the study area (Zones 4 and 5).

Plots of weighted useable area of habitat (WUA) against discharge (Q) are shown in Attachment 8.3 for all fish species for Zone 1, Zone 3 and combined for Zones 4/5. They show a general trend for most fish, with declining habitat availability at very low flows (typically less than 7 cumecs) and at high flows (typically greater than 50 cumecs). Many of these curves peak at very low flows, and show a marked decline as discharges increase above these low levels (largely due to the poor suitability of deep, fast water). There are also substantial differences in the response of habitat availability to changing discharge between bars and runs. For bar habitats, there is a distinct peak in WUA as bar slopes become inundated. For pool-runs, WUA-Q curves are much flatter, as there is still substantial wetted area remaining when discharge approaches zero. One exception is the bar at Site 75 (Zone 1), which has a high lateral cobble – boulder deposit which only becomes fully inundated at very high flows. This causes a secondary increases in fish habitat as discharge approaches 200 cumecs (see Attachment 8.3).

These curves indicate that optimal habitat area for all species is not achieved by the same flow. In general, low flows are preferential for *G. brevipinnis*, *G. truttaceus* and *A. australis* whilst higher flows are beneficial for ammocoetes of *G. australis* and *M. mordax*. This high flow preference for ammocoetes is largely due to the greater availability of sandy substrates at high positions on the river bank and hence the availability of these areas is restricted to high flows. Optimal flows for fish lie between 7 and 50 cumecs, but habitat availability declines significantly at discharges above ~100 cumecs for fish in Zones 3, 4 and 5, largely due to high velocities and depths across the main channel. Thus, both sustained discharge of the power station under efficient load or full gate, and pulsing of discharge between very low and high values results in decreases in habitat suitability for most fish species. It should be noted that increases in wetted area of stream-bed are not synonymous with increases in habitat availability for aquatic biota. This can be seen in the example plot of WUA and wetted area vs Q shown in Figure 13.

Habitat (as indicated by WUA) time series are shown for natural and present scenarios for pool-run and bar habitats for Zone 3 in Figure 14 for *Galaxias truttaceus*. Large natural floods tended to cause short term severe reductions in habitat availability under natural conditions. Such events were infrequent and associated with slower rates of change compared to the present regulated conditions. Despite large floods being eliminated under the present flow regime, the frequent flows above the optimal habitat flows means that habitat is now significantly reduced for most of the time compared to natural flows in both bar and pool-run habitats.



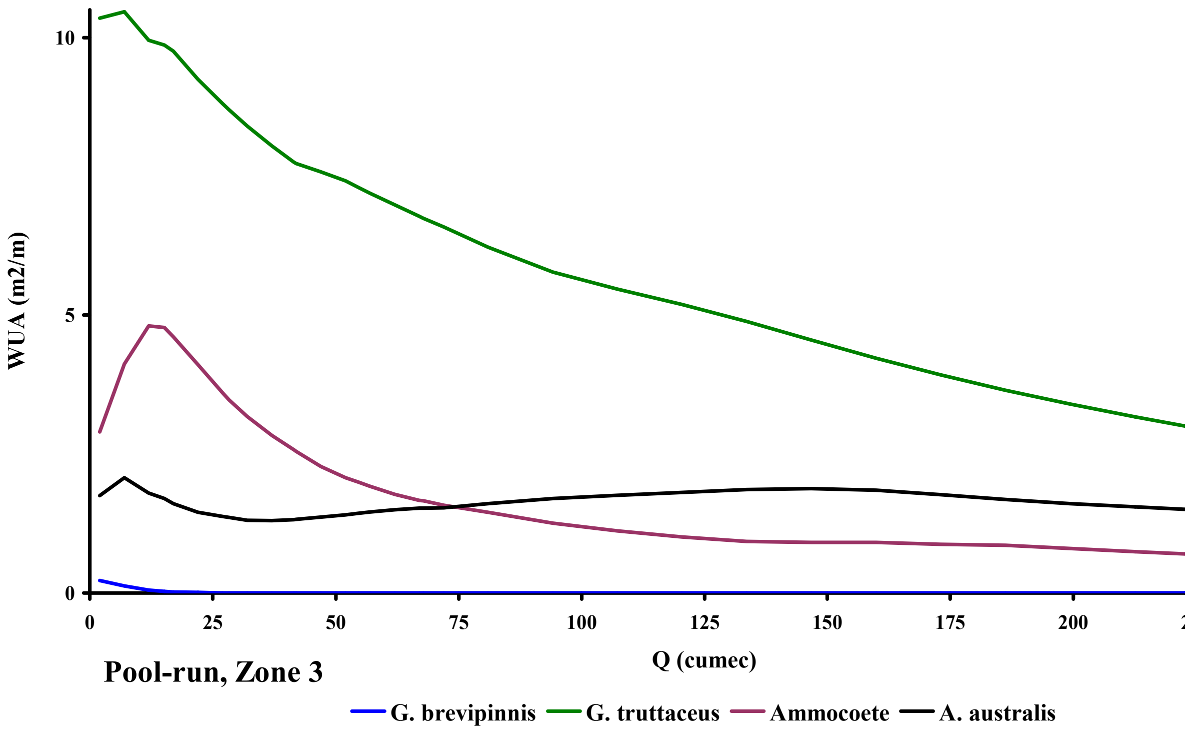
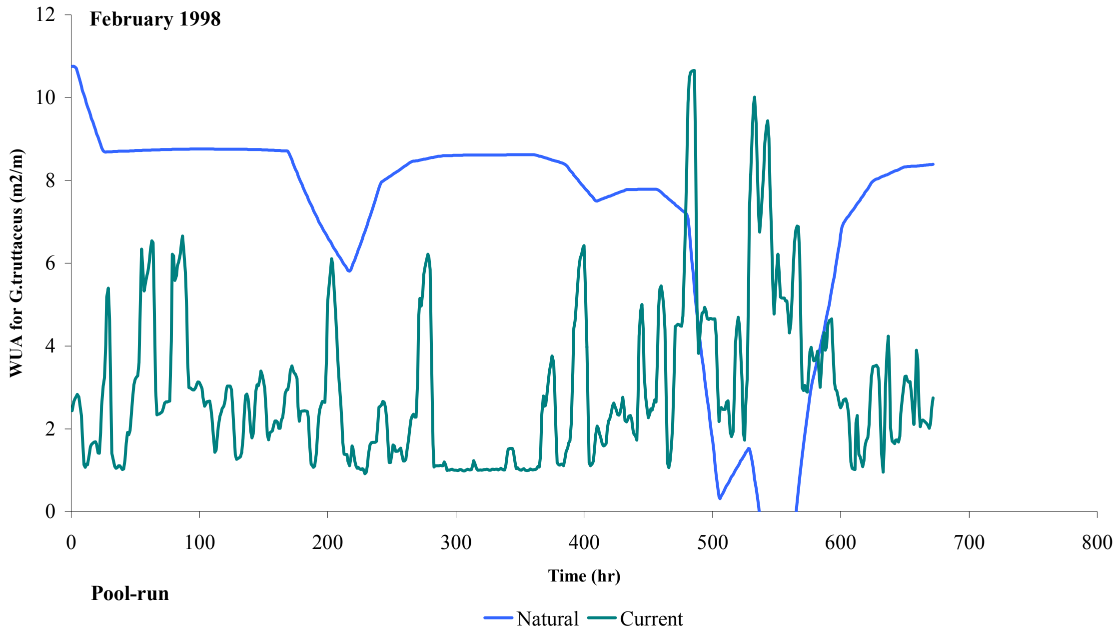


Figure 13. Plot of weighted useable area (WUA) for instream fauna against discharge for bar and pool-run habitat at Zone 3. Note how WUA decreases at high discharges for most biota.



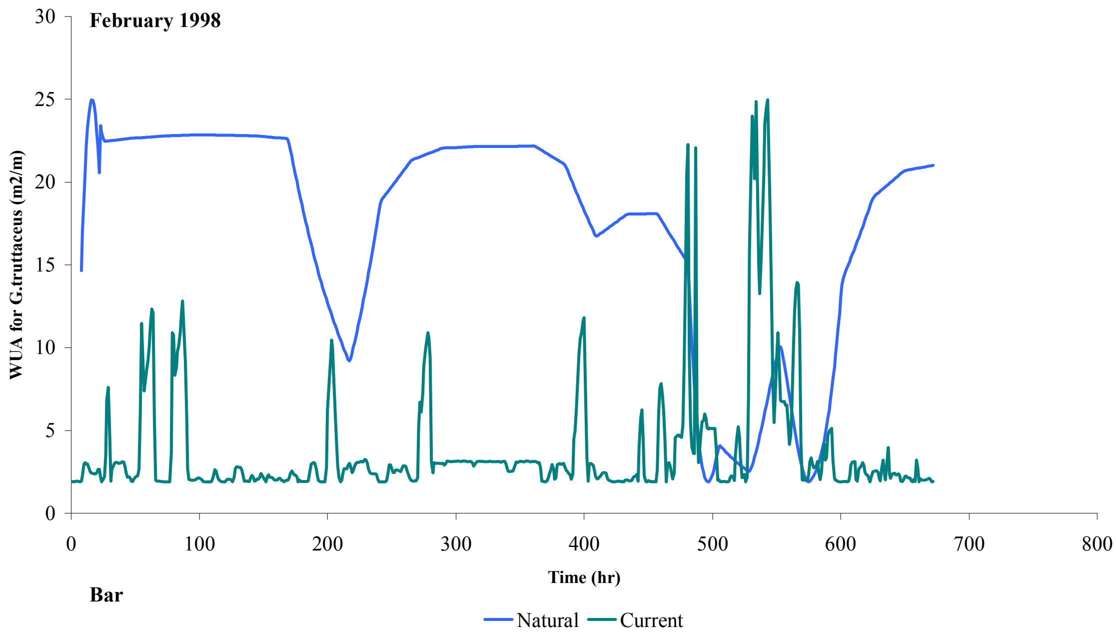


Figure 14. Plots of simulated useable habitat (WUA) for *Galaxias truttaceus* at pool-run and bar habitats for Zone 3 under natural and present flow regimes during February 1998. Note the generally lower habitat availability due to high flows under the present flow regime, compared to higher WUA with occasional significant declines during natural floods.

3.4.2 Stranding and colonisation

The issue of stranding is a complex one that appears not to be simply related to the rate of flow decrease. The relationship between river discharge and the river height at a site (ie. its rating curve), as well as the presence of hydrological controls within the river, will greatly influence the rate of change during power station discharge decreases. Sites such as Site 75 are dewatered within a matter of minutes following shutdown, whereas Site 72 would take significantly longer. The presence of areas for fish to become trapped also has a major influence as a smooth, steep-walled channel is unlikely to strand fish, whereas shallow backwaters with limited escape points will. Other hydrological factors include the river height at which a backwater or pool becomes disconnected from the river, the rate that the backwater drains relative to the river level and whether it drains as surface flow or through the substrate. It should be noted, however, that backwaters are not a major feature of the Gordon River in any zone. The influence of the power station on rates of change is dampened with distance downstream due to attenuation of the flow pulses and through augmentation of flows by tributary inputs (which have natural rates of change). In some instances the rate of level change is irrelevant and other factors, such as the biology of the species and even water temperature (see Bradford 1997; Halleraker *et al*. 2000), can influence the incidence of stranding.

There are several locations in the Gordon River where fish have been found 'stranded' in pools disconnected from the main river. These fish were all found in what could be regarded as permanent pools (ie. those fed by ground water seepage, or regularly flushed by river water) and the fish were in good health. No fish with the exception of one (discussed below) were found dead as a result of stranding even though fish surveys were often conducted immediately following dewatering. It would appear that the fish of the Gordon River have adapted behaviourally to this changing environment, and that potential stranding areas are either avoided or are utilised in such a way that the rapid rate of decrease provides enough cues to the fish to evacuate. In addition, it is probable that responses to the existing flow regime including stranding-associated mortality have already occurred, resulting in low population densities and diversities in the zones most impacted by the power station operations. This would partially explain the low stranding rates observed during the 1999/2000 surveys.

At Site 72 particularly, trout were regularly captured from isolated pools with the number of fish per pool roughly proportional to the size of the pool rather than its position on the bank. Interestingly, Bradford (1997) found that *S. trutta* responded quickly to decreasing flows and that they would have a reduced susceptibility to stranding compared to some other species. This would suggest that these pools form part of the frequent habitat for such fish and that retreat to these refuges should not be considered as 'stranding' which contributes to mortality. There are no data available to determine the survival times of fish under these conditions.

At Site 65, a single dead ammocete was recorded at the water's edge following power station shutdown. These fish burrow in sandy sediments, generally in very shallow water and utilise these habitats for up to 3 years before migrating to the sea as adults. Hence both *G. australis* and *M. mordax* are highly susceptible to stranding, as it takes a short period of time for their habitat to dewater since sandy deposits drain quickly, often without surface flow. *G. australis* was not captured in Zones 1 or 2 during the 1999/2000 surveys and *M. mordax* was captured only in Zone 5 of the main river. Interestingly, *M. mordax* were captured in tributaries of Zones 2 and 3 (Table 7), although in very low numbers, with a large adult in the Albert River and an ammocete in the Olga River. This indicates that at least this species of lamprey can occasionally negotiate the barriers downstream of these zones. It is likely therefore, that the reduced opportunities for migration past the gorges in the Gordon River due to high flows, are limiting their abundance in the upstream reaches of the Gordon River.

In the lower reaches, it is probable that stranding of ammocoetes does occur in greater numbers than indicated by the observation at Site 65, particularly as individuals may remain under the sand and therefore undetected. It is possible that stranding-induced mortality in these zones limits population numbers, as suitable habitats (sandy pool edges and backwaters) are generally available at the high flows produced by power station discharges. Unfortunately, the rates of stranding under natural conditions are unknown and the impacts of hydro-peaking on stranding rates for these species cannot be quantified.

It is likely that fish, particularly in the upper reaches of the Gordon River, have developed behavioural responses that either lead to avoidance of high stranding-risk areas (hence a reduction in habitat utilisation) or have developed an acute sensitivity to flow change. It is also likely that species, or individuals, susceptible to stranding have been eliminated through repeated stranding events in high-risk areas over the 23 years of power station operation.

Similarly difficult is the assessment of true habitat availability given that habitats are not instantly utilised by all species suited to those areas. The rate of colonisation (ie. movement of species into newly available suitable habitat) is largely unknown, but is thought to be greater for mobile open-water predator species and slower for cryptic, vulnerable organisms.

During short-term hydro-peaking, the location and quality of suitable habitats changes episodically. In the case of the Gordon River (see Section 3.4.1), the most suitable habitats for native fish species are created either during shutdowns or when the power station discharges very low flows while being run for "spinning reserve" (~8 cumecs). Alternatively, at high flows in Zone 1, additional habitats are created through the inundation of riparian verges. These habitats may not be utilised if the hydraulic rate of change is such that it exceeds the colonisation rate of the species involved. Hence, true availability of such habitats is effectively reduced from what is modelled. As there are no data available on colonisation rates of Gordon fish species, there are no appropriate corrections that can be applied to the analyses in Sections 3.4.1 and 4.1, although it can be assumed that the shorter the duration of a habitat availability 'event', the less effective this habitat will be in supporting aquatic life.

3.4.3 Food availability

The presence of both the Gordon and Serpentine Dams limits the downstream delivery of material into the middle Gordon River, in terms of both fine particulate organic matter as a food source for macroinvertebrate communities and downstream macroinvertebrate drift. The aquatic ecosystems immediately downstream of the dams are essentially starved of aquatic food resources.

Reduction in macroinvertebrate food resources has occurred in the Gordon River, particularly in Zones 1 to 3, as described by Davies and Cook (2001). Channel areas impacted by periodic dewatering would be associated with intermittent reductions in food production for fish, while areas affected by reduction in macroinvertebrate abundance due to substrate infilling and large fluctuations in velocity will also produce less benthic macroinvertebrate food. It is unlikely that erosion-associated tree-fall has resulted in reductions in terrestrial food supply, as most wetted margins are still associated with the forest edge and/or overhanging trees and understorey plants.

Bank instability and erosion is unlikely to play a significant direct role in fish habitat availability. Loss of availability of snag habitats due to periodic dewatering may be important, however. Native galaxias use snags as shelter and feeding habitat (eg. Ault 1991), though this is not a dominant habitat for juveniles. The value of snags as a shelter habitat from high velocities may have increased during periods of power station discharge, but their value as both a food source and shelter habitat has been reduced overall, due to periodic rapid water level fluctuations (see Davies and Cook, 2001). Generally, the distribution of snag habitats increases at higher levels on the bank and increases in the inundated area of this habitat type occur only at higher flows.

Another factor which may affect food availability is the ability of fish to access this resource during high flow velocities. The macroinvertebrate population of the Gordon River is primarily concentrated within the area of constant inundation (Davies and Cook, 2001) located along the thalweg ('centre-line') of the main river channel. During power station shutdowns or periods of minimal discharge, these areas would be subject to lower flow velocities and hence are more likely to offer suitable native fish habitat (Attachment 8.4 shows the relationship between velocity and native fish habitat preferences). Hence, low flows allow a coincidence of the food resource and suitable native fish habitat. At high discharges, the thalweg invertebrate communities are exposed to higher flow velocities which would serve to limit fish access to these areas. Davies and Cook (2001) derived flow velocity distributions across the channel at high flows (equivalent to power station efficient load or full gate operation). These velocities were significantly greater than the upper limit at which fish could swim upstream or hold position (ca 0.3 – 0.4m/s, see Walker 1999), being typically between 1 and 3 m/s. Only adjacent to the channel edge are velocities suitable for active fish foraging at high flows. High flows therefore have the effect of reducing food availability as fish cannot move to the thalweg area to forage for benthic macroinvertebrates. Consequently, the modified flow regime of the Gordon River, with higher proportions of time at high flows under present conditions compared to natural, would limit fish access to a major macroinvertebrate food resource.

The influence of flow pulses on macroinvertebrate drift (another food source for fish) was not assessed in this study. It is not known whether food availability is the limiting resource for fish populations in the middle Gordon River.

3.4.4 Fish migration

The major barriers to fish migration within the middle Gordon River are described at the start of Section 3.1. These barriers act as partial or complete barriers to fish migration under a range of flow regimes and are species-specific. Walker (1999) and Davies and Walker (unpub. data) assessed maximum swimming speeds of Tasmanian native freshwater fish and water velocities required to allow fish passage. *G. truttaceus* had maximum sustained and burst swimming speeds of ca. 0.31 and 0.43 m/s respectively, similar to other galaxiid species but lower than brown trout, which had sustained and burst swimming speeds of 0.42 and 0.55 m/s, respectively. They also calculated relationships between water velocity and distance swum over a range of body sizes. They observed that water velocities over 0.6 – 0.7 m/s would prevent passage of any native fish or trout over distances more than a few metres. High velocities in the gorge and rapid sections of the middle Gordon would exceed these flow velocities during high power station output and thus prevent fish passage at these times.

As a consequence of power station operation, higher flows are presently experienced over a longer period of time, particularly during the warmer months, which is an important period for the upstream migration of galaxiid juveniles. This flow regime is converse to the natural flow regime that produces periods of low flow regularly during these seasons. This has probably contributed to reduced juvenile galaxiid recruitment upstream of the major gorge sites. The most downstream barrier identified, the Sprent River delta, is an incomplete low-flow barrier, with high water velocities occurring through a constricted area at low discharges. Even at low discharges this area would not form a complete barrier as there are low-velocity refuges along the delta edges. Galaxiid migration past this point would occur naturally during spring and summer and it appears that recruitment upstream to tributaries such as the Sprent River, Platypus and Howards Creeks is still regularly successful, with consistent catches of varying sizes of *G. truttaceus* during the 1999/2000 surveys at these sites.

The high flow barriers presented by Ewarts Gorge, the two Splits and Abel Gorge are far more influential under the high summer power station discharges and must contribute to dramatically reduced populations of galaxiids in the upper zone tributaries. The Serpentine River was found to have very low numbers of *G. brevipinnis* of large size (and hence age) classes, with no juveniles captured during the surveys (section 3.3.2). The ages of these fish were not determined as the fish were released unharmed in order to not further deplete the low population numbers. However, it is expected that galaxiid recruitment to these tributaries in Zone 1 is an infrequent occurrence under the present power station operating regime. It is likely that present operations will continue to restrict native fish recruitment to the upper zone tributaries to an infrequent basis and therefore it is probable that these ageing populations will eventually die out from these tributaries unless more frequent replenishment takes place. Conducting age determination studies on fish from such populations would allow back-calculation of migration times, and hence correlation with power station operations at those times similar to the methods of Davies *et al.* (1996) for the King River, and is discussed further in Section 7.

The majority of galaxiid juveniles migrating into the Gordon as whitebait are likely to recruit from a pool supplied by the entire drainage flowing into Macquarie Harbour. Recruitment from the King River catchment has been eliminated due to heavy metal pollution, but there are still significant sources of recruitment outside the middle Gordon, including the Franklin - lower Gordon catchments (see Davies *et al.* 1996). The abundant populations of native species in the Birchs Inlet tributaries, as well as other small creeks draining into Macquarie Harbour (Davies *et al.* 1996), indicates that the larval source pool in Macquarie Harbour is still abundant. It is considered highly probable that it is the riverine processes which are reducing fish abundance in the middle Gordon.

3.4.5 Water quality

The influence of water quality on the fish of the Gordon River is unknown. The temperature of water discharged from the power station is more constant now than would be expected naturally, by virtue of the depth of the power station's intake - as discussed in Appendix 3 of this report series – Gordon River Water Quality Assessment (Koehnken, 2001). Consequently, temperatures in the Gordon River are cooler than natural compared to the in-flowing tributaries during summer and are comparatively warmer during winter. This reduced temperature variability, in combination with the reversal of the flow regime, is suspected to have an influence on the fish, in particular, through the disruption of cues that may control the timing of critical life-cycle events such as spawning and migration. Similarly, the attraction of migrating larval or juvenile fish, such as eels and whitebait, to the mouth of the river may be affected by the altered water quality and may lead to reduced recruitment.

When there is a large temperature differential between tributary inflows and the power station discharges, a variable discharge regime will lead to rapid fluctuations in water temperature at sites downstream of major tributaries. The largest differential is likely to occur in spring, and is estimated to be in the order of 6°C (Koehnken, 2001), and could lead to thermal shock in exposed fish. The effects of temperature are very species specific, and little is known about the temperature tolerances of the Tasmanian galaxiids. Hence the true effects of water temperature fluctuations of this order on fish of the Gordon River are unknown, but are expected to be secondary in order to the other issues posed by flow regulation.

Dissolved oxygen concentrations discharged from the Gordon Power Station are currently above 6 mgL^{-1} and are therefore suitable for the maintenance of fish populations in the Gordon River. Additionally, it appears that oxygenation to ambient saturation concentrations occurs very rapidly (Koehnken, 2001) and therefore it is not expected that dissolved oxygen concentrations are currently influencing the distribution of fish in the middle Gordon River. The presence of adult freshwater crayfish (*Astacopsis tricornis*) in zone 1 (see Davies and Cook, 2001) also supports this conclusion.

3.5 Influence of exotic species

The only exotic fish species found during the 1999/2000 fish surveys was the brown trout (*Salmo trutta*). This species has an advantage over native fish species under the regulated Gordon River environment in that its life-cycle does not require migration to the sea to spawn, as do most native fish. As a result, juvenile recruitment for this species can be maintained through spawning in adjacent tributaries above the major barriers within the Gordon River. Therefore, brown trout populations can maintain successful recruitment regardless of conditions within the Gordon River itself. The limiting factors here are the availability of habitat and resources within tributary streams and the presence of natural barriers such as waterfalls in these waterways that may preclude colonisation of these areas by trout. Even so, the brown trout has a documented ability to negotiate small waterfalls through high burst speeds and leaps similar to other salmonid species, such as the Atlantic salmon (*Salmo salar*). Spawning opportunities for brown trout in the Gordon River itself are likely to be very limited. WUA-Q curves for spawning trout (Attachment 8.3) indicate low spawning habitat availability under present conditions. Even in zones where spawning habitat is available under higher flow conditions (such as at Site 75 - Figure 18), this habitat is unlikely to be available for the full period required for egg incubation, and hence dewatering of redds and the subsequent mortality of the eggs and larvae would be likely to reduce recruitment success from within the Gordon River to a very low level.

Brown trout appear particularly adaptable to regulated conditions. Garcia De Jalon *et al*. (1994) note the persistence of brown trout following hydro-power regulation, even after the disappearance of other fish species. This species was also found to be highly responsive to falling river levels by Bradford

(1997) and therefore may have a competitive advantage over other species with respect to stranding (as discussed in Section 3.4.2).

The fish communities in the Davey River catchment, which is trout-free, revealed very different native fish communities to those in the Gordon River. Similar habitats in both catchments were sampled, particularly those downstream of major fish migration barriers. Where fish surveys of these habitats in the Davey catchment rivers produced a diversity of species at high densities, similar habitats in the Gordon often revealed either one or no native species and brown trout. The reaches of the Crossing River, upstream of its gorge, provided a suitable habitat for *G. brevipinnis*, similar to the upper reaches of the Gordon River. The Crossing River in this reach had the highest CPUE for *G. brevipinnis* for all the surveys, whilst comparable sections of the Gordon had none at all.

A similar pattern was found in the rivers flowing into Birches Inlet (which would have access to the same pool of migratory fish species as the Gordon) in which trout were not captured, but would be expected to have access to these reaches. Several lower river native species such as sandies (*P. urvillii*) and common jollytails (*G. maculatus*) were present in these rivers, suggesting an absence of fish migration barriers downstream.

Even where trout are known to be present, such as in the Henty River, which supports a popular sea-run trout fishery at its mouth, the absence of trout at some sampling locations was accompanied by far higher diversity of native species than those sites where trout were recorded. Only two sites (tributaries of the Franklin River) contained both trout and *G. brevipinnis*. At these sites, the trout were always downstream of *G. brevipinnis* and the two species were never found co-inhabiting the same sections of creek. The complete absence of *G. brevipinnis* in samples where trout were recorded confirms the incompatibility of this species with brown trout.

It is apparent therefore, that the presence of brown trout has a major influence on the fish fauna of south-west Tasmania and has implications for the management goals that could be met for the Gordon. This is discussed further in Section 4.5.

3.6 Summary of present conditions

Clearly, the environment downstream of the Gordon Power Station has been substantially modified by the Gordon power scheme. The more significant effects on the native fish fauna are related to the on-going operation of the Gordon Power Station, which include increasing barriers to fish passage and a dramatically altered flow regime. Any residual effects from the dam construction period or the interception of major floods are likely to be secondary in magnitude.

The effects of hydro-electric operations on riverine fish populations are widely known and at least for a few overseas species, widely researched. Prior to this study, no specific work on the impacts of the Gordon Power Station on fish populations had been conducted, so the surveys conducted during 1999-2000 are a major advance in the understanding of these issues.

The existing, modified hydrology of the Gordon River is typified by a seasonal inversion of flows, such that the bulk of the water is discharged during the naturally drier months. Currently there are short-term fluctuations in power station discharge, although these are not as frequent or as extreme as those predicted under Basslink. The power station does shut down frequently, leading to close to zero flows at the power station tailrace, although there is significant catchment pickup below both the Gordon and Serpentine dams during rainfall.

Habitat availability for fish species in the Gordon River is, as a general rule, inversely related to river discharge. High river flows translate into higher velocities and greater depths which degrade the utility of otherwise suitable habitats. Hence, low flows equate to a low wetted perimeter, but the amount of habitat that is suitable for fish is greater than at high flows. This relationship is particularly true for the sites downstream of Abel Gorge. Above the gorge, there are some habitat area increases at high flows due to inundation of riparian verges that normally do not provide useable habitat. The presence of such habitat does not necessarily equate to more abundant fish populations as it appears that native fish migration under present operations is reduced. This is principally related to high flows during Spring and Summer which hamper fish passage past fast flowing gorge sections at the Splits and at Abel Gorge. The present operational patterns of high Spring and Summer power station discharges have therefore led to reduced recruitment of galaxiid species to both the middle Gordon River itself and its upper tributaries.

The presence of brown trout is concluded to also be a major influence on the fish fauna of the Gordon River. The degree to which the hydrological modifications and the presence of this exotic species interact is largely unknown, although there is significant evidence that the trout are better able to cope with the hydrological stresses and habitat availability fluctuations found under present operations.

The negative effects on Gordon River fish of present power station operations are caused by:

- the reversed seasonality of flows, due to the increase in power station discharges during the naturally driest months of the year (summer-autumn). This produces high flow velocities at gorge sites and would limit fish migration opportunities during important migratory periods. The effect of reversed seasonality on spawning and migration cues is undocumented but suspected to be significant;
- the alteration of the river's thermal regime, with decreased water temperatures in summer and increased temperatures in winter. The effects of this thermal disturbance are unknown. It is considered likely that some fish species depend on temperature cues for migration and spawning activity;
- reduced fish migration opportunities affect not only the Gordon River channel, but have a great influence on the fish fauna of adjoining tributaries, particularly those upstream of Ewarts Gorge and include the Denison River;
- rapid dewatering of the hydro-peaking zone may cause fish stranding. The present rates of dewatering exceed the documented response rates for fish;
- habitat availability and quality is reduced through high flows (habitat availability for native fish is much lower at high flows) and regular dewatering. The utilisation of these habitats depends on colonisation rates for both fish and invertebrate food supply; and
- reduced food supply due to lowered macroinvertebrate abundance, and access by fish to the food resource at periods of high flow.

Independent of the power scheme, but acting to compound the adverse effects on native fish species, is the widespread presence of brown trout, which appear to be less sensitive to the altered flow regime of the Gordon River. This, combined with the fact that they have direct access to spawning areas in tributaries without needing to migrate to the sea, leads to domination of the upper sections of the middle Gordon River by this species. Brown trout have negative effects on the native fish fauna through direct predation and competition for resources.

4 POTENTIAL BASSLINK CHANGES

The predicted flow regime under Basslink is more variable in the short-term, ie. there is an increased frequency of peaking flows, with the duration of both 'on' and 'off' events being decreased. The unnatural seasonality of present flow patterns will be continued with the majority of power station operation occurring in the drier months, although there is the likelihood of more winter operation under Basslink than at present.

4.1 Fish migration

Under present operations there appears to be at least partial exclusion of migratory species from tributaries of the Gordon River. This may be caused by the frequent high flows during the migration periods for these species and the inability of these species to negotiate the various flow barriers along the river. Currently, very few periods of low flow occur during the important spring-summer migratory period. Under Basslink, the river will still be highly regulated, however, the TEMSIM modelling suggests that there will be more frequent shutdowns of the Gordon Power Station, leading to short-duration periods of low flow at these barrier locations.

The length of the shutdowns is expected to be short, in the order of one to two days however, this is still expected to be utilised by migrating galaxiids. It has been noted (Howland, pers obs) that galaxiid whitebait runs in the Forth River will very quickly (in the order of minutes) react to migration opportunities presented by changes in flow conditions, and there is every reason to believe that fish in the Gordon River will behave similarly. It is envisaged that passage past critical sections in the gorges could easily be achieved during short power station shutdowns.

In this aspect, the operation of the Gordon PS could be beneficial as it may provide for enhanced opportunities for upstream fish migration and hence recruitment to the tributaries of the Gordon. This would be particularly beneficial for the major tributaries such as the Denison River, which currently has unexpectedly poor native fish populations and which is dominated by brown trout.

It is still unlikely that native fish utilisation of the Gordon River itself will increase permanently, mainly due to the degraded habitat and reduced food availability.

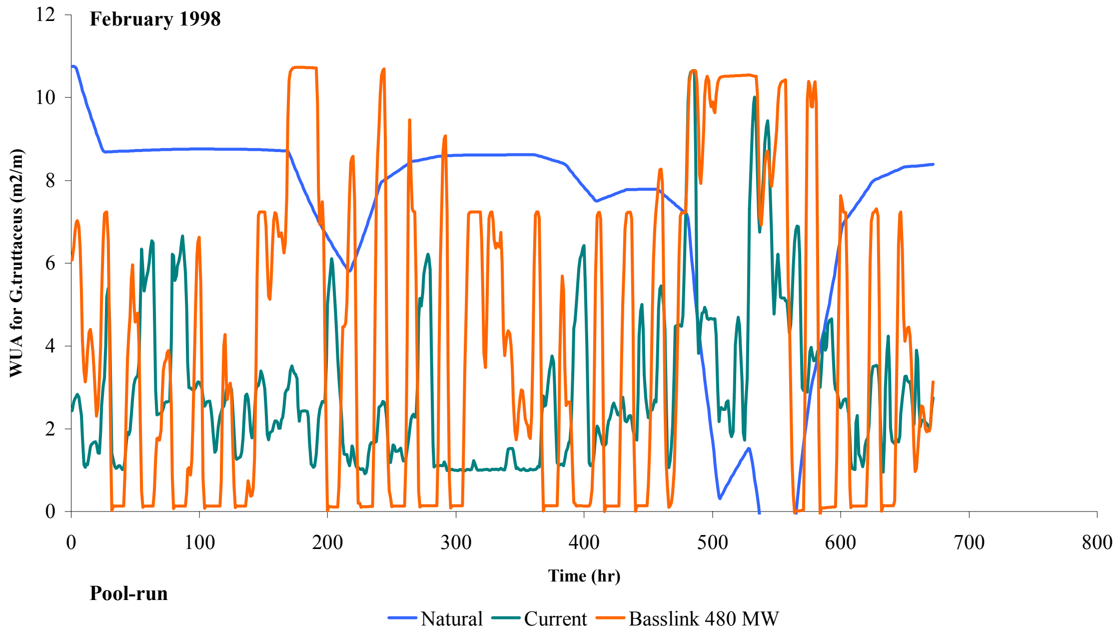
4.2 Habitat availability

Basslink is expected to result in more variable power station operation, with a greater percentage of time at very high flows, with a similar increase in the amount of time at very low flows. A further reduction in habitat availability and quality in the middle Gordon River is anticipated due to this regime. The higher proportion of time that discharges are at high flows will reduce overall fish habitat availability. This is because (as discussed in Section 3.4.1), WUA-Q curves for most fish species tend to peak at low discharges and decline at higher discharges. This is particularly true of the lower sections of the river (ie. those site from Site 72 downstream) where natural catchment pickup can provide the bulk of the water required to make up these low flows, and any additional discharges tend to reduce fish habitat availability. Conversely, there is some potential for increased habitat availability due to the increase in low flow events as WUA peaks for most fish species at low discharges.

In some instances, potential habitat is increased for some species within Zone 1 due to the large fluctuations in water levels with power station flows and the consequent flooding of riparian zones at high flows. In general, however, there is reduced habitat availability at high flows. Habitat (WUA) time-series are shown for natural, present and Basslink scenarios for pool-run and bar habitats for Site 63 (Zone 3) in Figure 14 for *Galaxias truttaceus*. Large natural floods tend to cause short term severe reductions in habitat availability under natural conditions. Despite these floods still being eliminated under Basslink, habitat is significantly reduced for most of the time compared to natural flows and much more variable than under present conditions. In addition, habitat becomes significantly more limiting in pool-runs (Figure 15) under Basslink due to higher velocities associated with more frequent operation of the power station at 'full gate' (Figure 13). This is a common pattern for most of the fish species.

It is expected that the Basslink flow regime will result in a further loss of bank and edge habitats and significant reduction in availability of upper elevation portions of the bed to native fish due to repeated flooding and dewatering. It is considered unlikely that fish will effectively utilise the habitats made available at high flows by the short-term variability of Basslink operations. There will be both little chance for colonisation of these habitats and an increased risk of stranding induced mortality (section 4.3).

Further loss of instream snag habitat availability and quality of habitat is also expected under Basslink (see Davies and Cook, 2001)



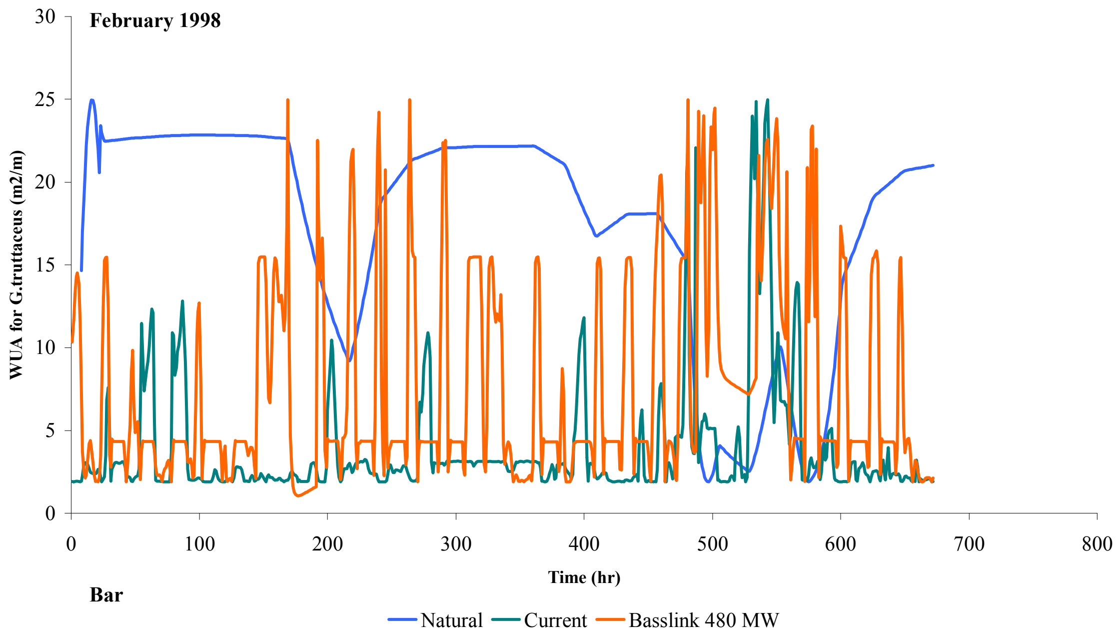


Figure 15. Plots of simulated useable habitat (WUA) for *Galaxias truttaceus* at pool-run and bar habitats for Zone 3 under present, simulated natural and simulated Basslink flow regimes during February 1998. Note the generally lower habitat availability in pool-runs due to high flows under Basslink compared with the present and natural flow regimes.

4.3 Stranding and colonisation

The issue of stranding is a complex one as described in Section 3.4.2. The maximum rate of change for flow reductions is not expected to change under Basslink, as this is controlled by physical constraints such as turbine governor response rates rather than electricity demand patterns. Even so, the present rates of change are well in excess of those experienced under natural conditions.

Under a Basslink scenario, there is certainly more potential for stranding, as the frequency of flow fluctuations, particularly over the full operating range of the power station is increased. The level of actual stranding that may occur is closely linked to colonisation rates for newly inundated habitats. If flow fluctuations are too frequent and flows do not stabilise for an appreciable amount of time, such habitats may not be colonised and hence the potential for stranding of fish in those areas could be lessened to some extent. Unfortunately, data on colonisation rates are not available for Tasmanian fish species. However, it is considered likely that fish, particularly trout, will colonise newly inundated areas reasonably quickly, in search of flooded terrestrial insects and hence are susceptible to stranding during rapid drawdown events.

There is some evidence that, under present operations, there are behavioural responses in the Gordon River fish to dewatering, as very few fish were observed stranded, and those that were had utilised substantial pools that would allow survival until the next power station start up. With the potential increase in native fish recruitment to the upper reaches of the Gordon River, there is an increased chance that schools of these fish will be prone to stranding as they utilise the low-velocity channel margins during upstream migration. These fish would not have any behavioural adaptations to the unnatural flow regime and may therefore be very susceptible to stranding.

Fish colonisation of habitats that become available under the highly variable Basslink flow regime is likely to be reduced compared to present operations. Davies and Cook (2001) discuss the likelihood of a reduced bank margin macroinvertebrate population and it is likely that fish colonisation would follow a similar pattern as the lack of food resources in these areas will reduce the impetus to utilise them.

It is considered likely that the greater variability in flows introduced by Basslink and the consequent effects this will have on colonisation of habitats during hydro-peaking will be more significant than measures of modelled habitat availability.

4.4 Food availability

Food availability is controlled largely by the macroinvertebrate abundance within the river. Davies and Cook (2001) detail the potential impacts of Basslink on macroinvertebrate populations and demonstrate that overall, the effect of Basslink will be negative in terms of both abundance and diversity of macroinvertebrate species. This will translate into reduced food availability for fish species in the river. The potential for increased migration of galaxiid juveniles to the upper reaches of the river will, unfortunately, also provide a greater food resource for brown trout, but not for the galaxiids themselves.

Increased time at full discharge under Basslink is an issue as this will increase channel flow velocities, particularly in the thalweg zone (discussed by Davies and Cook, 2001). These increased velocities will limit fish utilisation of these habitats and restrict the ability of native fish to feed in these permanently wetted areas that contain the bulk of the available food resource. Power station shutdowns during the night, as expected under Basslink, will not facilitate a significant amount of feeding to occur in these zones as all Gordon fish species are visual predators and rely on light availability to detect their prey.

Importantly, it is not known to what extent food resources are the limiting factor for native fish species in the river, given that there are several other major potential impact mechanisms acting on them under present conditions. Despite this, it is felt that a reduction in the food supply will have a negative effect on both the trout and native fish populations in the Gordon River itself, and hence Basslink will most likely lead to some decline in fish abundance, particularly in the upper reaches of the river.

4.5 Exotic species

For a number of reasons discussed earlier, brown trout (*Salmo trutta*) appears to be out-competing and displacing native species within the Gordon River, particularly in the upper zones. The apparent incompatibility between brown trout and *G. brevipinnis* means that these upper zones may never be fully utilised by this native fish.

The increased frequency of flooding and dewatering of habitat expected under Basslink will have negative impacts on the fish of the upper zones of the river. Currently, these areas are dominated by brown trout and therefore the negative influences will be largely concentrated on this species. A decline in the abundance of trout is predicted due to hydro-peaking impacts, but it is unlikely that native fish will be able to fill the void as they are affected by trout under the present operating regime and will probably continue to be so. The additional seasonal food resource for trout in the form of migrating galaxiid juveniles may temporarily offset some of the negative effects of Basslink operations on this exotic species.

Although unlikely, if there is successful recruitment resulting from trout spawning in the Gordon River itself, the increased fluctuation in flows would lead to a higher probability of dewatering redds and reduced recruitment success for this exotic species. This could be seen as a positive impact. However, as a general rule, increased peaking is detrimental to the aquatic environment and cannot be treated in isolation. It is more probable that trout use the tributary streams as the major spawning areas and that Basslink, therefore, will have a limited impact on trout spawning or the subsequent recruitment of juveniles to the Gordon River catchment. The fact that brown trout can utilise tributaries for local spawning places this species at an advantage compared to the natives.

4.6 Summary of Basslink changes

The hydrology of the Gordon River is expected to change as documented in Appendix 2 (Palmer *et al*, 2001). In general, Basslink will result in greater fluctuations in power station flows, more frequent (but shorter) shutdowns and slightly more generation during winter than at present.

These changes in the hydrology translate into:

- Reduced habitat availability for native species and brown trout, particularly in the upper zones of the river. Reductions in habitat availability are most likely to affect trout populations, which currently dominate these upper zones. Forecast habitat availability is further reduced through delays in colonisation of new habitats – hence habitats may be present but not utilised due to continual flooding/dewatering of these areas;
- Increased probability of native fish migration upstream to Gordon River tributaries. This may translate into increased abundance/diversity of native fish populations in these waterways and should help to replenish ageing populations in these tributaries. Native fish populations of the Gordon River itself may increase, particularly during the warmer migration months as transitional populations of juveniles migrate upstream. It is unlikely that permanent native fish populations in the Gordon River itself will increase due to habitat and food availability issues.
- Reduced invertebrate food availability due to reduced habitat, as detailed by Davies and Cook (2001), and a potential increase in trout dominance due to an increased food supply provided by improved native fish migration.
- Increased potential for stranding. However, there was little direct evidence of stranding under present conditions, indicating that the fish fauna had behavioural adaptations to frequent dewatering. Increases in native fish migration may introduce more fish to these areas that may not exhibit these behavioural adaptations. Hence, improved fish migration and access to these hydro-peaking zones may result in more stranding due to temporarily increased fish abundances.

It is expected therefore that there will be a reduction in fish populations of the upper zones of the main river due to reduced habitat and food availability. There may be a transitory native fish population in the Gordon River during the warmer months that could lead to more frequent recruitment of these migratory species to tributary streams. There will be increased potential for fish strandings if rapid water level fluctuations coincide with improved migratory success of native species. There is no predicted benefit from a slight shift to winter generation. The major benefits of more winter generation will be manifested in lower flow rates during spring-summer and the subsequent benefits for fish migration.

5 MANAGEMENT ISSUES

In the absence of any clear specific management objectives for the fish populations in this part of the World Heritage Area, the default aim for any future management should be to protect against further degradation of the communities. In addition, where there are opportunities for improvement, these should be exploited in the interests of improved environmental sustainability.

The Gordon River fish community is already highly degraded by flow regulation, particularly in the upper sections of the middle Gordon River. Similarly, fish populations in tributaries of these upper sections are also depauperate, with increasing abundance and diversity as distance downstream of the power station increases. The presence of brown trout is seen as another major influence on the native fish populations in the river. The presence of this exotic species will undoubtedly lead to sub-optimal outcomes in ecological management for this area.

The flow-related mechanisms of impact are several-fold and are discussed in more detail in sections 3 and 4. Under Basslink, it is likely that these impacts will continue to occur, that is:

- the short-term peaking that currently occurs, will continue to do so in a more exaggerated manner, leading to cyclic inundation and dewatering of habitat – effectively negating the habitat value of the areas within this hydro-peaking zone for much of the time;
- the power station shutdowns and associated low flows in the river will continue to occur, although on shorter time-scales, which again serves to limit the total amount of wetted area available for aquatic biota in the river, particularly in the upper sections. This may prove to have a positive impact in terms of both fish migration and in increases of useable habitat area, which is greatest at lower flows; and
- the seasonal inversion of the flow regime in comparison to the natural pattern has the potential to disrupt spawning and migratory cues, as may the temperature patterns in the river. Although there is some indication that median flows will increase in winter under Basslink, the seasonality of flows predicted for Basslink is still highly inverted and is not predicted to improve the situation.

The specific fish-related management issues for the operation of the Gordon Power Station are summarised in Table 8.

Table 8. Fish related management issues for the Gordon River.

Management Issue	Present causes	Incremental Basslink Impact
Low CPUE figures for all fish in Gordon River compared to reference streams	Habitat modification and/or availability due to flow regime; Predation/competition with trout; Disruption of migration; Reduced food availability	Neutral to slightly negative, the upper sections are already impacted and mitigation in lower areas is likely to be due to natural tributary inputs which is independent of power station. It is possible that native fish migration may increase under Basslink, however the Gordon River itself will always be poorer than the tributaries due to habitat and food availability issues.
Lower diversity of fish in upper sections of the Gordon River than would be expected from natural gradation	Habitat modification and/or availability due to flow regime; Predation/competition with trout;	Neutral to slightly negative, depending largely on the interaction between trout and native species under the further modified conditions. Very few fish live in the upper reaches of the river and therefore few fish will be affected.
Absence of juvenile galaxiids in upper Gordon River tributaries	Disruption to migration due to reversed seasonal flow patterns and sustained high flow velocities at gorge sites; Predation/competition with trout; natural ageing of isolated populations.	Possible benefit as more frequent shutdowns may improve 'window of opportunity' for upstream migrations to refuge streams; otherwise neutral. Tributary galaxiid populations in upper zones will probably continue to decline with or without Basslink if migration opportunities aren't increased.
Dominance of brown trout	Apparently better able to deal with the regulated flow regime than native fish species. Preys on native species.	Unknown, the flow regime is not likely to differ enough to have a measurable effect, although more short-term peaking is less natural and present trends suggest that trout may be better able to cope than natives. The possible presence of transitory migrations of native species to upstream habitats may temporarily offset trout dominance but also provide a food resource for trout. *G. brevipinnis* is not likely to colonise areas inhabited by trout.
Potential presence of Australian Grayling (*Prototroctes maraena*) listed as vulnerable under the TSPA 1995 and EPBCA 1999	The decline of this species statewide is a combination of factors and not specifically linked to hydro power generation	Neutral – occupies lowest reaches of the river, where hydrological changes due to Basslink are minimised. No mechanisms of impact identified.

6 MITIGATION OPTIONS

Basslink is expected to have both negative and positive implications for the fish fauna of the Gordon River. In comparison to the changes that occurred with the original construction and operation of the power scheme, as well as the later installation of the 3rd turbine, the changes predicted to occur under Basslink are small.

The negative implications include extensions of the impacts that currently exist due to the operation of the Gordon Power Station. Consequently, mitigation of these impacts cannot be addressed without ameliorating at least some of the present impacts. That is, it is generally not possible to simply address the incremental impacts of Basslink without addressing at least some of the present impacts. The costs of doing so are not inconsequential.

Keeping this in mind, mitigation should be geared towards addressing issues where:

- a negative incremental environmental impact is predicted to occur as a result of the proposal;
- the impact is unacceptable;
- the mitigation measures are likely to achieve some or all of the management objectives;
- the mitigation measures are acceptable from a social and economic aspect; and
- the mitigation measures themselves do not cause environmental degradation.

Section 4 of this report details the changes that are expected under Basslink, indicating that there are some potential benefits and there are some negative impacts. The mitigation options typically used for protection of fish populations in hydro-peaking streams are discussed below.

6.1 Minimum environmental flows

Habitat availability for native species is seen as a high priority. Typically, habitat availability issues are mitigated through minimum environmental flows, often set at seasonal percentile levels based on natural flows. In the case of the Gordon catchment fish populations, the implementation of such a flow is problematic as there are potential negative aspects to such flows. Plots of habitat availability (WUA) for the study sites is given in Attachment 8.3, and indicate that generally, high flows reduce useable habitat. This is in contrast to the flows related to optimum habitat availability for many of the invertebrate species (Davies and Cook, 2001) and raises the question of trade-offs between various species and the maintenance of natural balances within modified ecosystems through the manipulation of suitable habitat availability for individual species.

The method utilised by Davies and Cook (2001) analyses the risks of various minimum flows on all species present, by taking a conservative approach based on the most sensitive species. This method avoids the need to make arbitrary management decisions based on selection or weighting of individual species, but is also very sensitive to the reference flow selected. The situation in the Gordon River and the need to assess (and mitigate against) the incremental effects of Basslink presents challenges that are not easily overcome.

The major features of the Basslink flow regime that differ from present operations are related to the increased frequency and reduced duration of flow events, particularly variations in flow over the full operating range. A minimum environmental flow would serve to reduce the effective operating range and hence would maintain an area that remained permanently wetted and that could theoretically act as a refuge for fish during hydro-peaking, particularly in Zone 1. There are still likely to be large variations in depth and velocity during hydro-peaking that reduce the suitability of these thalweg regions for fish (see habitat preference curves in Attachment 8.4). The reduction in the operating range resulting from a minimum environmental flow is likely to be beneficial as the hydraulic variability within the channel is reduced.

The major advantage of a minimum environmental flow is to provide a quantum of available habitat during power station shutdown events. This is potentially most important in the upper reaches of the river, where natural catchment pickup is the least due to the Gordon and Serpentine Dams. Currently, the longest period shutdowns are during some of the wettest times of year (spring), where natural inflows to the river are the greatest and the need to supply a minimum environmental flow is at its least.

It is anticipated that a minimum environmental flow in isolation would only partly mitigate the impact of high flow variability and that this measure should be incorporated with other strategies such as partial ramping (Section 6.2) to minimise any negative impacts of Basslink.

6.2 Flow ramping

The rate of change in discharge under present Gordon Power Station operations far exceed those of similar, unregulated catchments. Power station startups produce large bed shear stresses (see Davies and Cook, 2001) due to the steep water surface gradient in the advancing 'flood wave'. This is particularly true for increases that start from zero flow, as frictional forces at the bed of the river slow the toe of the wave down, leading to a steeper water surface gradient and hence greater bed shear stress. The effects of this can therefore be mitigated by a minimum environmental flow, which maintains a wetted perimeter of the river bed and reduces startup shear stresses in these areas. This is discussed previously in section 6.1. Reducing bed shear stress has the advantage of reducing 'catastrophic drift' of macroinvertebrates (Davies and Cook, 2001) and scour of bank sediments (Appendix 4 of this report series – Gordon River Fluvial Geomorphology Assessment (Koehken *et al*, 2001)). Reductions in either of these processes to rates approaching natural will be beneficial for fish due to the maintenance of food supply and habitat. The advantages of further reductions in 'ramp up' rates are not known for Tasmanian species, particularly with respect to the potential for downstream displacement during rapid flow increases. It is envisaged that downstream displacement impacts in the main river channel are minor in comparison to other flow related influences.

The ramping down of flows has potentially far greater benefits. Under present conditions, the rate of flow decrease is very rapid. Although there was very little direct evidence of fish stranding, the present rates of decrease can far exceed known threshold levels for fish response in hydro-peaking situations. The effects of stranding are discussed more fully in Appendix 7 (Gordon River Macroinvertebrate and Aquatic Mammal Assessment) of this report series and in section 3.4.2 of this report.

Despite the potential advantages of a near natural ramp down rate, applied to the full range of power stations flows, there are some major disadvantages to such a rule when combined with multiple high flow discharges separated by short shutdowns (as predicted under Basslink). The major problem arises because a ramp down rule would increase the duration of high flow events. In the situation illustrated in Figure 16 the green lines indicate the maximum and minimum natural recession rates for floods ca 300 cumecs in size. A ramp down rule equivalent to the fastest natural drawdown would result in a baseflow of over 150 cumecs (pink line in Figure 16). This is far higher than the natural baseflow in any part of the Gordon River and would result in a dramatic reduction of habitat availability for fish over the entire length of the river. The level of baseflow that is achieved is dependant on the duration of the 'off' events, however, it is a consistent trend that down ramping of flows results in prolonged and often continuous discharge at flows higher than natural.

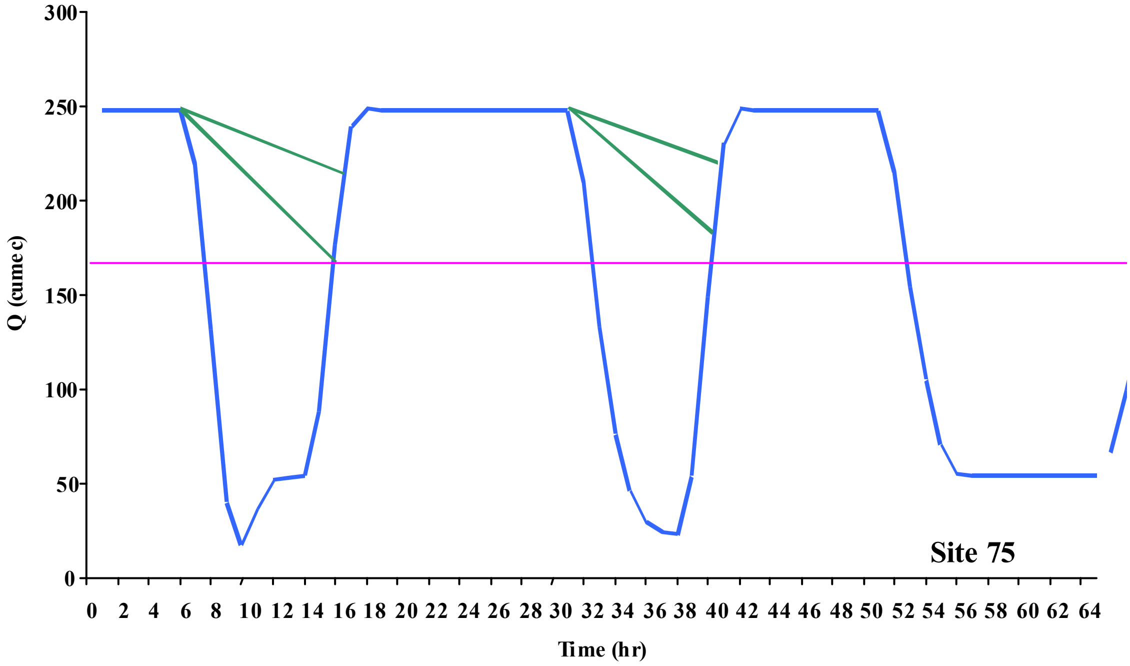


Figure 16. The effect of ramp down rules on hydro-peaking operation at Site 75 (Adapted from Appendix 7)

On the other hand, the provision of a ramp down cue, that is a partial flow reduction before complete power station shutdown, could well be advantageous for fish in the Gordon River. Such an event, would in essence, 'notify' fish downstream of the power station of an impeding drawdown. To be beneficial, such an event should not drop below the flow that inundates high-risk stranding areas. The highest risk areas are considered to be those around Site 73 and Site 72 where wide, flat bars are subject to largely unattenuated power station flow variations. The flows that keep these banks inundated are in the order of 150 cumecs, hence a full drawdown event would ideally be interrupted by a stabilisation of flows above this level before continuing to fall. The benefits of such a rule as well as the time of stabilisation required before further drawdown would be largely indeterminable without detailed experimentation. Despite this, a pause of 1 hour would be ample given a maximum channel width of 50 metres at sites 73 and 72 and a sustained swimming speed of 0.31 m/s (Walker 1999) for the native fish *G. truttaceus* .

6.3 Re-regulation dam

The construction of a re-regulation dam downstream of the Gordon Power Station may allow for a degree of amelioration of the short-term peaking impacts downstream of the power station, as flow pulses could be dampened to rates of change approaching natural. Additionally, a minimum environmental flow could be implemented even during periods of power station shutdown due to the storage of such an impoundment. As such, there would almost undoubtedly be improvements in the present fish fauna of the Gordon River downstream of such as structure.

There are of course, significant environmental drawbacks with such a mitigation strategy as the dam would need to have enough storage to store and process huge volumes of water. Consequently the dam would need to be at a suitable site at some distance downstream of the power station tailrace in order to avoid tailrace backwater effects. This would lead to inundation of otherwise pristine tributaries as well as a substantial portion of the Gordon River bed itself. Consequently, the adverse environmental effects of such an undertaking are considered to far outweigh the benefits that could be provided from such a structure.

6.4 Scheduled shutdown events

Periodic shutdowns during the migratory seasons could result in regular natural recruitment of migratory galaxiid species to the upper sections of the river, and importantly, to the tributaries flowing into these zones. Presently, these tributaries appear to have ageing populations of native fish. This is most likely to be a result of failed recruitment due to sustained high flows through gorge sections during the migratory season (spring-summer) as discussed in section 3.4.4.

Flow modelling for Basslink has indicated that the Gordon Power Station is likely to shutdown periodically, particularly on weekends during low electricity demand periods. As such, it is predicted that Basslink will improve the recruitment of native fish species to the upper Gordon River tributaries without intervention.

One aspect that could not be modelled under TEMSIM (Palmer *et al.*, 2001) is the effect that NEM price pressures may have on maintenance practices for Gordon Power Station. It is generally accepted that a station as critical as the Gordon will have its maintenance schedules optimised to ensure minimum down time, particularly for the station as a whole. The present practice of periodic long intake tunnel maintenance shutdowns, such as that which occurred during Sept-Oct 2000, is still likely to occur, and logistically cannot be compressed much further. It is therefore expected that any opportunities that these shutdowns currently offer for this migration will continue to exist, although generally, this time of year is too early for the bulk of the whitebait migration and the shutdowns are probably of limited value. No juveniles of any galaxiid species were captured in the Gordon River during the abovementioned shutdown.

The scheduling of long shutdowns further into the whitebait migration season (eg. December), would offer the best opportunities for natural recruitment of galaxiids to the upper zones of the Gordon River and tributaries, although this may not be possible due to electricity system constraints and the importance of the Gordon Power Station during dry times. It should be noted that this is not a mitigation measure necessary for the incremental effects of Basslink, as Basslink may improve fish migration opportunities even during short shutdowns.

6.5 Restocking of native fish

It is expected that the flow regime under Basslink will provide more opportunities for upstream migration of native species than at present. Basslink therefore represents an environmental improvement in this respect. Consequently, it is not expected that stocking of fish in upstream areas would be necessary to mitigate any of the incremental effects of Basslink.

Stocking of fish into upstream areas could be seen as a method for improving the native fish populations in upstream areas relative to present conditions. This is particularly true for tributaries, where native fish populations appear to be adversely affected by flow impacts on the Gordon River barriers but are otherwise unaffected by the operation of the Gordon Power Station. Stocking of native fish in the Gordon River itself is likely to be far less productive either with or without Basslink, as habitat availability for native species is generally poor, and the synergistic effects of flow regulation and the presence of trout appear to limit the ability of native galaxiids to exist in the upper reaches of the river.

Stocking of fish would be required on an annual or biennial basis, and would incur significant costs associated with obtaining and distributing suitable stock.

6.6 Removal of brown trout

The eradication of brown trout from the Gordon River system would undoubtedly improve the native fish populations of the system and would allow these species to cope far more favourably with the flow regulation effects of Basslink. The complete eradication of this species would be impossible.

Even for large fish in enclosed waters, such as Lakes Crescent and Sorell, a major program undertaken by the Inland Fisheries Service to remove Carp (*Cyprinus carpio*) has continued for several years and has not yet achieved total eradication. To achieve even a significant reduction in trout numbers in the Gordon catchment would be prohibitively expensive and also have the disadvantage of reducing the abundance of this fish for anglers who target this species in the tidal reaches.

6.7 Summary of mitigation options

Overall, the incremental effect of Basslink on fish in the Gordon valley are both positive and negative. The negative aspects relating to the Gordon River itself are outweighed by the potential for positive influences on the wider catchment through a return of greater fish migration opportunities.

It is considered that the mitigation option with the most benefit is the implementation of a rule that reduces the potential for stranding of fish. The potential for fish stranding is increased under Basslink due to the higher variability of flows and potential for increased native fish migration into stranding areas and should be mitigated against as it has the potential to affect both the Gordon River fauna and the success of recruitment to upstream tributaries. Full ramping of flows (ie. over the entire operating range of the power station) is not recommended due to the effect of further increasing the periods of high discharge. However, the temporary stabilisation of flows at ~150 cumecs for one hour during large drawdown events, has large potential benefits.

A minimum environmental flow would further mitigate the impacts of Basslink. It is felt that such a measure, will offer potential benefits for fish, particularly if set at a very low level (<10 cumecs) through a reduction in the effective operating range of the power station and provision of a greater useable habitat for native fish species.

It is interesting to note that Parasiewicz *et al.* (1988) found that implementation of mitigation measures (minimum flow and ramping) designed for ecosystem recovery did not lead to an improvement of fish biomass in a hydro-impacted river, despite improvement in macroinvertebrate abundance. They speculated that a ramping rate slower than the one implemented may have led to benefits for the fish, but there were no recommendations. Therefore, it will be necessary to monitor the effectiveness of any mitigation that is put in place for Basslink to ensure that the aims of mitigation are being achieved.

Neither of the non-flow related mitigation options is recommended. In the case of the re-regulation dam, the environmental impacts of its construction are likely to outweigh any benefits that it may offer. Native fish restocking in tributaries is not likely to be required, as fish passage is likely to be enhanced under Basslink and natural recruitment in tributaries may take place without intervention. The complete removal of brown trout is regarded as a virtually impossible task and hence its presence and resultant negative effects on instream biota will need to be accepted in any management goals for the Gordon River.

7 MONITORING CONSIDERATIONS

Any further monitoring of Gordon River fish populations should consider the following.

A monitoring program for fish populations of the Gordon River and its tributaries is recommended in order to quantify any changes that may occur with the commissioning of Basslink. The fish monitoring program should be run in conjunction with hydrological monitoring as detailed in the Gordon hydrology report (Palmer *et al*, 2001). The fish monitoring program presented here is designed to:

- quantify pre- and post-Basslink variability in the relative abundance of fish populations and allow statistical comparison between these times and appropriate reference sites (ie. a Before-After-Control-Impact design);
- assess changes in the longitudinal community structure of the Gordon River with the aim of identifying any changes in the zone of influence;

- assess potential changes in CPUE that may be related to habitat availability or other hydrological parameters;
- determine the incidence of fish stranding both pre- and post-Basslink; and
- determine any changes to the fish populations of affected tributaries, in particular, if recruitment success for juvenile galaxiids is improved under Basslink.

The major features of the recommended monitoring program are:

- Fish surveys be conducted for a total of 6 contiguous years, ie. 3 years pre-Basslink and 3 years post-Basslink. The surveys undertaken as part of this study during 1999-2000 can be utilised as the first year of the monitoring program.
- Fish surveys are conducted twice annually: in December and April, to provide an estimate of seasonal variation in samples. The December samples should coincide with the migration periods of all the native fish species. Some comparison (particularly for the April surveys) can be made to invertebrate samples collected during Spring and Autumn following the RIVPACS protocol.
- Surveys are to be undertaken by backpack electrofishing, with a target shocking time of 1200 seconds for each survey site/visit. All fishable habitats should be included in the site surveys to ensure a representative sample.
- Impacted sites to be surveyed are essentially 3 per zone for the main river as well as 3 tributaries. These will include areas prone to stranding events. The sites to be surveyed in the Gordon River catchment are listed in Table 9.

Table 9. Gordon catchment sites to be surveyed during the recommended monitoring program.

Zone	River Sites	Tributary Sites
1	75, 74, 73	Serpentine River, Indigo Creek, Piguenit Rivulet (1 site each)
2	72, 71 and 69	Albert River, Splits Creek and Mudback Creek (1 site each)
3	68, 63 and 57	Smith River (1 site), Harrison Creek (1 site) and Denison River (3 sites - u/s Gorge, @ Maxwell, u/s Maxwell)
4	54, 51, 46	Howards Creek, Olga River, Platypus Creek, Sprent River (1 site each)
5	45, 44, 42	Franklin @ Pyramid Island

Additionally it is recommended that sites outside of the influence of the Gordon Power Station are monitored as reference sites using the same methods as above. The recommended sites are listed in Table 10.

Table 10. Reference sites to be surveyed during the recommended monitoring program.

Catchment	River sites	Tributary sites
Franklin	Franklin d/s Big Fall Franklin u/s Big Fall Franklin @ Canoe Bar	Forester Creek, Ari Creek, Wattle Camp Creek
Birchs Inlet	Sorell River	Pocacker River
Henty	Henty u/s Bottle Creek Henty @ Yolande River Henty @ Sisters	None recommended

At a minimum, all fish should be identified, counted and measured (fork length to the nearest mm).

These data should be analysed to assess changes in time with in comparison to reference sites by conducting an ANOVA with time (year) and location (Gordon Zones vs reference rivers) as factors, and abundance (CPUE) of each species and overall diversity as test statistics.

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ATTACHMENTS

1. **Sample site locations**
2. **Field Proforma (1 table)**
3. **Weighted useable area plots for Gordon River fish species (12 plots)**
4. **Habitat preference curves for native fish and brown trout**

8.1 Attachment 1. Sample site locations

Site	Easting	Northing	Flows into
Albert River	410200	5265900	Gordon
Ari Creek	397400	5288400	Franklin
Crossing @ Bent Strut	422000	5221200	Davey
Crossing @ Clover Corner	428500	5225450	Davey
Crossing @ Gorge	425000	5224150	Davey
Crossing d/s Dodds River	430550	5227450	Davey
Crossing d/s Gorge	423850	5223500	Davey
Davey @ Crossing River	417600	5226700	Davey
Davey @ Hut Creek	414900	5222900	Davey
Davey Creek	417400	5226800	Davey
Davey d/s Hardwood River	416400	5232750	Davey
Davey u/s Crossing River	417850	5227300	Davey
Denison @ D1	416750	5281000	Gordon
Denison @ Denison Camp	405350	5269650	Gordon
Denison @ Maxwell River	407150	5272700	Gordon
Denison d/s Maxwell River	407150	5272200	Gordon
Denison u/s Gorge	407550	5270250	Gordon
Denison u/s Maxwell River	408700	5271800	Gordon
Denison u/s TNR	415500	5279150	Gordon
Canoe Creek	397750	5288700	Franklin
Forester Creek	398350	5291450	Franklin
Franklin @ Canoe Bar	397600	5288500	Gordon
Franklin @ Flat Island	398000	5296950	Gordon
Franklin @ Forester Creek	398400	5291250	Gordon
Franklin @ Pyramid Island	396550	5283700	Gordon
Franklin @ Shingle Island	396900	5284550	Gordon
Franklin @ Third Island	397200	5284950	Gordon
Franklin @ Wattle Camp Creek	398150	5298750	Gordon
Franklin d/s Big Fall	397650	5287100	Gordon
Gordon @ Franklin Eddy	396500	5283650	Gordon
Gordon @ G14 (Site 44)	397100	5280950	Gordon
Gordon @ G15 (Site 42)	397000	5282200	Gordon
Gordon @ G2 (Site 76)	413880	5266669	Gordon
Gordon @ G3 (Site 73)	411700	5266550	Gordon
Gordon @ G4 (Site 75)	413050	5266600	Gordon
Gordon @ G4a (Site 74)	412200	5266400	Gordon
Gordon @ G5 (Site 72)	410300	5266400	Gordon
Gordon @ G5a (Site 71)	409900	5266250	Gordon
Gordon @ G6 (Site 69)	408000	5266900	Gordon
Gordon @ G7 (Site 63)	404600	5269350	Gordon
Gordon @ G9 (Site 60)	403000	5271250	Gordon
Gordon @ Grotto Creek (Site 64)	408900	5266850	Gordon
Gordon @ Harrison Creek (Site 57)	401950	5273600	Gordon
Gordon @ Howards Creek (Site 54)	399000	5273650	Gordon
Gordon @ Platypus Creek (Site 51)	398000	5276100	Gordon

Site	Easting	Northing	Flows into
Gordon @ Serpentine River (Site 77)	414850	5266500	Gordon
Gordon d/s Sprent River (Site 46)	397550	5279900	Gordon
Gordon u/s Serpentine River (Site 77)	415000	5266550	Gordon
Gordon u/s Sprent River (Site 46)	397450	5279750	Gordon
Gordon u/s tailrace (Site 78)	415600	5267700	Gordon
Grotto Creek	409050	5266800	Gordon
Hardwood @ Turner Creek	415000	5237800	Davey
Harrison Creek	402000	5273900	Gordon
Henty @ Sisters	373248	5346530	Henty
Henty @ West Sister	372105	5345613	Henty
Henty @ Yolande	371280	5344400	Henty
Henty @ Zeehan Hwy	373250	5349500	Henty
Henty u/s Bottle Creek	364612	5343053	Henty
Howards Creek	398850	5273550	Gordon
Hut Creek d/s waterfall	414450	5222700	Davey
Hut Creek u/s waterfall	414500	5222450	Davey
Indigo Creek	412900	5266600	Gordon
Jane u/s J1	408250	5300450	Franklin
Maxwell River @ boundary	409350	5278500	Denison
Mudback Creek	408850	5267050	Gordon
Olga @ Fly Creek	400700	5264100	Gordon
Olga @ Gordon	399822	5272364	Gordon
Olga @ Riffles	400400	5265600	Gordon
Orange River	405900	5266800	Gordon
Piguenit Rivulet	412020	5266300	Gordon
Platypus Creek	397950	5276200	Gordon
Pocacker River	380950	5287950	Sorell
Serpentine River	415000	5266200	Gordon
Smith River	401500	5273900	Gordon
Sorell River	379000	5287200	Birchs
Splits Creek	407150	5266600	Gordon
Sprent @ Division	397000	5279800	Gordon
Trutt Creek	397350	5279900	Gordon
Sprent River	397450	5280000	Gordon
Wattle Camp Creek	397900	5298550	Franklin

8.2 Attachment 2. Fish field survey proforma

Site:				Easting:							Site Description:	
Date:				Northing:							Comments:	
Personnel:				Habitats present:								
Shot code	Gear Type	Area Fished (sq.m)	Time Set (24 hr)	Time Pulled (24 hr)	Electro fishing Effort (seconds)	Pool Edge	Backwater	Macrophytes	Riffle	Snags	Water Depth (m)	Species (length)
(eg. BT01 or G75)	BT=Bait trap G=Gill Net E=Electro fish O =Observed	(calculate area swept for active gear)	(ie. when did the gear go in the water)	(ie. when was the gear checked or pulled out)	(as given by time counter on unit)	(Place an 'X' in any column)					(The average depth in metres)	List each fish caught by species and length in brackets [eg. G. truttaceus (110), S. trutta (250, 150), A. australis (450) etc.]

8.3 Attachment 3. Weighted Usable Area plots for Gordon River fish species (12 plots)

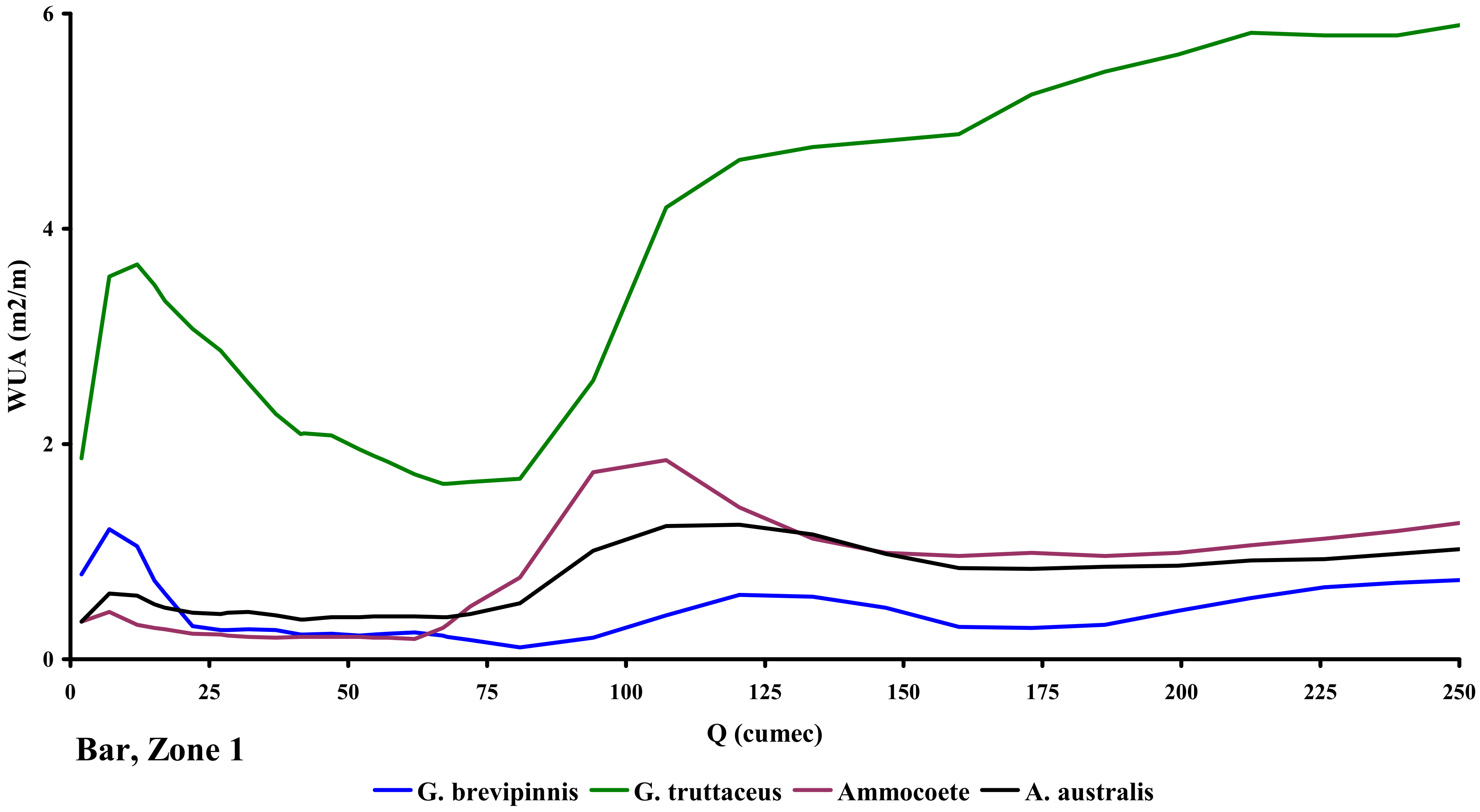

Figure 17. Weighted Useable Area for Native fish for bar sections of Zone 1, Gordon River.

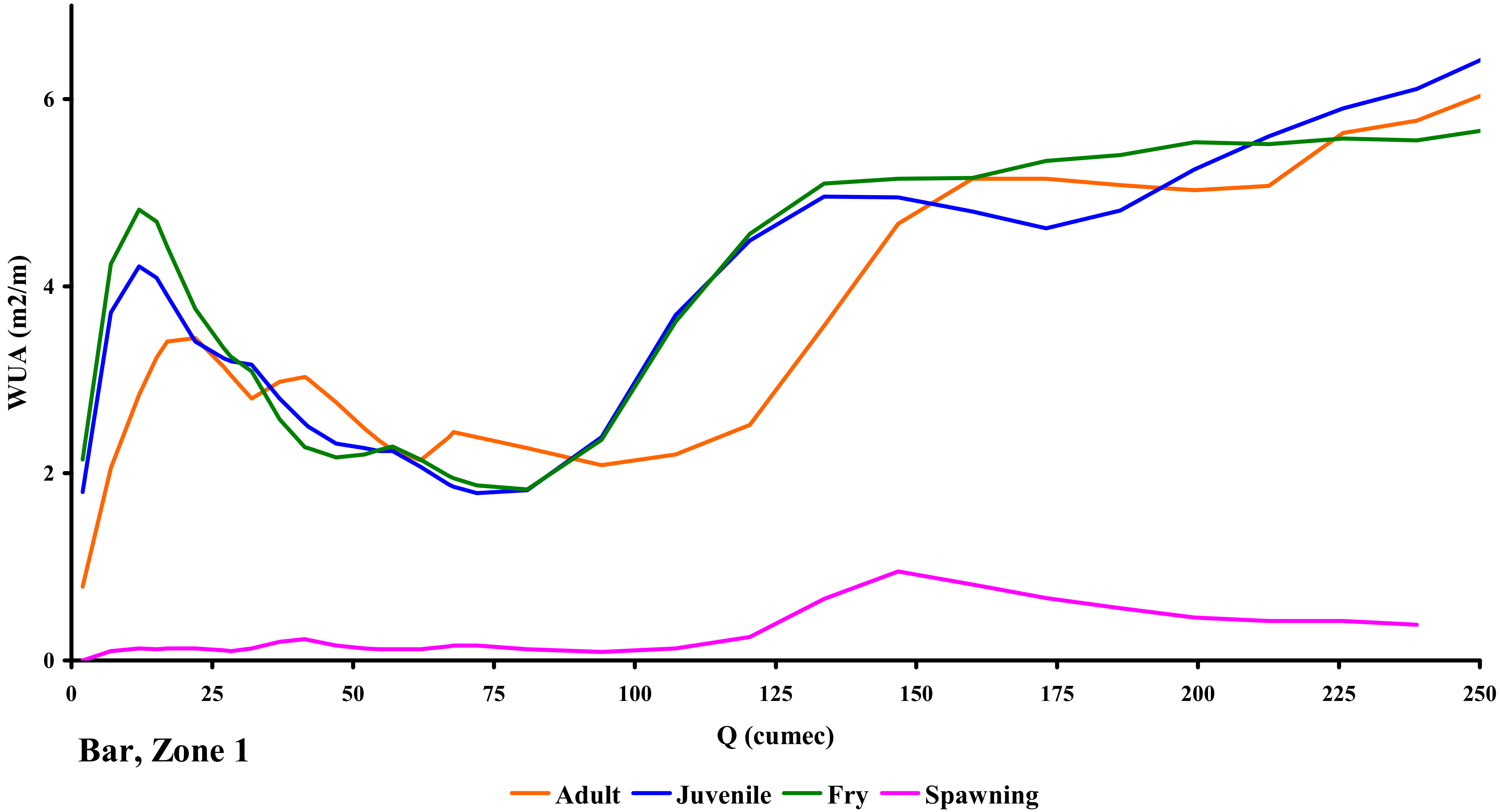

Figure 18. Weighted Useable Area for brown trout for bar sections of Zone 1, Gordon River.

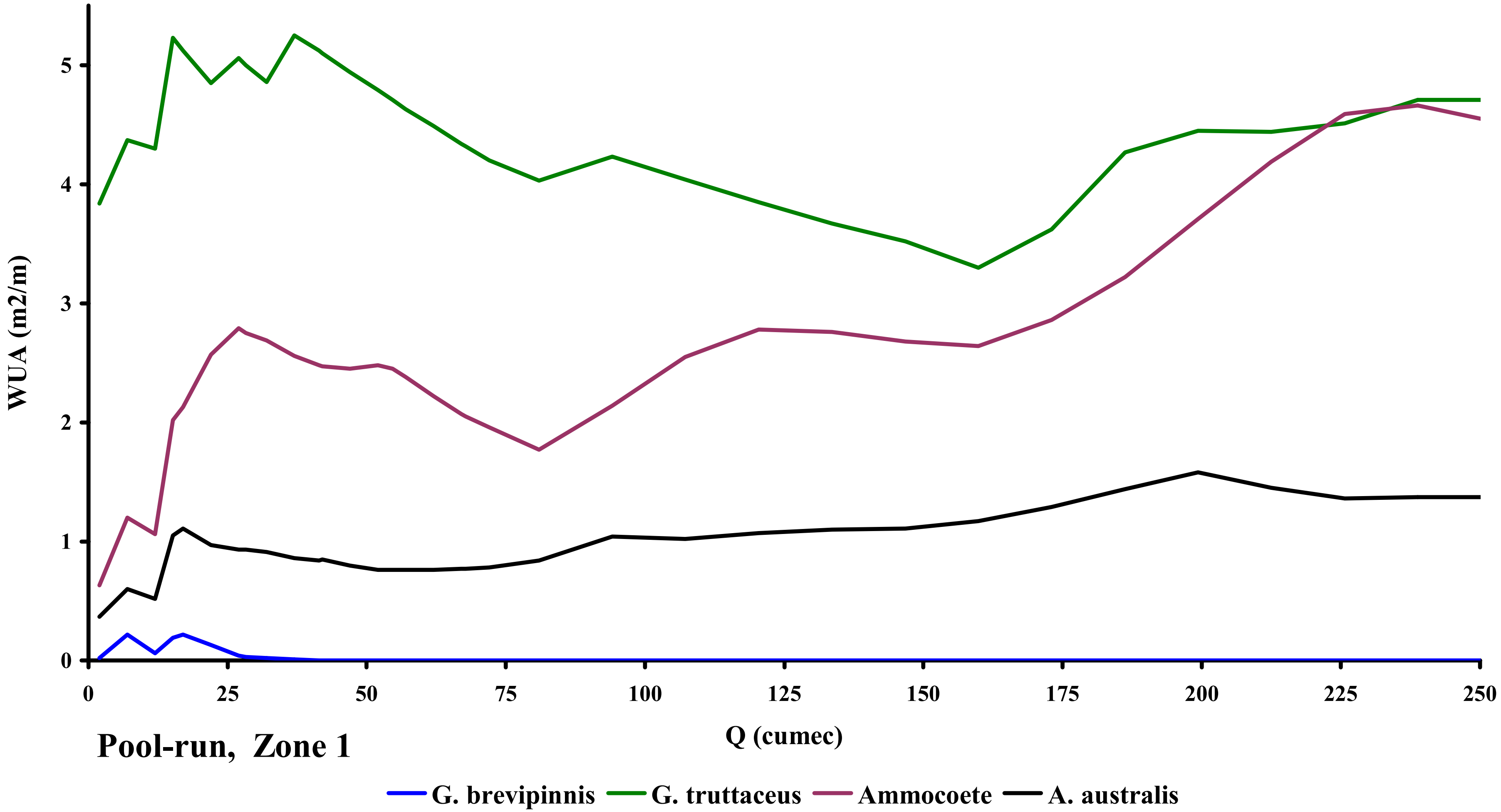

Figure 19. Weighted Useable Area for Native fish for pool-run sections of Zone 1, Gordon River.

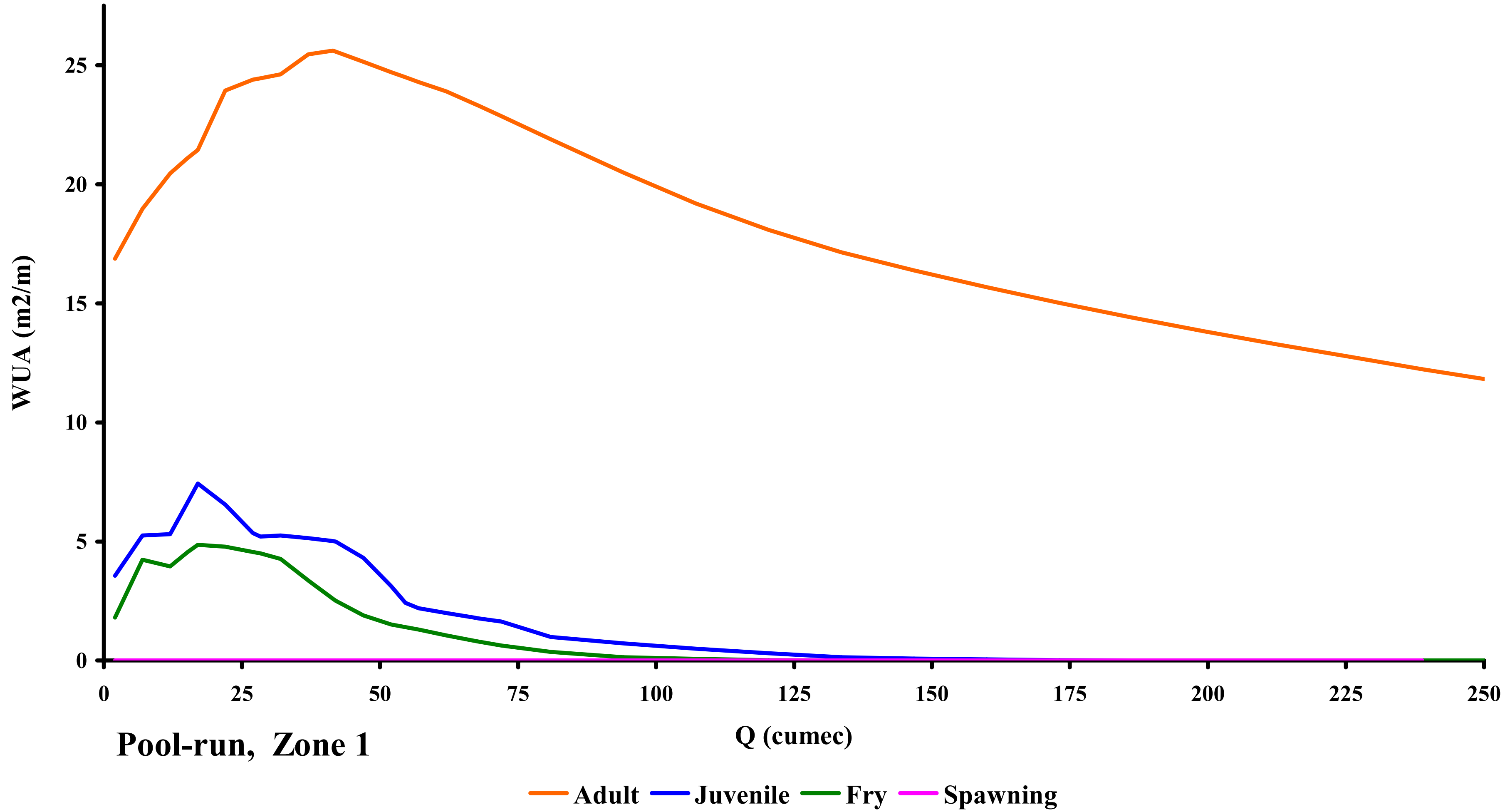

Figure 20. Weighted Useable Area for brown trout for pool-run sections of Zone 1, Gordon River.

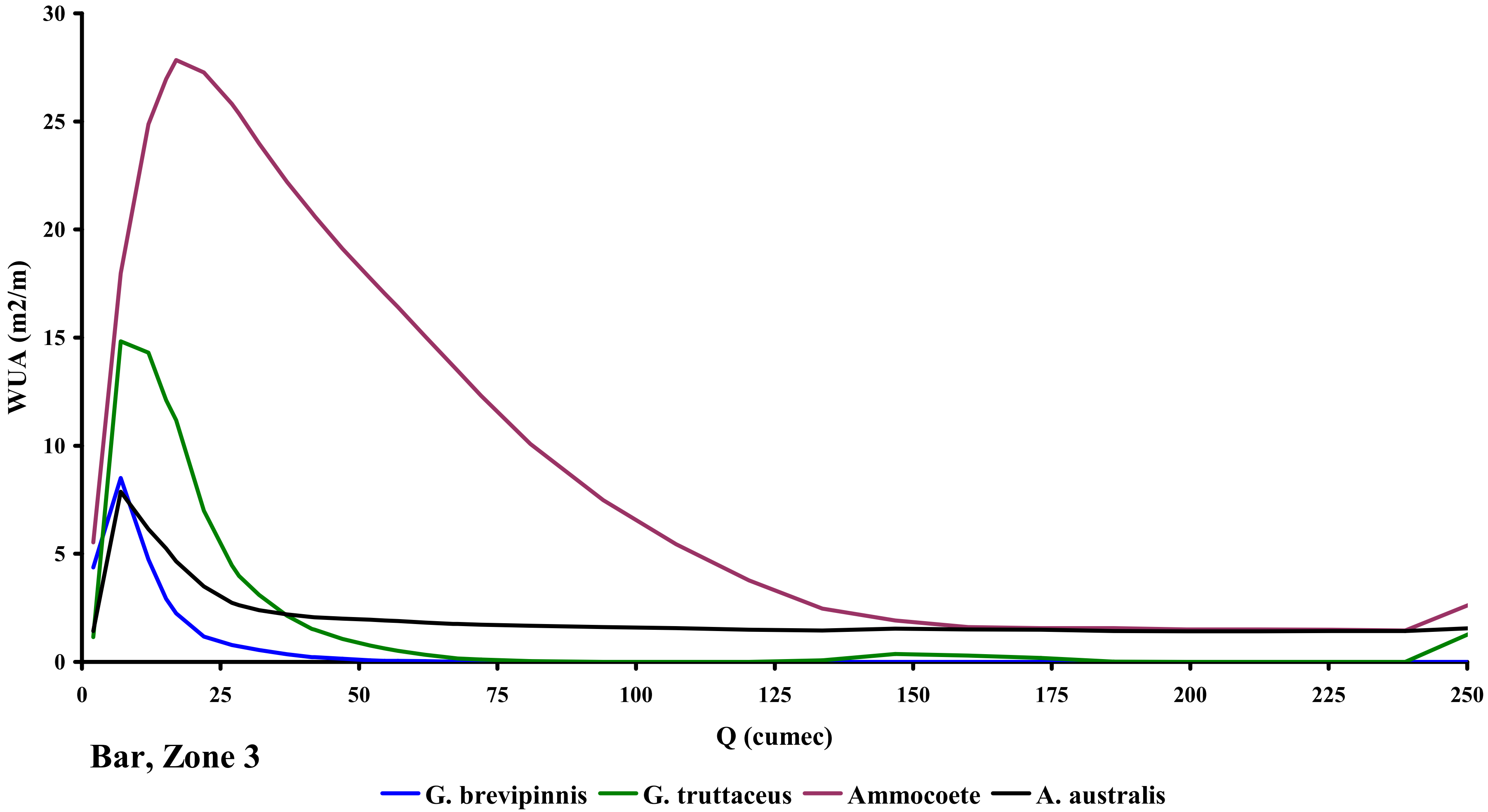

Figure 21. Weighted Useable Area for Native fish for bar sections of Zone 3, Gordon River.

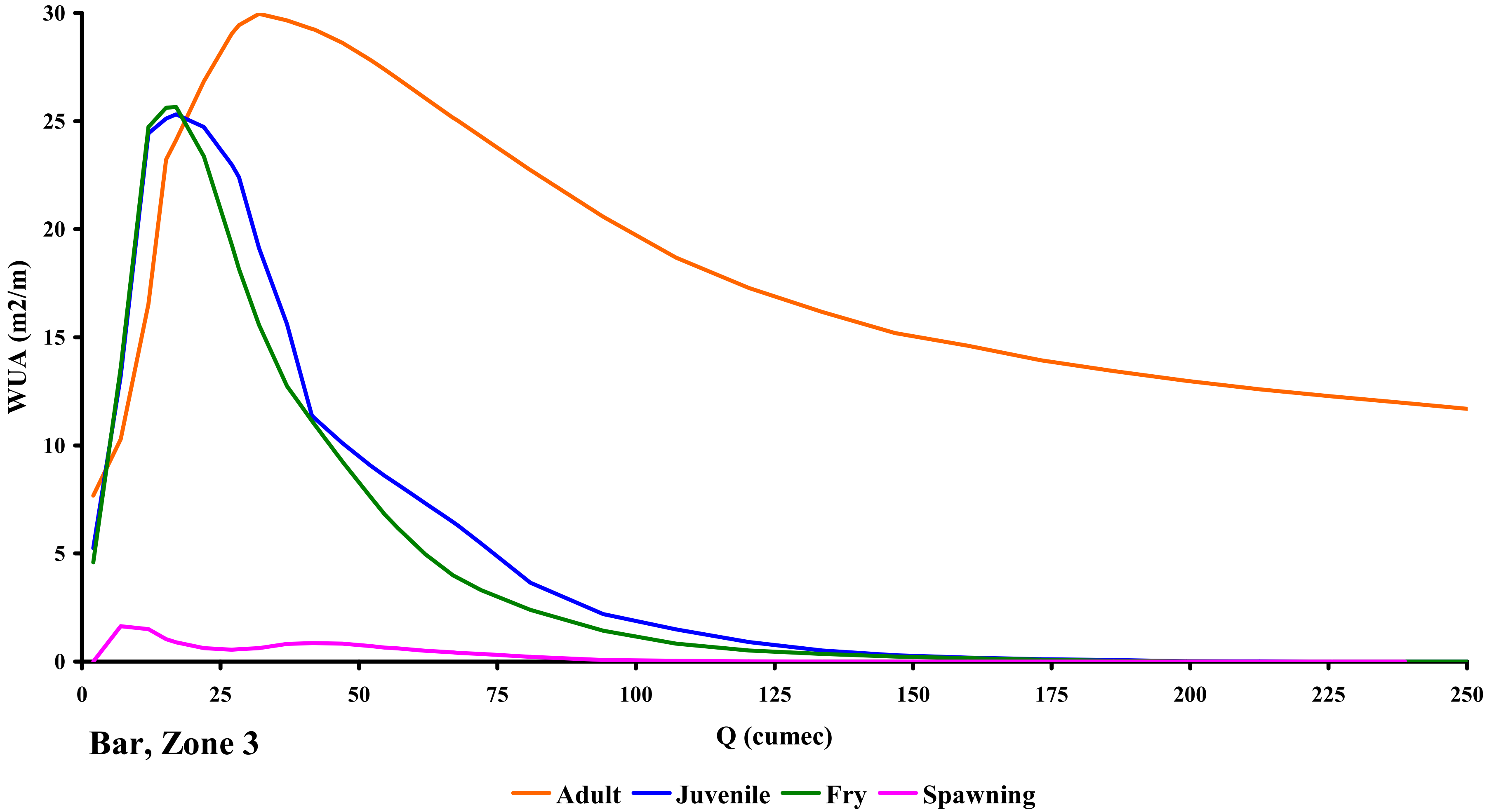

Figure 22. Weighted Useable Area for brown trout for bar sections of Zone 3, Gordon River.

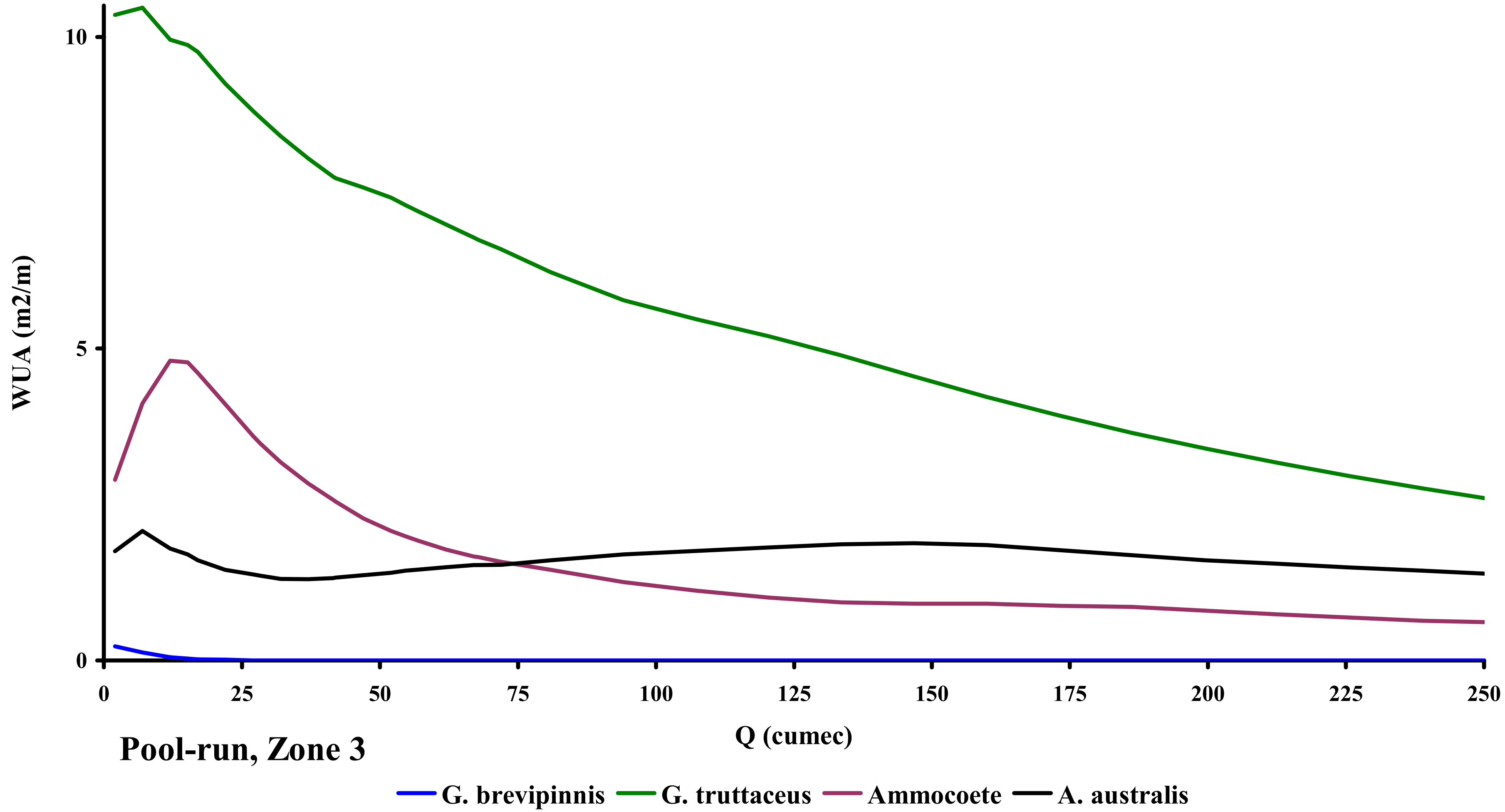

Figure 23. Weighted Useable Area for Native fish for pool-run sections of Zone 3, Gordon River.

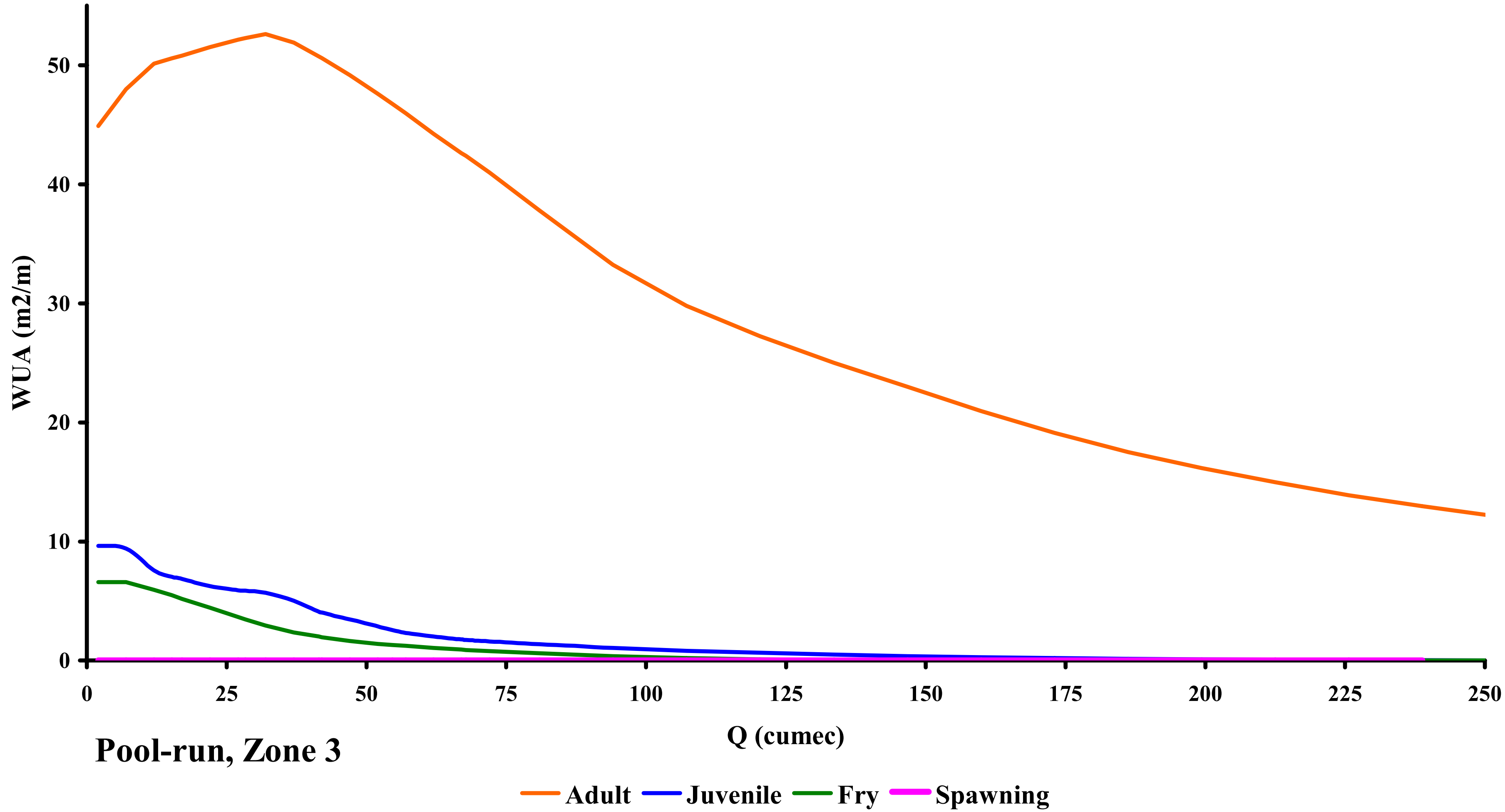

Figure 24. Weighted Useable Area for brown trout for pool-run sections of Zone 3, Gordon River.

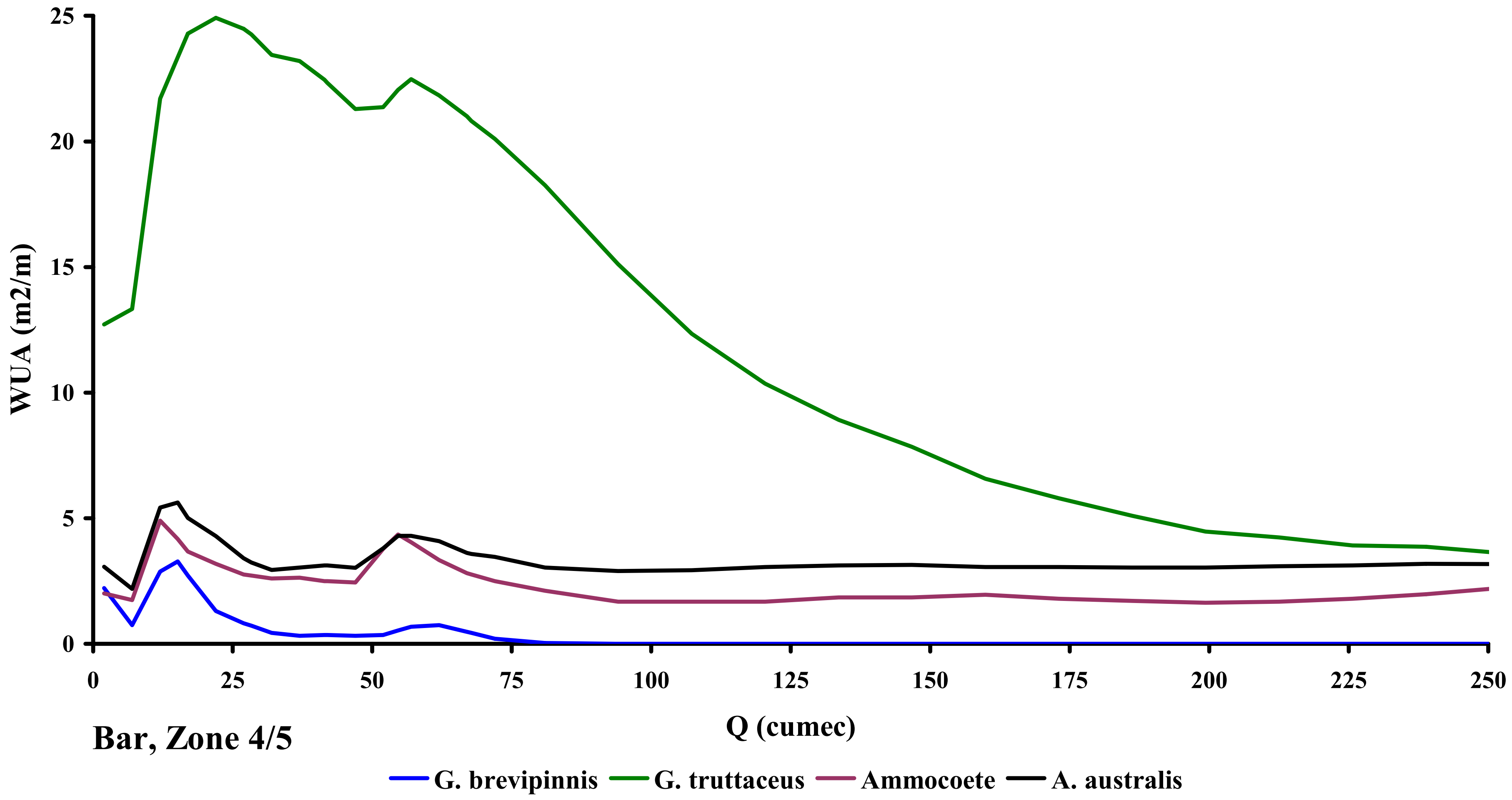

Figure 25. Weighted Useable Area for Native fish for bar sections of Zone 4/5, Gordon River.

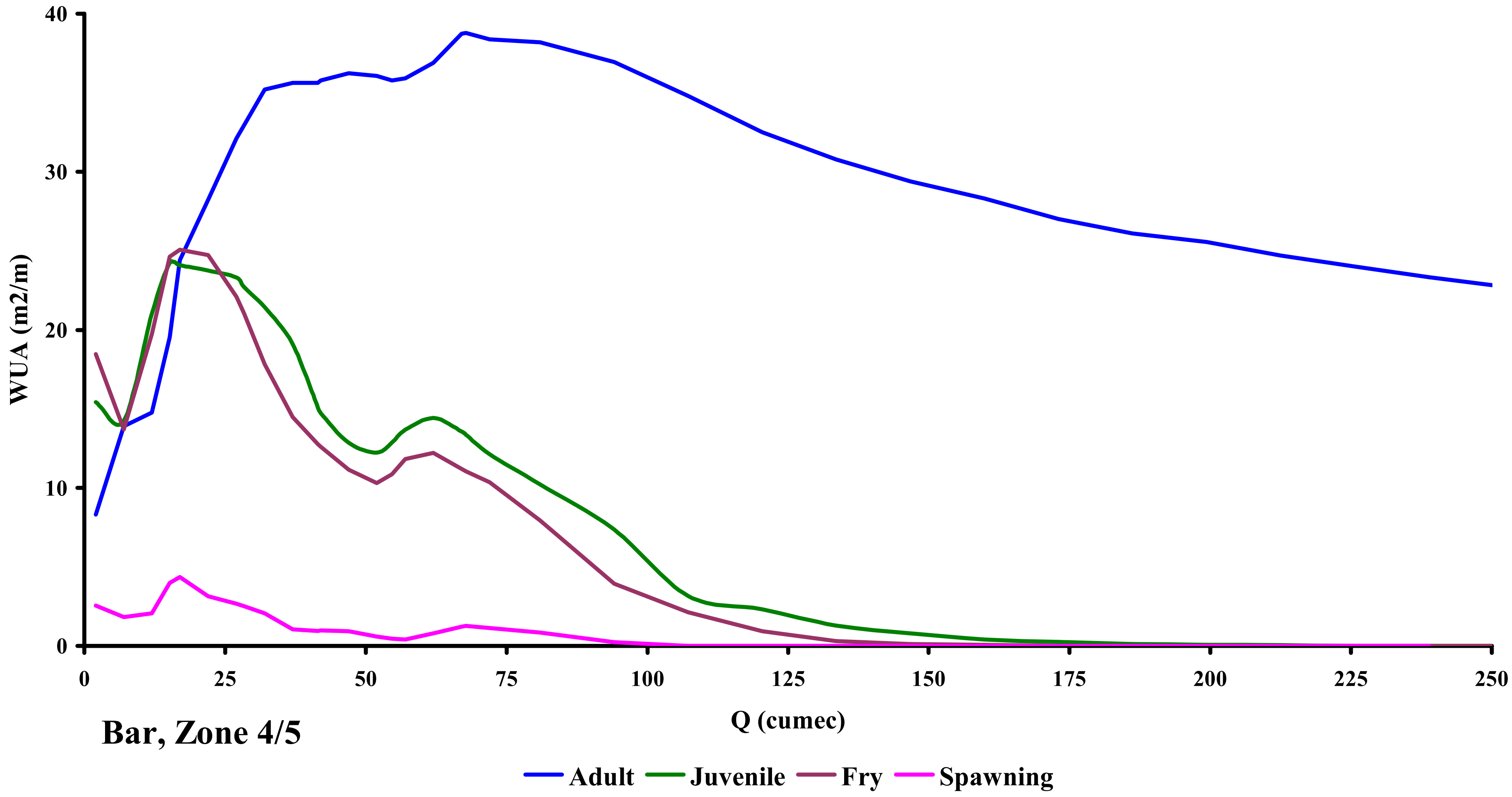

Figure 26. Weighted Useable Area for brown trout for bar sections of Zone 4/5, Gordon River.

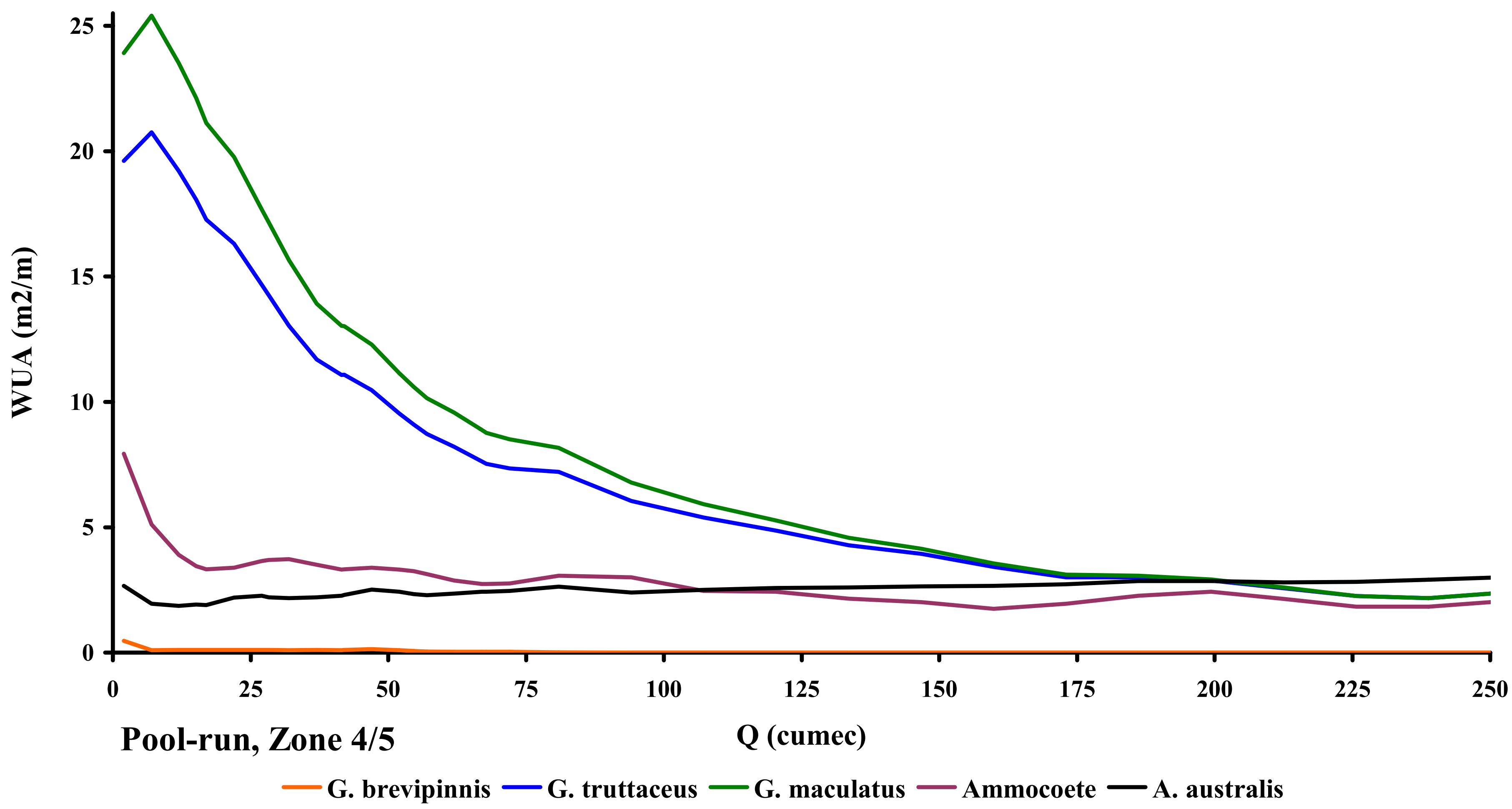

Figure 27. Weighted Useable Area for Native fish for pool-run sections of Zone 4/5, Gordon River.

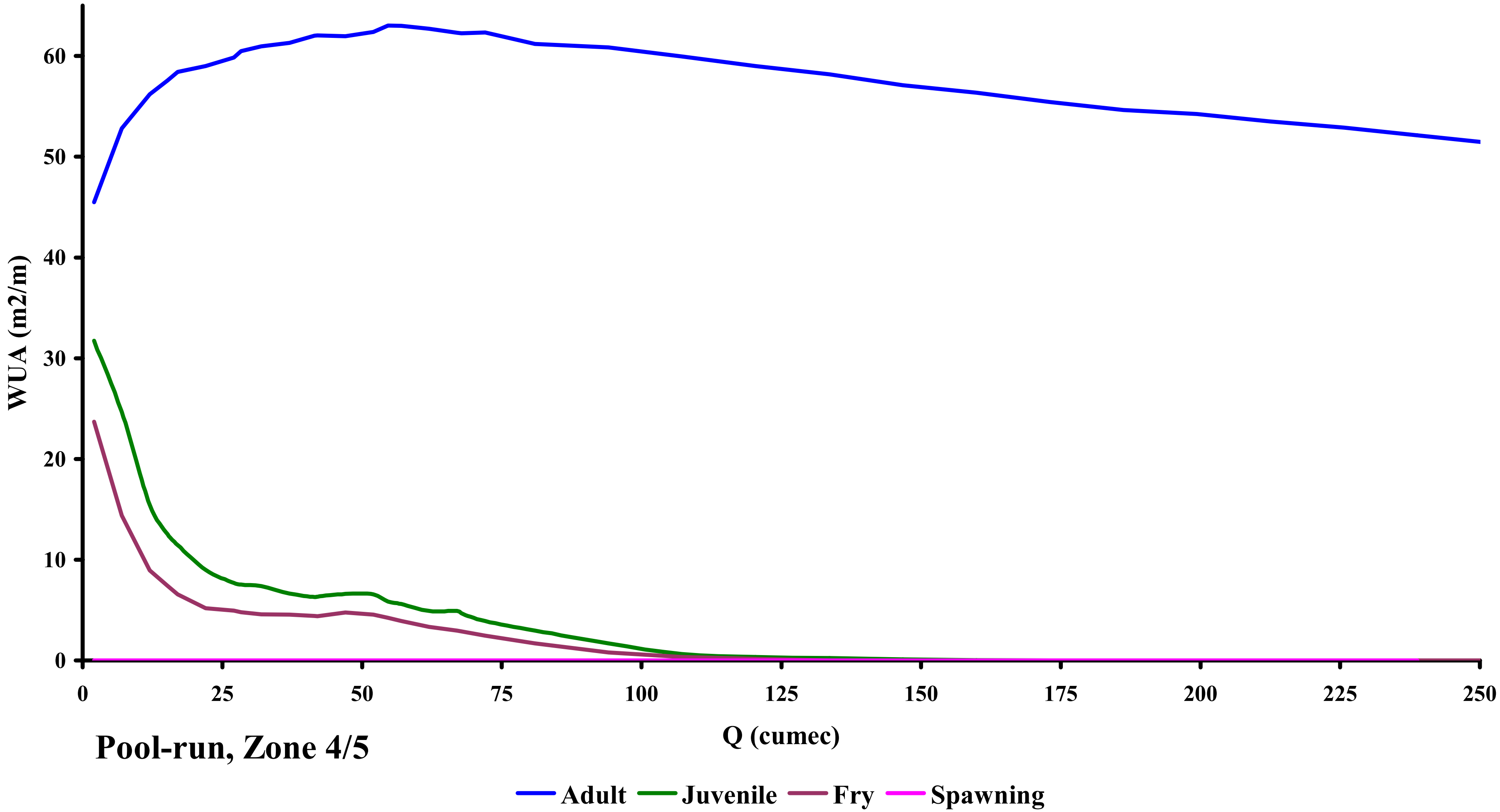

Figure 28. Weighted Useable Area for brown trout for pool-run sections of Zone 4/5, Gordon River.

8.4 Attachment 4. Habitat preference curves

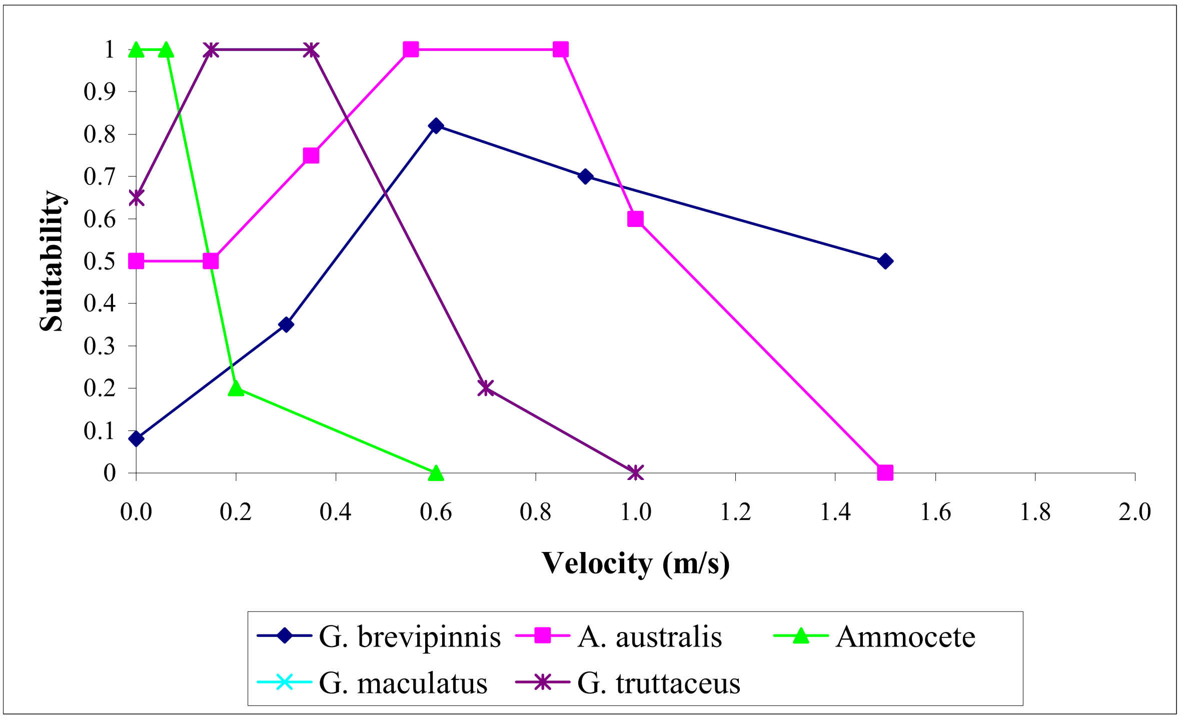

Figure 29. Velocity preference curves for native fish species. Note: preferences for *G. maculatus* and *G. truttaceus* are identical.

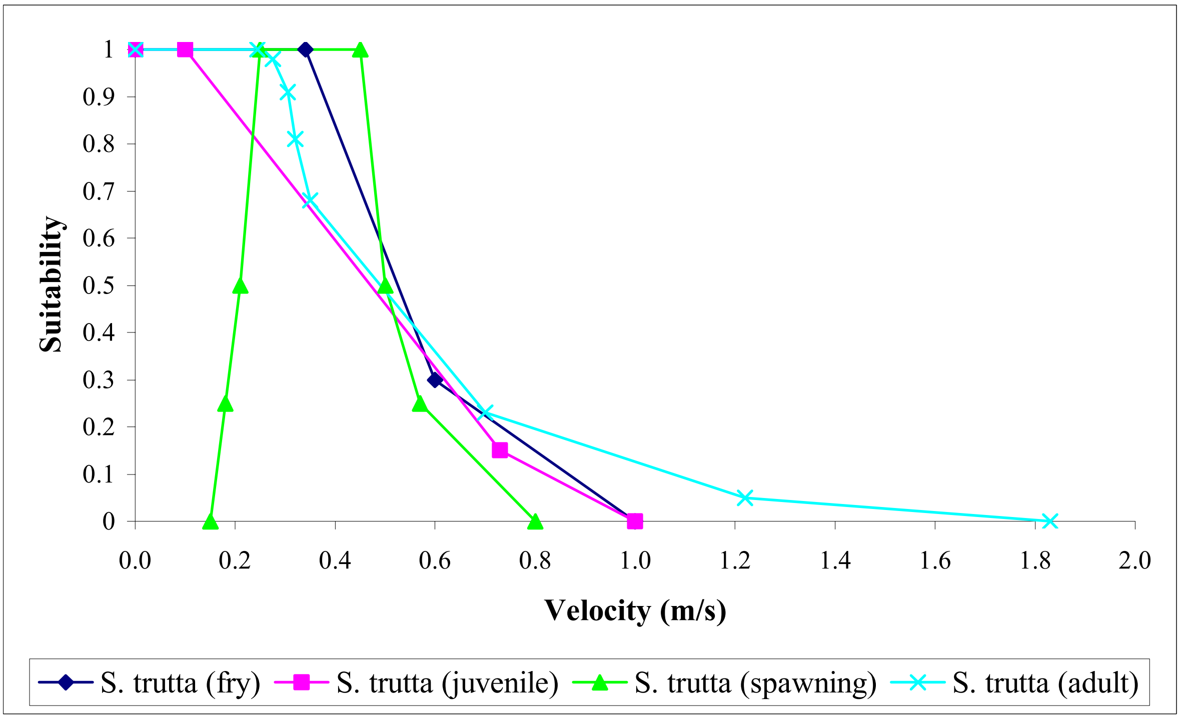

Figure 30. Velocity preference curves for brown trout life-stages.

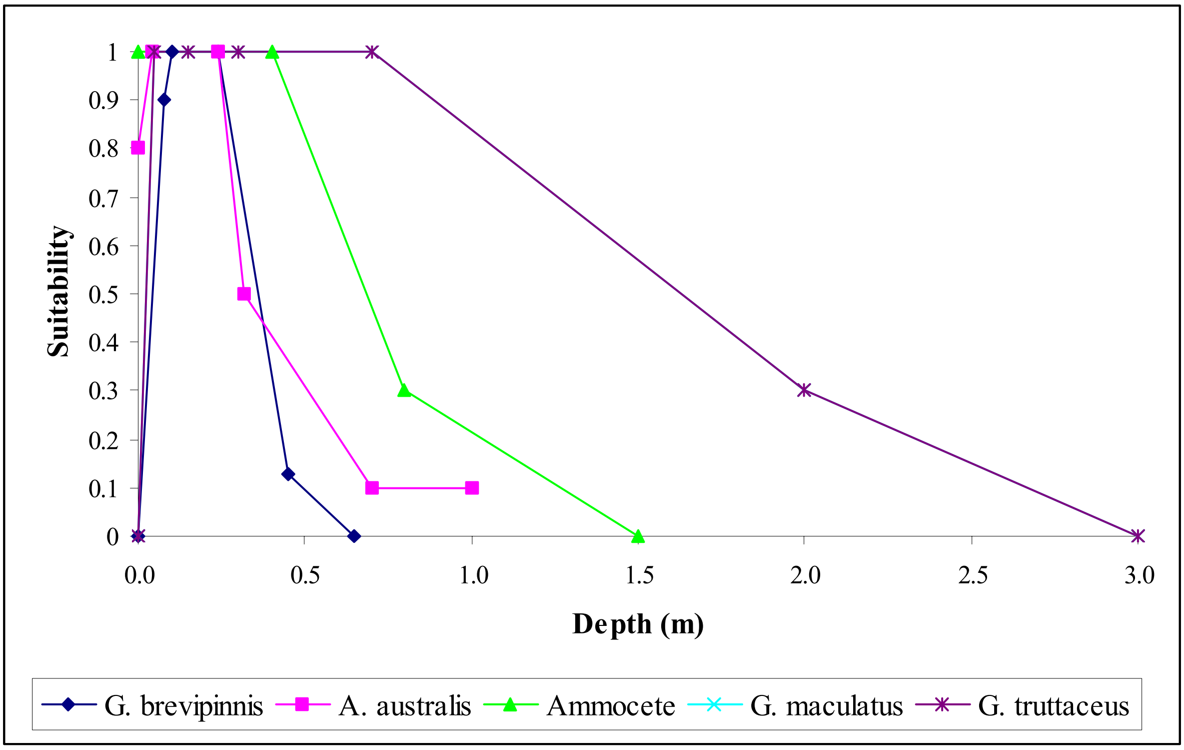

Figure 31. Depth preference curves for native fish species. Note: preferences for *G. maculatus* and *G. truttaceus* are identical.

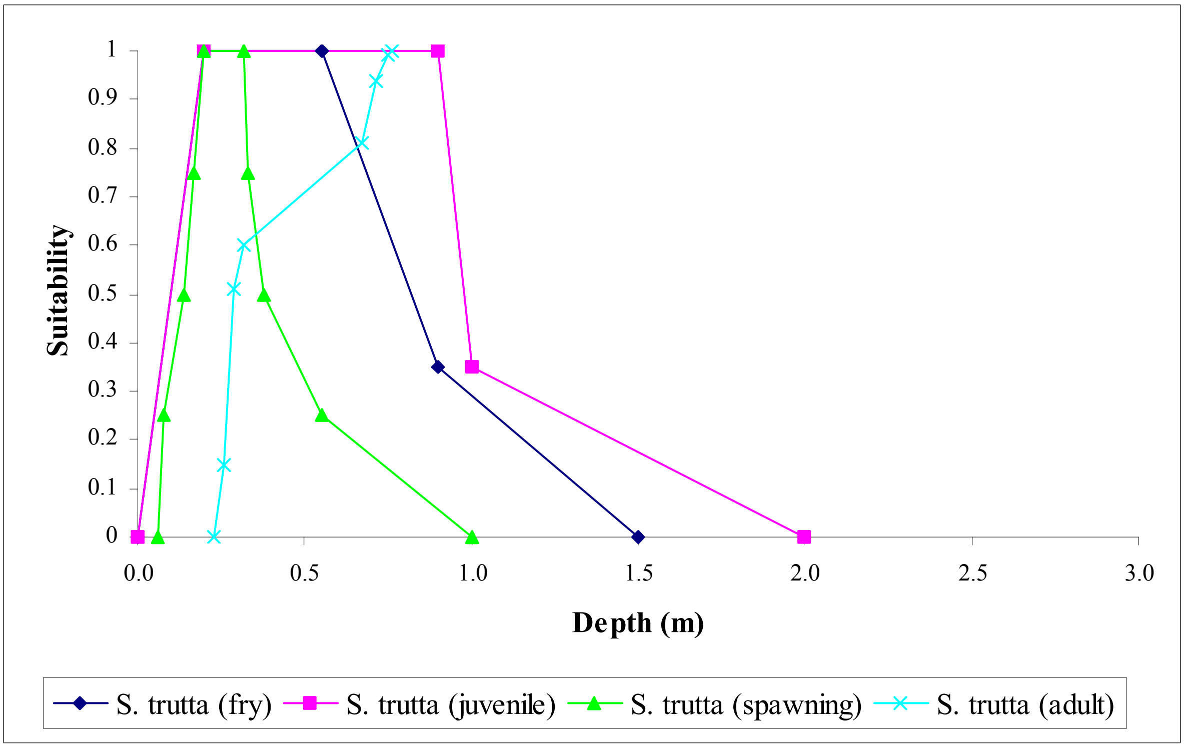

Figure 32. Depth preference curves for brown trout life-stages.

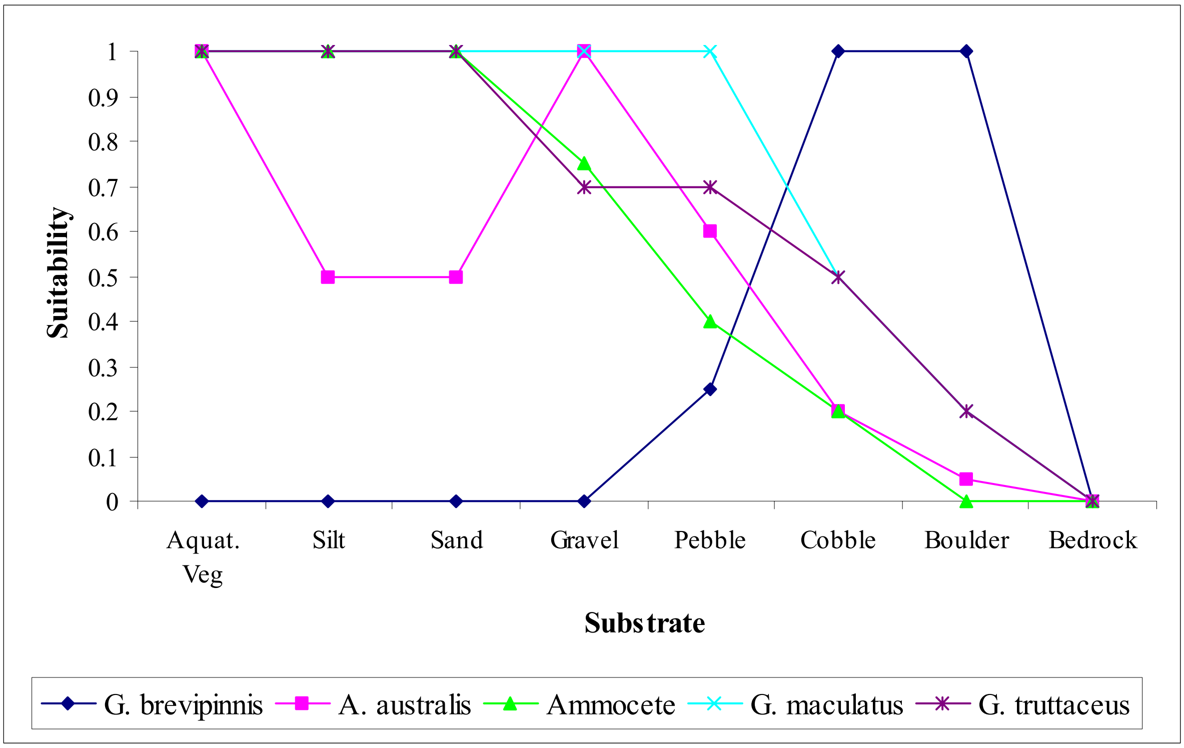

Figure 33. Substrate preference curves for native fish.

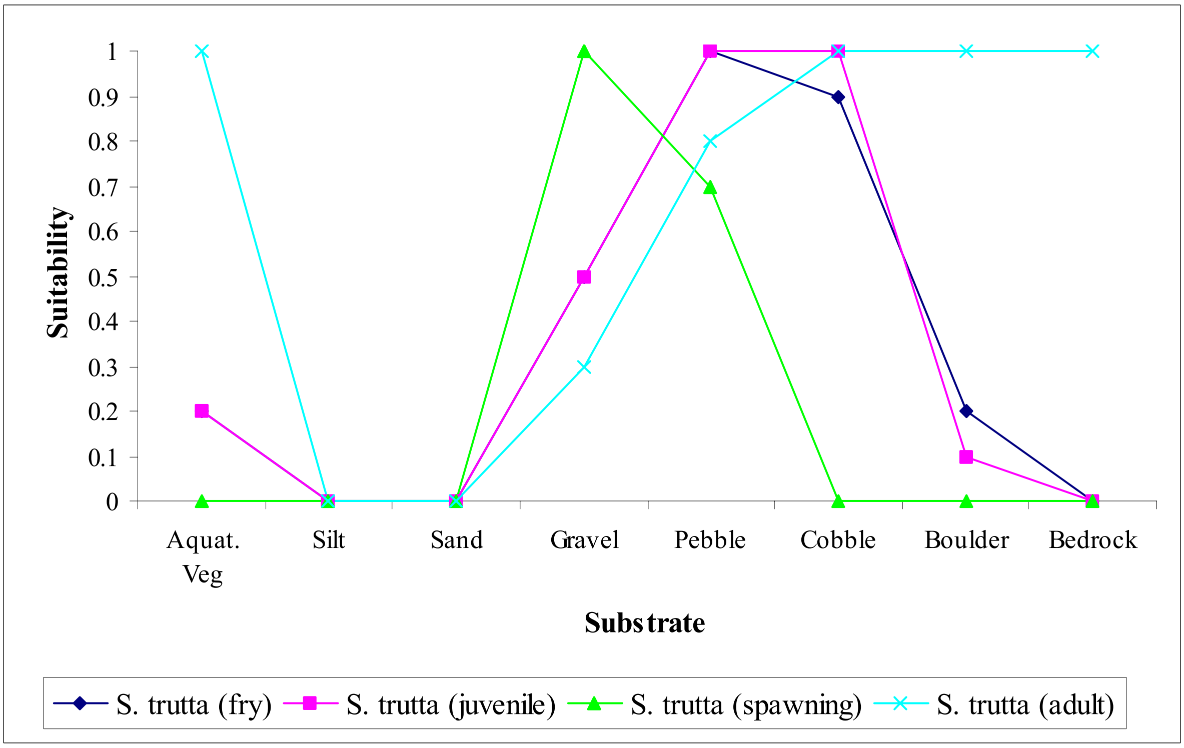

Figure 34. Substrate preference curves for brown trout life-stages