South Esk – Great Lake Water Management Review

Scientific Report on Cataract Gorge

August 2003

Prepared by
Hydro Tasmania

Research into the environmental flow requirements for Cataract Gorge and the habitat requirements and distribution of *Beddomeia launcestonensis* was conducted by *Freshwater Systems Pty Ltd*.

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CATARACT GORGE

1. Assessment of Issues and Status

Background

Through the Environmental Review and Community Consultation processes of the Water Management Review for the South Esk – Great Lake catchment, a number of issues were identified for Cataract Gorge.

The principal issues were:

- low flow in the Gorge during the summer when the dam is not spilling. This impacts on recreational use and visual aesthetics, as well as environmental health and water quality;
- elevated nutrient concentrations in the South Esk River that may encourage excessive growth of green algae and potentially toxic blue-green algae;
- increased bacterial levels in the Gorge that result in closure of the waterway for recreational use (swimming); and
- the presence of a listed threatened species (*Beddomeia launcestonensis*), which may be impacted by present water management in the Gorge.

This report provides information on these issues as well as the results of studies that were undertaken to identify appropriate options to manage these issues. The options that were subsequently identified were then costed and reviewed as part of a cost-benefit analysis covering the whole of the South Esk – Great Lake catchment.

Hydrology

Flows for Cataract Gorge downstream of Lake Trevallyn are largely regulated through riparian release of water from the base of Trevallyn Dam. Hydro Tasmania maintains a constant minimum flow of 0.43 m^3s^{-1} in accordance with the *Water Act 1957*, and this is released through a valve at the base of the dam. Hydro Tasmania also maintains a minimum water level of 124.97 m above sea level in the lake under an agreement with the Launceston City Council, as the lake is a very popular recreational resource for the city. This agreement allows the lake level to be lowered for infrastructure maintenance and prior to the arrival of floodwaters to increase the storage capacity of the lake and reduce energy loss through spill.

Outside of the minimum flow release, the South Esk River in Cataract Gorge is subject to spills of water over the dam wall, the crest of which is located at 126.49 m above sea level. The duration plot for water levels in Lake Trevallyn (see Figure 1) shows that the level of the lake is above full supply level for approximately 25% of the time. A peak water level of about 129.1 m above sea level was recorded on December 30th 1993, when flow passing over the spillway was estimated to have been in excess of 1,200 m^3s^{-1}.

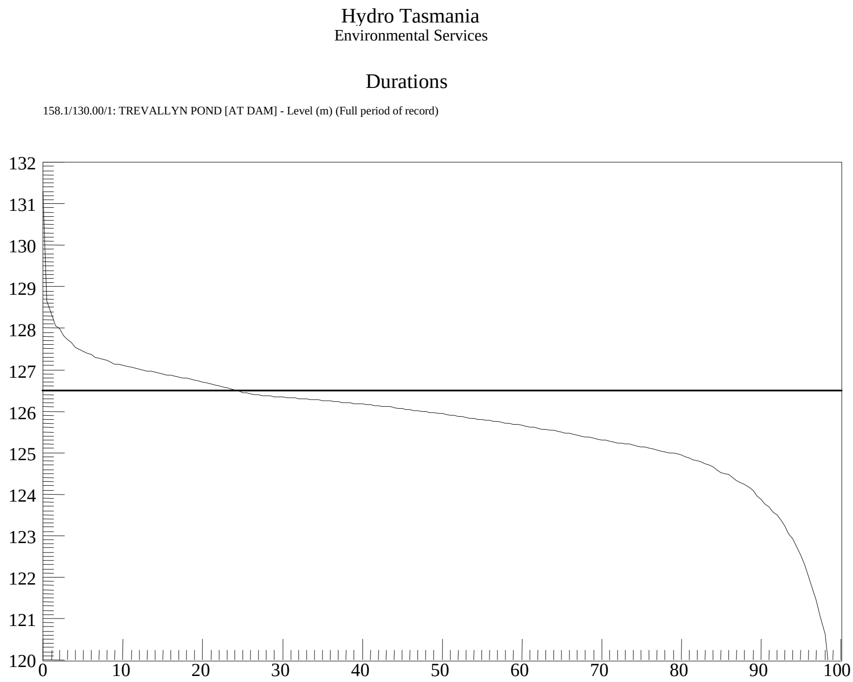


Figure 1: Duration curve for Lake Trevallyn. Full supply level is 126.5mASL (indicated by darker horizontal line) and the plot shows that spill from the lake occurs approximately 24% of the time. The large bulk of this happens during the winter months.

An analysis of the seasonal pattern of spill over Trevallyn Dam between 1995 and 2001 (see Figure 2) shows that the large majority of spills occur between the months June to October. During August, water level in the lake is above full supply level (and hence spilling) more than 55% of the time.

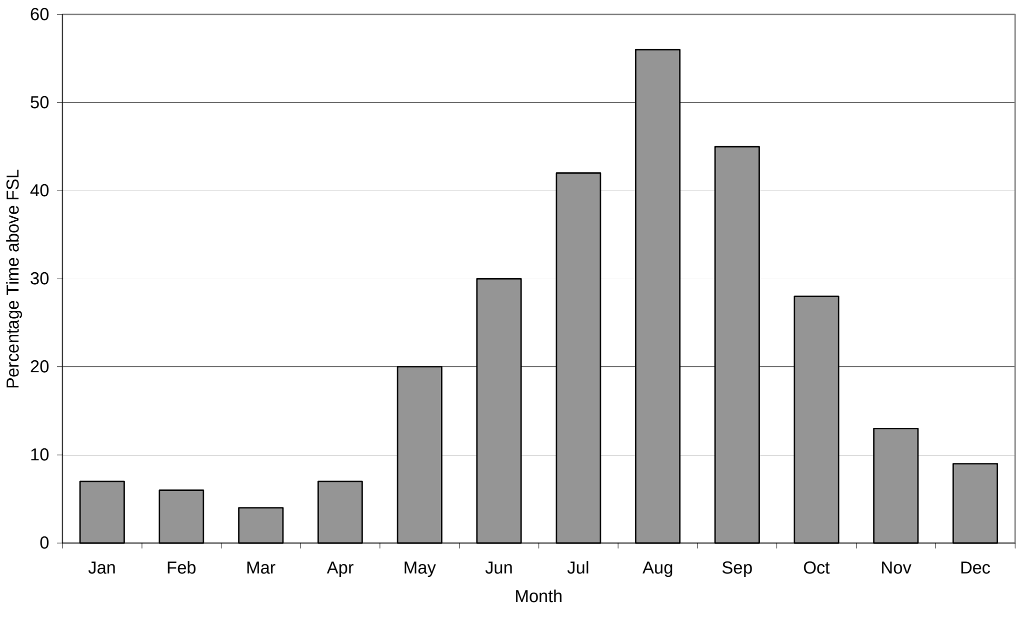


Figure 2: Analysis of spill over Trevallyn Dam. The period of record used for analysis extends from 1995 to 2001. The plot clearly shows that the large majority of spill over the dam occurs between June and October.

A time series plot of the estimated inflow to Lake Trevallyn from the South Esk, Meander and Macquarie Rivers (see Figure 3) shows the pattern of flow that would be present in Cataract Gorge if Trevallyn Dam were not present. Although the pattern of flow appears almost 'natural', this plot includes a large constant baseflow from the Macquarie River during summer months due to discharge from the Poatina Power Station. When discharge from Poatina is extracted from the record, the summer baseflow that would be expected to flow through Cataract Gorge in the absence of Trevallyn Dam would be in the vicinity of 5-10 m^3s^{-1}.

Figure 4 demonstrates the effect of the diversion of water through to the Tamar River via Trevallyn Power Station. Essentially, baseflows below 50 m^3s^{-1} have been removed from the South Esk River at Cataract Gorge and have been replaced with a steady 0.425 m^3s^{-1} as released from the valve at the base of the dam. However, most of the seasonal flood peaking is still evident and is a dominant feature of flows in Cataract Gorge.

From this information, it is clear that the high incidence of spills during the winter results in a pattern of flow through the Gorge that is reasonably similar to what might occur naturally. However, Trevallyn Dam does reduce the size of baseflows in the South Esk River at Cataract Gorge, especially during summer months, and flood flows start and end much more abruptly than would occur under unregulated conditions.

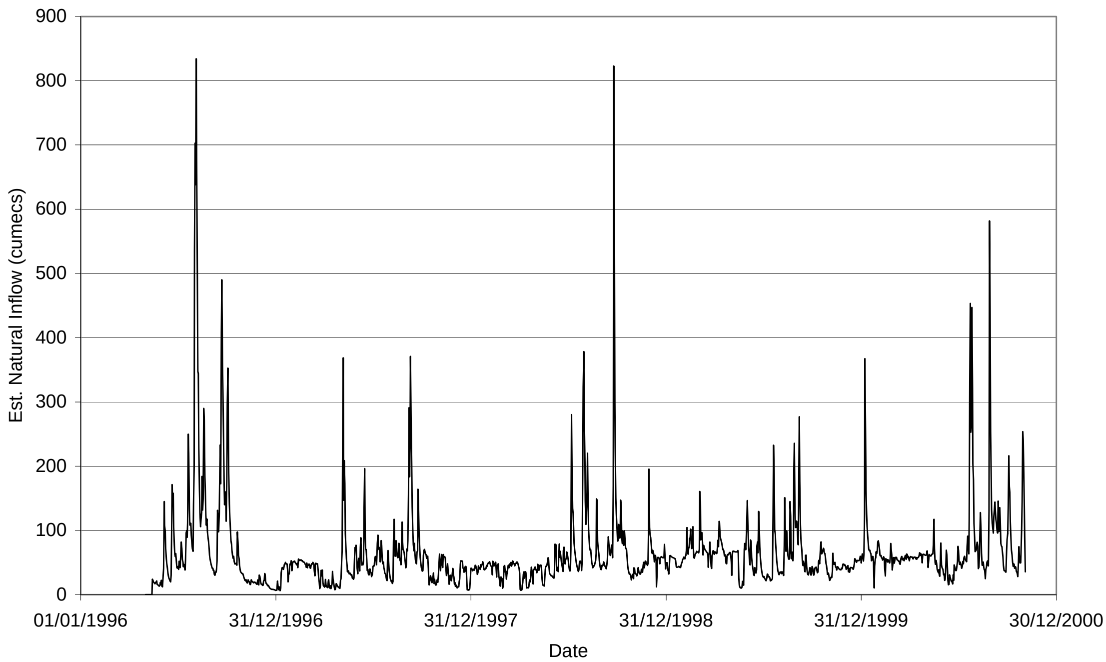


Figure 3: Combined inflow to Lake Trevallyn from the South Esk, Meander and Macquarie rivers between January 1996 and December 2000

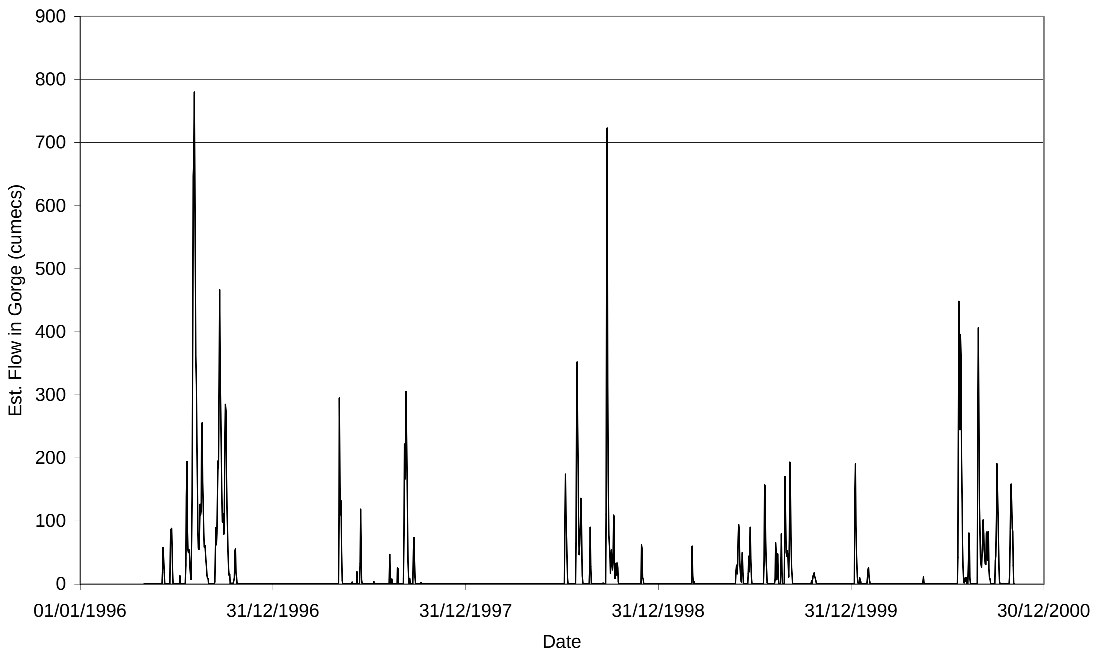


Figure 4: Estimated flow in Cataract Gorge through spill from Lake Trevallyn for the period January 1996 to December 2000. Riparian flows between flood events kept at $0.425 m^3 s^{-1}$.

Water Quality

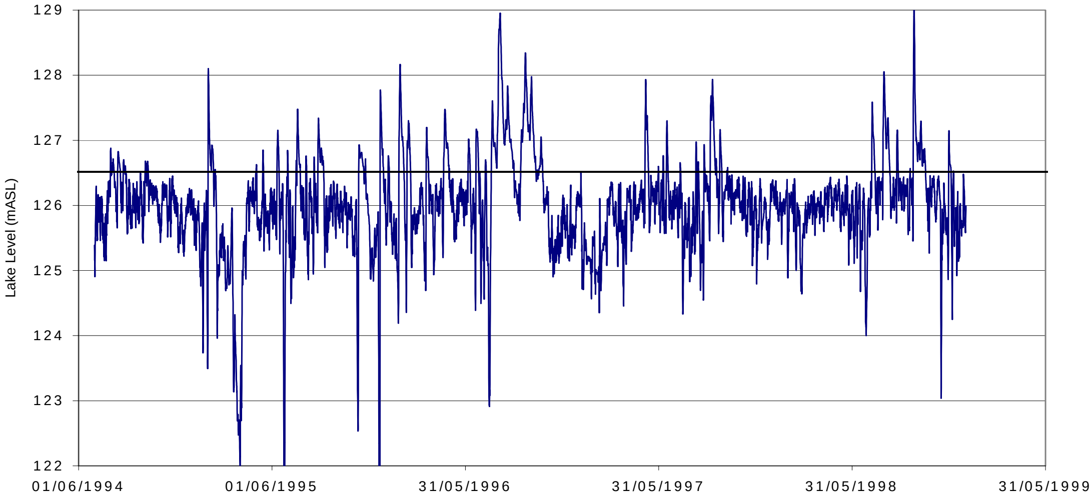
The following section presents historical data obtained from internal and external sources. Together, these data present a comprehensive outline of condition and quality of the water resource in Cataract Gorge.

West Tamar Water Supply

Water quality has been monitored within Lake Trevallyn for more than 35 years by the West Tamar Water Supply, which extracts water for domestic use by the western suburbs of Launceston. Daily records of water quality (comprising water temperature, pH, colour and turbidity) have been collected on inflow ('raw') water supplying the scheme since 1962. Electronic files of these data were obtained from the Department of Primary Industries, Water and Environment database for the period 1994 to 1998 and time series plots of pH and turbidity against lake level examined. The plots show that most suspended sediment is carried during flood events when the dam is also likely to spill (spikes in Figure 5a that rise above full supply level as marked by the heavier solid line at 126.5 m above sea level). When the lake is stable below full supply, as is seen in summer 1996 - 97 and summer/autumn of 1998, turbidity is maintained at a stable minimum of around 3 nephelometric turbidity units (Figure 5b). It is also noteworthy that although late winter / early spring inflows may be stored within the capacity of the dam (no spill), turbidity levels are consistently above 10 nephelometric turbidity units.

The data for pH (Figure 6b) shows a pattern that is less reactive to changes in lake level (Figure 6a), but there is still a broad seasonal cycle, whereby pH drops noticeably during the summer period and recovers somewhat during winter. There is also a visible drop in pH of water in the lake between January 17th and March

23rd 1997, when the lake level fell to about 125 m above sea level for an extended period. There is no clear explanation for this change in pH.



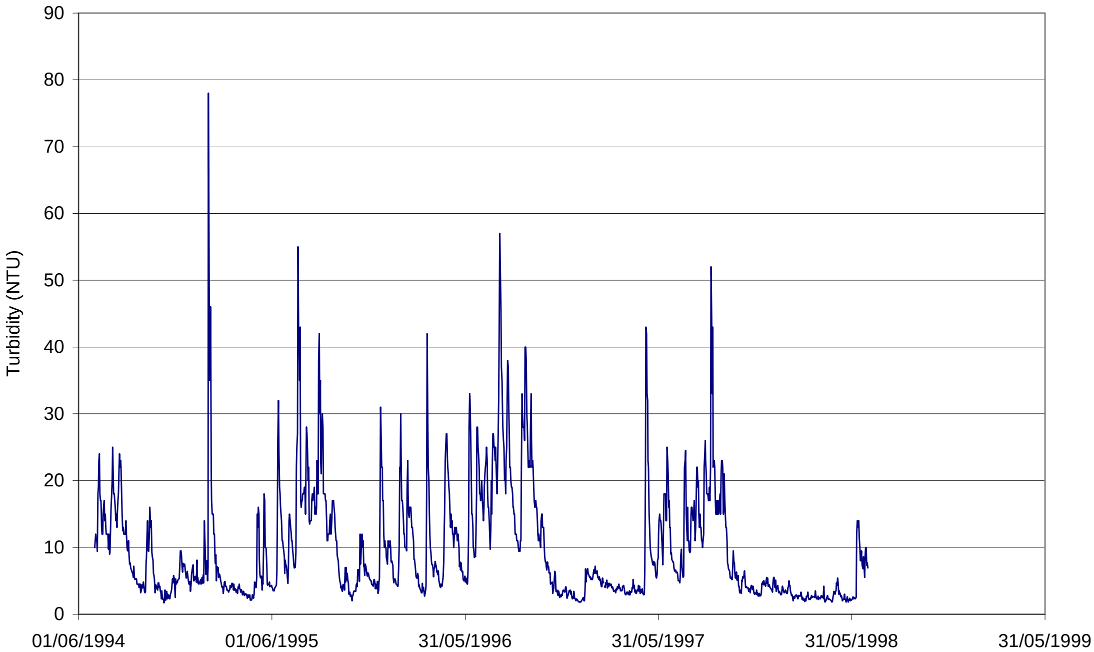
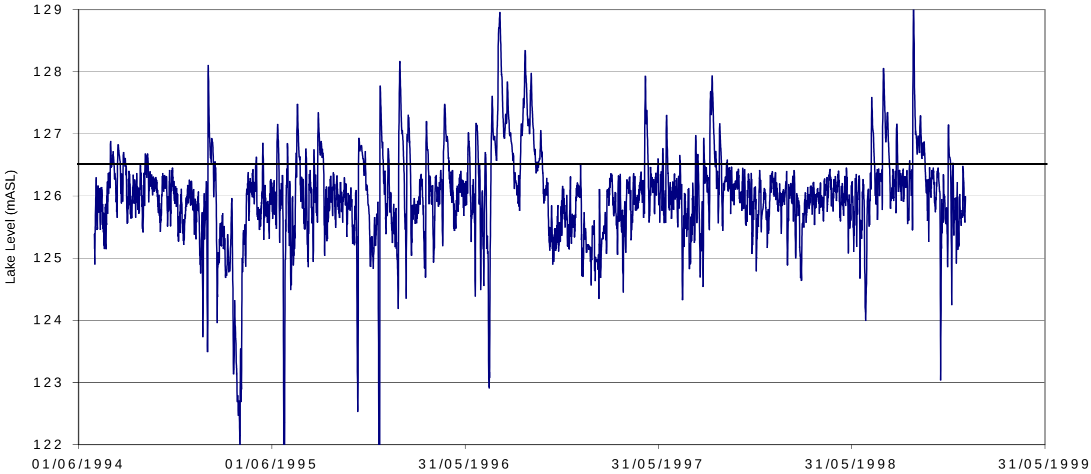


Figure 5 a & b: Time series of water level and turbidity of 'raw water' in Lake Trevallyn as measured by the West Tamar Water Supply, between June 1991 and July 1998



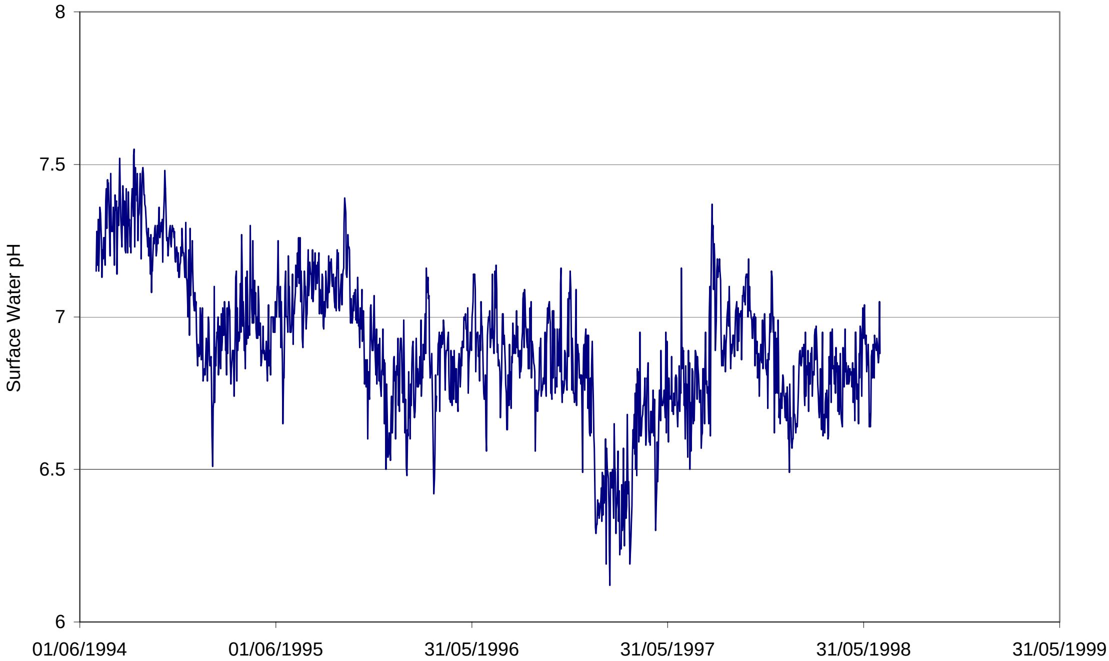


Figure 6 a & b: Time series of water level and pH of 'raw water' in Lake Trevallyn as measured by the West Tamar Water Supply, between June 1991 and July 1998

South Esk Basin 'State of Rivers' Study – Department of Primary Industries and Fisheries

The 'State of Rivers Report for the South Esk Basin' (Bobbi *et. al.*, 1996) presented some recent water quality information for the lower South Esk River and Lake Trevallyn. It found that nutrients such as nitrate and phosphorus were more variable than many other sites in the South Esk catchment. This is likely to be a result of the variation in inflows from each of the major rivers (Meander, South Esk and Macquarie rivers) and the diversity of land use impacts on water within these sub-catchments. The median concentration of phosphorus in Lake Trevallyn (0.021 mg/L) was also slightly elevated compared with most other sites in the basin and has the potential to stimulate algal production both in the lake and in the South Esk River downstream. The median concentration for nitrogen was

0.22 mg/L, which is substantially lower than the trigger level of 0.5 mg/L presently utilised by Hydro Tasmania's 'Waterway Health Monitoring Program'.

Sampling undertaken during that study also found that a wastewater treatment plant at Prospect Vale, which discharges to the South Esk River via a small tributary (Dalrymple Creek) in the upper reaches of Cataract Gorge, contributed an estimated annual load of 3,026 kg of phosphorus and 5,168 kg of nitrogen. The estimated annual volume of water from the plant is 473 ML, which is equivalent to approximately 1.3 ML per day. This is a consistent load to the South Esk River downstream of Trevallyn Dam and the report suggested that this might be a significant contributor to nutrient enrichment in Cataract Gorge. It also suggested that this discharge is likely to cause some environmental deterioration during low flows, though no data was presented to justify this statement.

From the data collected during the 'State of Rivers' project and known flow releases from Trevallyn Dam, it can be calculated that the 'baseflow' load of nitrogen and phosphorus contributed to the South Esk River in Cataract Gorge by Trevallyn Dam releases is 281 $kg.yr^{-1}$ of phosphorus and 2,949 $kg.yr^{-1}$ of nitrogen. These loads are much less than those being discharged to the river system by the wastewater treatment plant. This does not include spill loads, which would carry massive loads of nitrogen and phosphorus through the Gorge. However water velocities during floods through the gorge are more than sufficient to carry most of the suspended matter and nutrients through to the middle estuary. Hence these floods are likely to have only temporary impacts on water quality in Cataract Gorge.

Waterway Health Monitoring Program - Hydro Tasmania

More recent data from Lake Trevallyn is available from the Hydro Tasmania's 'Waterway Health Monitoring Program', which sampled the lake during 1998/99. The median concentration of phosphorus from this dataset (0.012 mg/L) indicates that conditions within the dam may have improved since the then Department of Primary Industries and Fisheries study, although the median nitrogen concentration is similar (0.214 mg/L). Concentrations of all the major metal species have also been sampled under the Waterway Health Monitoring Program and have generally been found to be near detection limits.

The other finding from this program has been that the lake does not show signs of significant stratification at any time. Although the very surface of the lake warms slightly during the summer, no strong thermocline develops. The lake also appears to be sufficiently well mixed so that there is no oxygen depletion at depth in the lake (see Figure 7), although oxygen concentrations throughout the water body are less in summer and autumn. It is therefore safe to assume that in broad terms, riparian water released from the storage through the valve is of a similar quality to that as measured by sampling from the surface of the lake.

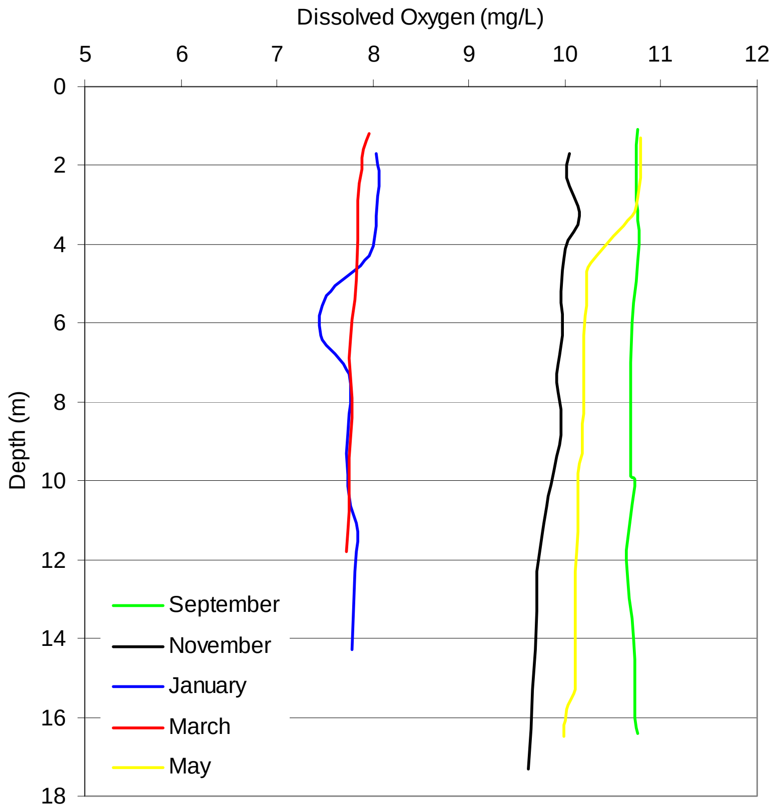


Figure 7: Depth profiles for dissolved oxygen in Lake Trevallyn recorded between September 1998 and May 1999

Recent Data from Launceston City Council

Recently collected data on the bacterial quality of water in the First Basin has been obtained from the Launceston City Council, who has been monitoring water during the warmer months for the last 8 years. This monitoring is undertaken solely for the protection of public health and is generally carried out on a monthly basis between November and March each year. The statistics of these data are presented in Table 1.

The most significant data are those for *E. coli* and Enterococci, which are common bacterial indicators utilised for human health protection in recreational waters. The results show that median levels are well within the ANZECC (1992) trigger guidelines of 150 fcu for faecal coliforms and 34 enterococci organisms. On several occasions counts of both faecal coliforms and enterococci were very high (> 3 times the trigger level), indicating that periodic pollution of the First Basin occurs, and the Launceston City Council has been known to close the area for short periods during the summer to protect swimmers. Examination of the times of closure in combination with flow records for the river does not suggest that these pollution events are flow related.

	Total Coliforms (fcu per 100 mL)	E. coli (fcu per 100 mL)	Enterococci (fcu per 100 mL)
ANZECC (1992) Triggers		150	34
Mean	242	84	32
Median	140	34	7
Maximum	1300	410	270
Minimum	8	2	1
Count	37	37	36

Table 1: Summary statistics of monthly bacterial monitoring during summer months by the Launceston City Council between 1992 and 1999

The main source of the faecal pollution of the South Esk River is known to be to be the Prospect Vale wastewater treatment plant, which discharges to Dalrymple Creek, a small tributary entering the South Esk River upstream from Duck Reach. This plant is currently being modified and upgraded by the Meander Valley Council to reduce the risk of contaminated effluent being discharged in future. As the manager of the First Basin, Launceston City Council will continue to monitor faecal coliforms in the area of the Gorge. It is also probable that the nutrient-rich effluent from this plant plays a significant part in encouraging algal blooms in the area of the Gorge when conditions are favourable.

During the summer period of 1999/2000 the Launceston City Council was forced to close the South Esk River to swimmers for some considerable time due to an outbreak of potentially toxic blue-green algae, which was found at Duck Reach and the First Basin. The species responsible for the outbreak was *Planktothrix*. While bacterial counts were very low at that time, blue-green algal counts as high as 3,000 cells/mL were recorded. It was thought that this outbreak was due to local nutrient enrichment of the river combined with extremely warm and stable climatic conditions in the Gorge; conditions that favour blooms of algae.

Aquatic Biota

Assessment of the aquatic community downstream from Trevallyn Dam has been carried out under various programs funded by Hydro Tasmania. Samples of aquatic invertebrates have been taken as part of the Waterway Health Monitoring Program and through separate studies of the biological impacts relating to hydro-electric dams (Davies, *et. al*., 1999). The results of these surveys have shown that the aquatic community in Cataract Gorge is modified to some degree along the entire reach, but more so immediately downstream of the dam. At this location, results from the Hydro RIVPACS (River Invertebrate Prediction and Classification System) rank abundance model (which is a model that is sensitive to changes in flow) suggests that changes in the aquatic macroinvertebrate community may be due to modifications in the flow regime rather than water quality. Further downstream at Duck Reach and the First Basin, impacts on aquatic invertebrates may also be due to changes in water quality or habitat or both.

Cataract Gorge also contains some aquatic fauna that are endemic or listed as threatened under Tasmanian Threatened Species Protection legislation. Australian grayling (*Prototroctes maraena*) is known to occur in this area and the Gorge is also known to contain the freshwater snail *Beddomeia launcestonensis*, known only from the Gorge. Both of these are listed as ‘vulnerable’ in Tasmania.

The only major document containing information on the snail species is a taxonomic paper on Beddomiid snails in Tasmania and eastern Victoria (Ponder, *et. al*., 1993). Remarks contained in this paper indicate that intensive searching in the area of First Basin only located a single individual, while 3km upstream the researchers were able to locate a reasonable population. The paper lists the species as living typically under large, stable slabs of rock in pools and side channels off the main bed of the river. They also suggest that samples from older collections indicate that the species may have been more abundant in the late 1800s than it is now. It is because of their apparently limited geographic distribution that most species of *Beddomeia* in Tasmania are considered 'threatened' (Bryant & Jackson, 1999) and Davies (1996) has suggested that conservation of *B. launcestonensis* may be dependent on maintaining suitable habitat through maintaining adequate flows through Cataract Gorge.

The Australian grayling (*Prototroctes maraena*) is native to Tasmania and south-east Australia. Formerly abundant in coastal streams it is now uncommon, though widespread in its distribution (Fulton, 1990). Although information on the basic biology of this species is scarce, it is known to spawn in freshwater in late spring to early summer and there appears to be a marine stage following hatching. It has a life expectancy of about three years and in Tasmania is totally protected.

Other migratory fish species also occur in Cataract Gorge, the most important of these being the short-finned eel (*Anguilla australis*), which arrives as glass eels and elvers in the Tamar estuary during the spring and early summer months. While many of these are attracted to the freshwater discharge from Trevallyn Power Station lower down the estuary, some find their way up to the base of Trevallyn Dam through Cataract Gorge. At present there are facilities to encourage their passage over the dam, though the efficacy of this ladder is presently being reviewed.

Key Issues

Key issues relating to the aquatic environment within Cataract Gorge can be summarised as:

- Low water flows during the summer when dam is not spilling
  - encourages the growth of algae (nuisance and toxic);
  - provides insufficient flows to dilute nutrient inputs from Dalrymple Creek;
  - may not provide flows that ensure the long term sustainability of aquatic biota, particularly the threatened aquatic snail *Beddomeia launcestonensis*; and
  - may not provide adequate habitat to ensure the long term viability of threatened aquatic snail populations.
- Nutrient concentrations in the South Esk River
  - increase the potential for algal blooms, particularly blue-green algae originating from Dalrymple Creek;
  - lead to prolific growth of filamentous green algae that may inhibit or modify the habitat or food supply of aquatic biota; and

  - lead to prolific growth of filamentous green algae that is unsightly and may impact on recreational use and amenity of users in the lower section of the Gorge.

- Bacterial levels in Cataract Gorge
  - cause public health risks during summer months and results a loss of public access to a major recreational resource for Launceston; and
  - restrict public use of water in the Gorge leading to 'bad press' about water in the Gorge.
- Blooms of potentially toxic blue-green algae
  - cause public health risks during summer months and results a loss of public access to a major recreational resource for Launceston; and
  - restrict public use of water in the Gorge leading to 'bad press' about water in the Gorge.

2. FORMULATION OF STUDY OBJECTIVES

From the information presented in the section above, it is clear that management should focus on providing river flow and water quality that is adequate to sustain biological processes as well as achieving water quality sufficient to support and sustain recreational use of the waterway and facilities located at the First Basin.

The critical information gaps in attaining this were:

- an understanding of what is required to reduce the threats posed by water quality on environmental condition;
- data on the present condition of the freshwater aquatic community in the Gorge;
- what flows are required to ensure the long-term sustainability of the aquatic fauna presently inhabiting the Cataract Gorge; and
- the habitat requirements of the threatened aquatic snail (*Beddomeia launcestonensis*), its present distribution and whether they are truly endemic to Cataract Gorge.

The basic aims of the technical study were therefore to determine the environmental flow requirements for Cataract Gorge and investigate the local distribution and habitat requirements of the endangered freshwater snail (*Beddomeia launcestonensis*). The objective will then be to derive management options that will assist in reducing the threat of poor water quality, improve the condition of the local aquatic environment, reduce threats to the long-term survival of the endangered freshwater snail, reduce risks associated with recreational use and improve public amenity. These latter two issues were raised during public consultations associated with earlier stages of the South Esk – Great Lake Water Management Review.

3. Data Collection and Analysis

Studies to determine the environmental flow requirements of the South Esk River in Cataract Gorge and the distribution and habitat requirements of *Beddomeia launcestonensis* were commissioned by Hydro Tasmania as part of a joint project between Hydro Tasmania and the Department of Primary Industry, Water and Environment with additional funding from the Natural Heritage Trust. Dr Peter Davies and Mr Laurie Cook of *Freshwater Systems* undertook this work and presented Hydro Tasmania with detailed reports, however for the purposes of brevity, the information from the original reports has been edited.

Additional data on water quality and biological health of the aquatic macroinvertebrate community in Cataract Gorge was collected by Hydro Tasmania to support these studies and examine the present impact of discharge from the wastewater treatment plant on water quality in Dalrymple Creek and the South Esk River.

Macroinvertebrates and Ecological Health

Aquatic macroinvertebrates were sampled at three locations in Cataract Gorge (see Figure 8) using the standard rapid assessment protocol sampling and sample processing techniques used for the Australian River Assessment Scheme (Davies, 2000). Samples were subsequently identified to family level (except for Oligochaetae, Hydracarina, Turbellaria, Hydrozoa and Nematoda). Samples were taken twice, one in spring, once in autumn. Sample data from the two seasons was summed to provide a composite sample for each site. Data from sampling for this study 2000/01 was compared to data collected during previous assessments in 1995/96. The composite samples were analysed using two River Invertebrate Prediction and Classification System models, one based on presence absence of taxa, the other based on rank abundance categories of taxa within samples. These models were developed by Davies *et al.* (1999) for bioassessment of rivers within Hydro Tasmania catchments. They each calculate the O/E ratio for each composite sample, where O/E is the proportion of the number of taxa predicted (expected, E) to occur at a site if it were unimpacted, that are actually found (observed, O).

O/Epa is the O/E value based on presence/absence data. It represents the departure of the test site macroinvertebrate community composition from reference as a proportion of taxa lost or gained. O/Erk is the O/E value derived using rank abundance data. It represents the departure of the macroinvertebrate community composition from reference as a proportion of both rank abundance categories and taxa lost or gained. The difference represented by O/Epa – O/Erk represents the incremental loss or gain of rank abundance categories over and above loss or gain of taxa. Thus:

- O/Epa – give information on the proportion of taxon richness lost due to an impact; and
- O/Epa-O/Erk – give information on further losses (or gains) in relative abundance of the remaining taxa, as a result of the impact.

Values for O/Epa and O/Erk are shown in Table 2 for the three sample sites in Cataract Gorge.

In 1995/96, the samples taken from Cataract Gorge between Trevallyn Dam and Dalrymple Creek (sites RAP1 and RAP2) indicated that the macroinvertebrate communities had lost between 27 and 43 % of the taxa expected to occur there (see Table 2). In addition, there was a further reduction in rank abundance of 14 % of the expected taxa, or 19 – 25 % of the taxa remaining at these sites. These results placed this reach of the Gorge in the 'B' and 'C' River Invertebrate Prediction and Classification System bands, meaning that the macroinvertebrate communities were 'significantly' to 'severely' impaired.

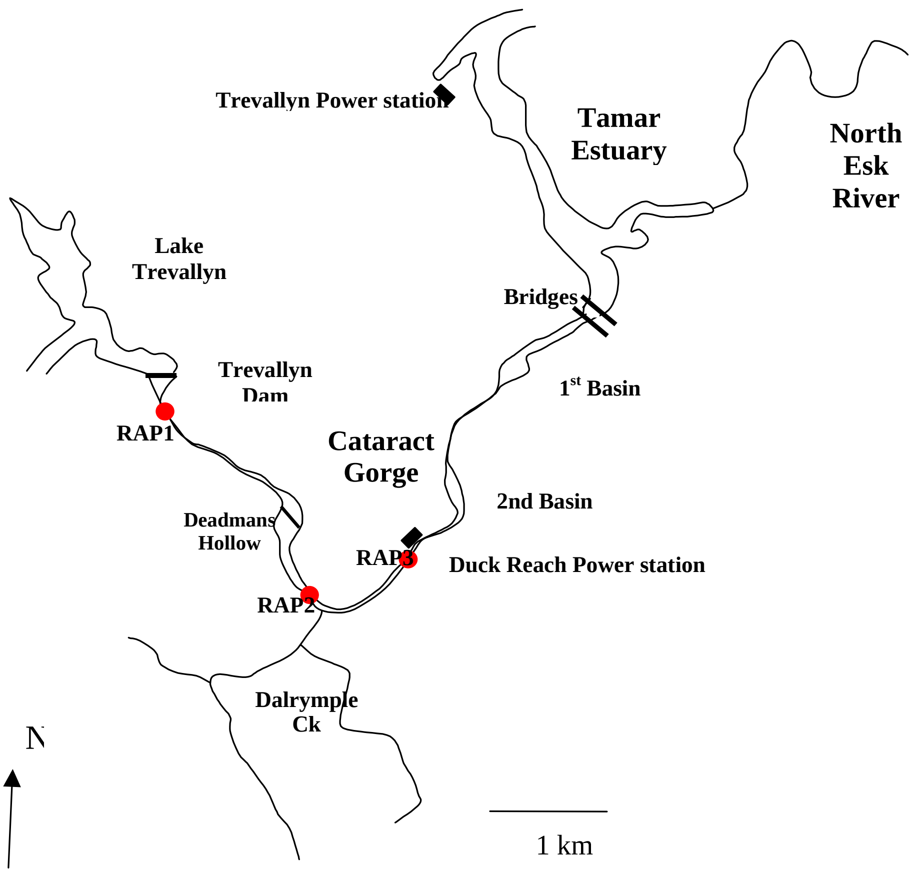


Figure 8: Cataract Gorge, South Esk River, showing major features. Circles indicate the three rapid assessment protocol (RAP) biological sampling sites (see Section 3.3)

Site	pa				rk			
	2000/01		1995/96		2000/01		1995/96	
	O/E	Band	O/E	Band	O/E	Band	O/E	Band
RAP1, d/s Trevallyn Dam	0.44	B*	0.57	B	0.41	C	0.43	C*
RAP2, u/s Dalrymple Ck	0.5	B	0.73	B	0.43	C*	0.59	B
RAP3, d/s Dalrymple Ck	0.38	C	0.45	B*	0.33	C	0.56	B

Table 2: O/E values and band assignments for macroinvertebrate communities at three sites in Cataract Gorge, based on RAP sampling and RIVPACS analysis conducted in 1995/96 (Davies et al. 1996) and 2000/01 (Hydro sampling).
*** indicates value within 0.02 of to B and C band boundary.**

This same reach was again sampled in 2000/01. From these samples, it appears that the macroinvertebrate communities have lost between 50 and 66 % of expected taxa. In addition, there was a further reduction in rank abundance for between 3 and 7 % of the expected taxa, or 7 and 14 % of the taxa remaining at these sites. These results placed this reach of the Gorge in the C band, meaning that the macroinvertebrate communities were severely impaired. Thus, the overall condition was somewhat poorer in 2000/01 than found in 1995/96.

O/E values for the reach downstream of Dalrymple Creek (site RAP3) were substantially lower than for upstream of Dalrymple Creek (site RAP2) on both sampling occasions. In 2000/01, this represented an overall loss of 62 % of macroinvertebrate diversity (O/Epa of 0.38), with a further reduction in rank abundance in 14 % of the remaining taxa (approx. 2 - 3 families). This reduction is highly likely to be a result of the decline in water quality conditions associated with the inflow of Dalrymple Creek into the Gorge.

Concentrating on the reach affected only by Trevallyn Dam, i.e. upstream of Dalrymple Creek, it is of interest to place the results of macroinvertebrate bioassessment into context. Figure 9 shows the overall distributions of O/E for a series of sites immediately downstream of Hydro dams and power stations in Tasmania (as reported by Davies *et al.* 1999). It can be seen that O/Erk values for sites downstream of dams range widely, with a median that falls below the reference condition. Figure 10 shows the results for Cataract Gorge from Table 2 superimposed from the results for all dams surveyed by Davies *et al.* (1999), indicating that Cataract Gorge communities are particularly impoverished, falling at the lower end of the range of reported results. The same plot shows the bioassessment O/E results for a similar gorge environment in the lower North Esk River (at Corra Linn), a slightly smaller unregulated river which has experienced similar catchment changes to the South Esk but no hydro development. The difference between these two reaches suggests a substantial effect of Hydro development over and above any impact of changes in instream water quality associated with catchment clearance.

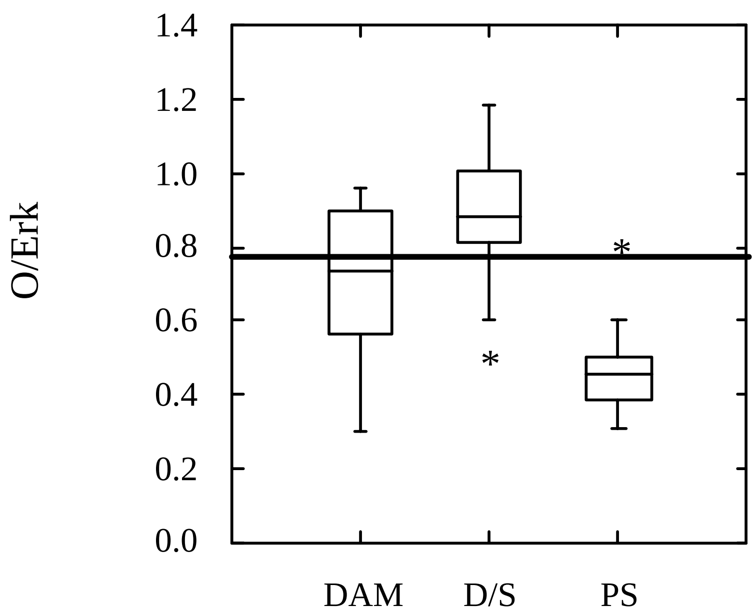


Figure 9: Box plot of O/E_{rk} values for test sites. DAM = sites < 1 and D/S > 1 km downstream of dams, PS = sites < 1 km downstream of power station. * indicates outliers. The bold line indicates lower bound of reference ('A') band, with all values falling below that line being significantly to severely impaired.

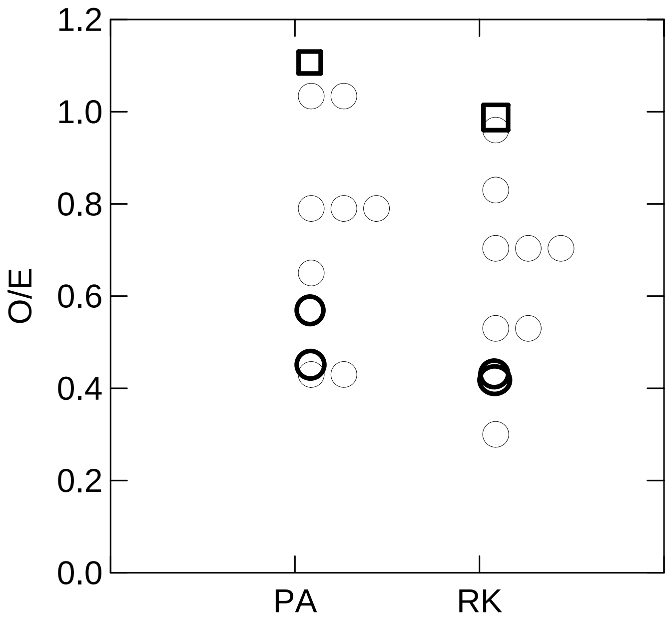


Figure 10: Dot histograms of values of O/E (pa and rk) reported for macroinvertebrate communities sites downstream of Hydro dams in Tasmania by Davies et al. (1999). Dark values indicate those reported for Cataract Gorge downstream of Trevallyn dam in 1995/96 (upper value) and 200/01 (lower value). Values for the un-dammed North Esk Gorge at Corra Linn are shown as bold squares.

Davies *et al*. (1999) found that the O/E values for the Gorge were in line with other stream sections from which large dams had removed all or the majority of natural flows. It is instructive to examine changes in taxonomic composition within the Gorge in order to further elucidate the cause of impacts on the biota. The expected faunal composition (as predicted by the hydro - River Invertebrate Prediction and Classification System rank abundance model developed by Davies *et al*. (1999) is shown in Table 3 along with the observed composition from sampling. Comparison of the differences between expected and observed composition between the Cataract and Corra Linn (North Esk River) gorge environments is particularly useful.

The extant Cataract Gorge fauna is dominated by chironomids (sub-family Chironominae), with all remaining taxa in low relative abundance. This is in marked contrast to the composition expected under unimpacted conditions, with abundant stoneflies, mayflies and caddis. It should be noted that the Corra Linn gorge has a fauna largely similar in composition to that expected, though with reduced relative abundances of gripopteryigid stoneflies and leptophlebiid mayflies and greater relative abundance of hydropsychid caddis and chironomids.

In order to assess the implications of these differences, macroinvertebrate families were classified according to their Flow Exposure Group, using data from Growns and Davis (1994). For taxa not classified by these authors, Flow Exposure Group status was estimated based on similar characteristics used by Growns and Davis (1994). Thus the following taxa were classified as follows:

- Flow obligates (O) - animals fully exposed to the water column on the upper substratum surface for most of their life cycle, usually with behavioural or morphological adaptations for attachment: Eusthenidae, Gripopterygidae, Leptophlebiidae, Blepheraceridae, Philorheithridae, Elmidae (adults and larvae), Simuliidae, Hydropsychidae, Athericidae, Hydrobiosidae, Conoesucidae, Odontoceridae, Polycentropodidae, Helicopsychidae, Philopotamidae.
- Flow facultatives (F) - as for obligates, but with the ability to move into low-flow areas: Baetidae, Tipulidae, Scirtidae, Empididae, Dipteran Pupae, Paramelitidae, Leptoceridae, Glossosomatidae, Psephenidae, Calocidae, Notonemouridae, Austroperlidae, Helicophidae.
- Flow avoiders (A)- animals that spend most of their life cycle within the substratum out of direct contact with stream flows: Oligochaetae, Turbellaria, Hydracarina, Sphaeriidae, Chironomidae, Ceratopogonidae.

Taxa were also assigned a grade indicating their relative sensitivity to declining water quality. The Stream Invertebrate Grade Number Average Level index (version 2) was used, an Australian macroinvertebrate biotic index of 'pollution sensitivity' described by Chessman *et al*. (1997) and further developed (Chessman 2001), ranging from 1 (for those taxa most tolerant to water quality degradation) to 10 (most sensitive).

It should be noted here that Flow Exposure Group and the Stream Invertebrate Grade Number Average Level (version 2) scores for the taxa occurring at these sites are not significantly correlated ($p > 0.5$ by regression, $n = 35$).

In order to assess to what extent the changes in Cataract Gorge macroinvertebrate communities were due to changes in flow regime and/or water quality, mean values of the Flow Exposure Group and Stream Invertebrate Grade Number Average Level (version 2) were calculated for the dominant taxa (high and moderate relative abundance taxa in Table 3) and compared. The mean Flow Exposure Group was significantly higher for the observed than expected communities in Cataract Gorge (p = 0.025, t = 3.98) indicating a significant shift from flow obligates to flow avoiders. The mean Stream Invertebrate Grade Number Average Level (version 2) values were also significantly different (p = 0.003, t = 13.5), indicating a shift from a water quality-sensitive to a pollution-tolerant fauna.

By contrast, there were no significant differences in either mean the Flow Exposure Group or the Stream Invertebrate Grade Number Average Level (version 2) values for the North Esk at Corra Linn. No change in mean Flow Exposure Group is observed (see Table 3), while a slight reduction in Stream Invertebrate Grade Number Average Level (version 2) is indicated (though not statistically significant). This is consistent with the lack of significant human-induced changes in flow regime in the North Esk River, but with the observed changes in water quality (Bobbi *et al*. 1996) probably associated with historical land clearing and land use activities.

	Sesk @ Cataract Gorge		N Esk @ Corra Linn	
Relative abundance	**Expected**	**Observed**	**Expected**	**Observed**
High	Gripopteryigidae Leptophlebiidae	Chironominae	Gripopteryigidae Leptophlebiidae	Chironominae Hydropsychidae
Moderate	Conoesucidae		Baetidae Chironominae Conoesucidae Eusthenidae Hydrobiosidae Simuliidae	Leptophlebiidae Elmidae (Ad.)
Low	Baetidae Chironominae Elmidae (Ad.) Elmidae (Lar.) Eusthenidae Glossosomatidae Hydracarina Hydrobiosidae Hydropsychidae Leptoceridae Oligochaetae Philorheithridae Psephenidae Scirtidae Simuliidae Tipulidae	Baetidae Conoesucidae Elmidae (Ad.) Elmidae (Lar.) Empididae Gripopteryigidae Hydracarina Hydrobiosidae Hydropsychidae Leptoceridae Leptophlebiidae Oligochaetae Parameletidae Philorheithridae Simuliidae	Austroperlidae Elmidae (Ad.) Elmidae (Lar.) Glossosomatidae Helicopsychidae Hydracarina Hydropsychidae Leptoceridae Oligochaetae Philorheithridae Psephenidae Scirtidae Tipulidae	Athericidae Baetidae Blephariceridae Conoesucidae Elmidae (Lar.) Empididae Eusthenidae Glossosomatidae Gripopteryigidae Hydracarina Hydrobiosidae Leptoceridae Oligochaetae Philorheithridae Polycentropidae Scirtidae Simuliidae Tipulidae
Mean FEG	**1.67**	**3.00**	**1.75**	**1.75**
Mean SIGNAL 2	**7.67**	**3.00**	**7.00**	**6.00**

Table 3: Expected and observed macroinvertebrate taxonomic composition for the South Esk River downstream of Trevallyn dam (and upstream of Dalrymple Ck), and for the North Esk Gorge at Corra Linn. Mean Flow Exposure Group and Stream Invertebrate Grade Number Average Level (version 2) scores for the dominant taxa (high and moderate relative abundance) are also shown.

Environmental Flows and Instream Biota

An environmental flow regime is required that is appropriate for the Gorge and its aquatic environment. Such a flow regime may contain low (minimum or base) flow and high (flood) flow elements.

A significant problem in determining such a flow regime is the identification of the specific values that are to be maintained. The Gorge cannot be maintained in a natural, pre-European state since:

- the presence of the Trevallyn Power Scheme precludes restoration of the natural flow regime and the geomorphic processes controlling substrate composition and behaviour in the Gorge;

- extensive alteration to the upstream catchment has undoubtedly resulted in changes in flow regime and water quality even in the absence of the hydro infrastructure;
- changes to the riparian environment have occurred, including local infestation by willows and other introduced plant species;
- changes to water quality have occurred associated with the WWTP discharges to Dalrymple Creek;
- changes to the internal connectivity and meso-habitats within the Gorge have occurred as a result of physical modifications (e.g. weirs etc) within the First Basin and at Deadmans Hollow; and
- recreational uses of the Gorge have adapted to the predominantly low flow environment.

Primary aims of environmental flow management for Cataract Gorge are therefore:

- to maintain the existing aquatic ecosystem values within the Gorge environment;
- to maintain or enhance the status of populations of threatened species which are dependent on the flow or water regime; and
- to maintain existing recreational uses within the Gorge in a manner compatible with its natural values.

It is recognised that the restoration of a significant proportion of the natural flow regime, which occurred prior to construction of the Trevallyn Power Scheme, is not feasible, and would conflict with the existing hydro-electric uses of the water as well as with existing tourism and recreational uses of the Gorge. If the existing Gorge aquatic ecosystem values are to be maintained, while maintaining viable populations of the known threatened species (particularly *Beddomeia launcestonensis*), then, two elements are required:

- a baseflow which maximizes habitat availability for all taxa, including the threatened species, while maintaining the broadly invariant nature of the existing baseflow; and
- a series of flood peaks which mimic the existing spill sequences occurring at the dam.

Increases in the magnitude of flood peaks to mimic a more natural flood regime is unlikely to achieve substantial aquatic ecological gains, and in fact is likely to cause more significant disturbance to the extant fauna and flora than occurs presently (see later section dealing with *Beddomeia launcestonensis*). This is quite apart from other issues associated with the impact of larger floods on safety and other human uses.

The existing flood sequence could be described as 'abrupt', with sudden increases in flows as the dam spills, coupled with rapid water level declines as the flood recedes (see Figure 11). This is markedly different from natural flood sequences, which have slower rates of initial rise and recession. In the case of flood rises, a key issue is whether the instream fauna (and flora) have sufficient refugia within the Gorge environment to provide suitable hydraulic conditions to protect them from sudden increases in shear forces associated with rapidly rising water levels. This appears to be the case, as the Gorge is a hydraulically very complex environment, with complex sequences of boulders and bedrock elements that are associated with highly variable flow and depth environments at a range of spatial scales. We believe, therefore that the issue of the impact of sudden rates of flood rise is not a major one for the instream fauna and flora.

There is a requirement for an improved minimum environmental flow in order to maintain sufficient habitat for both listed and unlisted species in the Gorge. Survey work was therefore conducted during 2001 to assess the magnitude of such a flow for the maintenance of optimum habitat for aquatic biota, taking into account locally endemic and listed aquatic species. A risk assessment approach was taken, with the aim of identifying minimum flows at which sufficient habitat was available to ensure reduction in risk to instream biota from the modified flow regime to at least a moderate level. The combined Instream Flow Incremental Methodology - risk assessment approach developed by Davies and Humphries (1996) was used to derive minimum environmental flows for the Gorge.

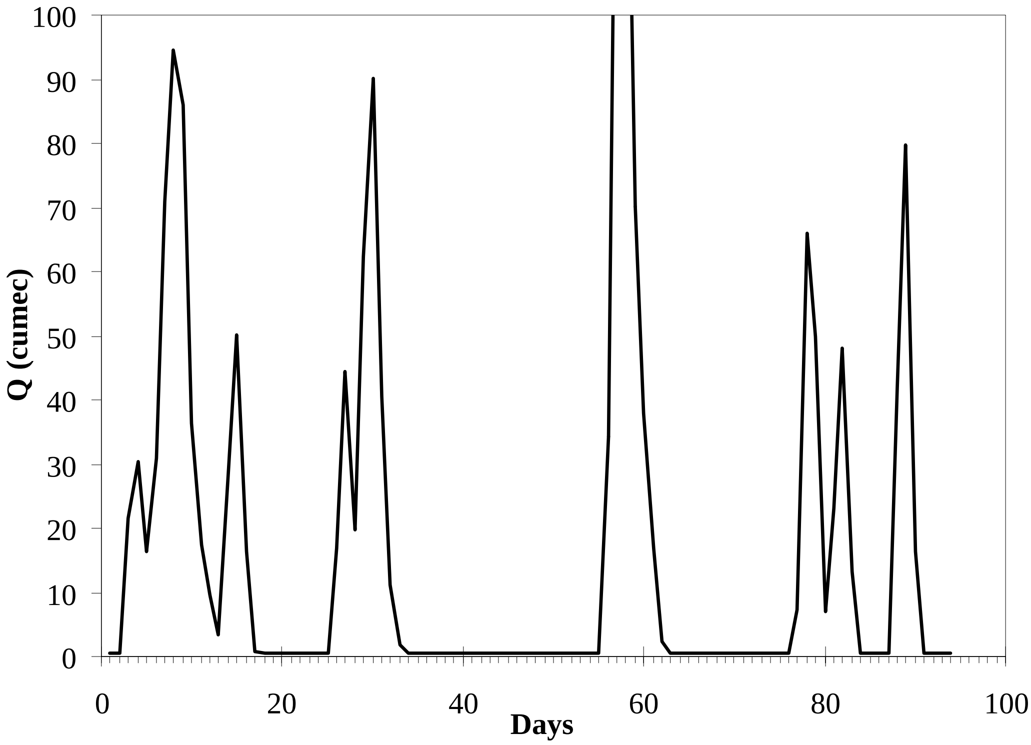


Figure 11: Example of flood sequence (in May - July 1999), showing truncation of flood peaks with rapid onset and recession of flows, following spill cessation, down to 0.425 cumec.

Hydraulic Data

Transects were established across the Gorge at 17 representative locations. Data was collected at 1 m intervals across each transect on substrate composition, channel profile, water depth and velocity (both near-bed and mid-water column). Transects were spaced by between 125 and 575 m apart, depending on changes in channel form and substrate. Additional observations were made of water surface elevation at several discharges in order to develop rating curves for each transect.

Each transect site and data were assessed for:

- the ability to adequately model hydraulic conditions over the flow range 0 to 20 cumec;
- the reliability and form of stage-discharge relationships; and
- the ability to adequately measure the elevation of stage at zero flow.

14 of the initial 17 transects and their data sets were deemed to have passed these criteria and were included in further analyses and the biological and recreational risk assessment. This set of transect data was deemed to adequately represent all the dominant habitats within the Gorge, with the exception of the large, artificial pool at Deadmans Hollow (created by a concrete weir to service the original Duck reach power station tunnel intake). The locations of the final set of 14 transects are indicated in Figure 12.

Habitat Preference Data

Data on habitat preferences was collected from existing sources for the following species known to inhabit the Gorge:

- the platypus – observed at several locations within the Gorge;
- two Galaxiid native fish species - *Galaxias maculatus* and *G. truttaceus*; and
- shortfin eel and juvenile lamprey.

While the rare and threatened fish Australian Grayling (*Protroctes maraena*) is known to inhabit the Tamar Estuary and has been seen in Cataract Gorge, the presence of this species is extremely difficult to quantify. Because of this, and the lack of detailed habitat information on this species, no habitat preference curves were developed for this species during this study.

Data on habitat preferences for macroinvertebrates had to be collected from the field. These data could not be collected from Cataract Gorge due to the confounding effects of the highly modified flow regime and the presence of a highly nutrient enriched inflowing stream polluted with wastewater entering the Gorge in its mid-reaches. An alternative site with similar habitat and an unmodified flow regime and an absence of point-source pollution was sought. A single reach of the North Esk River in the gorge at Corra Linn was sampled, and 78 samples collected by quantitative surber sampling across a range of depth, velocity and substrate types. These samples were hand-sorted and identified to family level, with a number of dominant taxa then further identified to species level. Additional sampling was also conducted in Cataract Gorge, which allowed development of habitat preference curves for the endemic snail *Beddomeia launcestonensis*.

Of the 44 taxa collected, there were sufficient data to develop habitat preference curves for the 21 taxa listed in Table 4. Habitat preference curves were also developed for macroinvertebrate taxon richness and total macroinvertebrate abundance.

The habitat preference data and the transect data were combined using RHYHAB habitat simulation software. Weighted Useable Area (of habitat in a river available to a species) - Discharge curves were developed for all the taxa and variables listed above, as well as for wetted area.

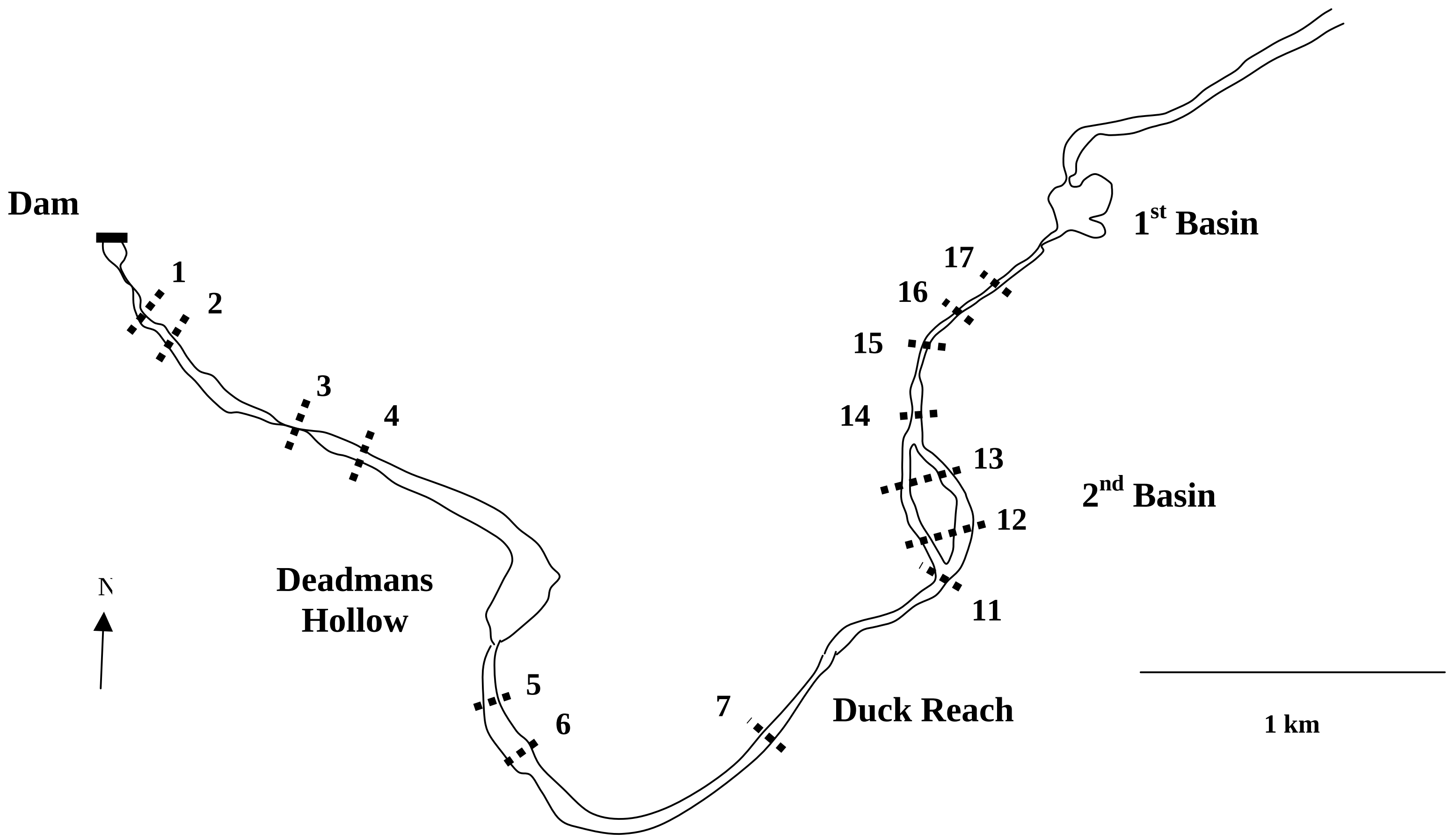


Figure 12: Position of transects used for hydraulic characterisation of Cataract Gorge

Simulations could be conducted between 0 and 25 cumecs. Simulations were validated by comparing depth and velocities from simulation runs with depth and velocity values measured in the field at the same discharges (in the range 2 – 10 cumec). Overall agreement was satisfactory with 80 % of all simulated velocities falling within 25 % of measured values.

Class	Order	Family	Sub-Family	Species
Mollusca	Bivalvia	Sphaeriidae		
	Gastropoda	Hydrobiidae		*Beddomeia launcestonenis*
		Ancylidae		
Arachnida	Hydracarina			
Insecta	Plecoptera	Gripopterygidae		
	Ephemeroptera	Caenidae		*Tasmanocoenis sp. B*
	Diptera	Chironomidae	Chironominae	
			Orthocladiinae	
		Simuliidae		
		Tipulidae		
		Ceratopogonidae		
		Empididae		
		Unid. pupae		
	Trichoptera	Conoesucidae		*Conoesucus nepotulus*
		Ecnomidae		
		Hydroptilidae		*Hydroptila acinasis*
				Hellyethira simplex
	Coleoptera	Adult Elmidae		
		Larval Elmidae		*Kingolus aeratus*
				SimsoniaL12E

Table 4: Macroinvertebrate taxa for which habitat preference curves were defined for use in the Cataract Gorge environmental flow assessment.

Reference Flow and Risk Analysis

Due to the unusual nature of the flow regime, no natural reference discharge could be selected to conduct a risk assessment. In addition the dominance of the flow regime by the 0.43 cumec release, coupled with the highly truncated spill flow peaks, precluded development of a flow statistic, which adequately described what is a strongly 'bi-modal' flow pattern. It is assumed that the fauna is largely adapted to a constant flow environment, with intermittent disturbance by high flow peaks. This is illustrated, we believe, by the unusual distribution of *Beddomeia launcestonesis* in the Gorge (see later section dealing with *Beddomeia launcestonensis*).

Instead of using a reference flow, an approach was taken which involved estimating the percentage of the maximum habitat area possible, for each of a series of discharges. The percentage of maximum useable habitat area available was calculated at each 0.5 discharge increment within the flow range 0 and 20 cumec for each taxon (see Figure 13 and Figure 14). The overall minimum of the % maximum habitat area values was then calculated at each discharge across all taxa (fish, platypus and macroinvertebrates). A plot was then prepared of the overall minimum of the percentage maximum habitat area at each discharge, and its peak was sought (see Figure 15). This curve defines the minimum percentage area available for any taxon at each discharge, and has a peak at 4.6 cumecs (see Figure 15 and Figure 16).

A minimum of 85 % of available habitat areas was defined as the cut-off between no and moderate environmental risk in previous work – see Table 5, taken from Davies and Cook (2001). This threshold is also shown in Figure 16. Discharge values for which the % maximum habitat area curve falls above this threshold are regarded as minimum environmental flows that will maintain the aquatic biota with minimum risk. This approach also provides a trade-off between the various taxa without any weighting, ensuring that the taxa with the lowest % maximum habitat area are protected.

Habitat preference curves for several taxa with sensitive responses to flow changes around the no-risk flow range are shown in Figure 17. These taxa have sharply defined preferences for low to moderate depths and / or water velocities.

Risk category			
I	**II**	**III**	**IV**
No risk or beneficial	**Moderate risk**	**High risk**	**Very high risk**
> 85% of maximum habitat	60 – 85% of maximum habitat	30 - 60% of maximum habitat	< 30% of maximum habitat

Table 5: Risk categorisation criteria for biological values and values for percentage change in habitat area i.e. % remaining Weighted Useable Area under nominal flow cf maximum habitat availability and/or reference flow (baseflow under natural conditions).

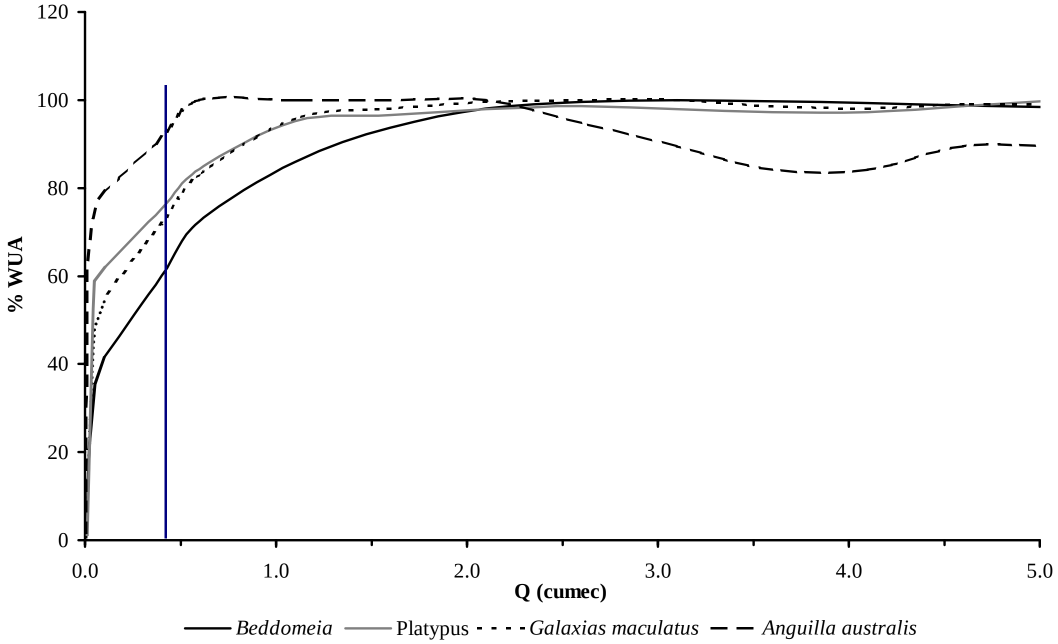


Figure 13: Percentage of maximum habitat area available for *Beddomeia launcestonensis*, platypus, the common jollytail and the shortfin eel over a range of low discharges in Cataract Gorge. The vertical line indicates the existing dominant flow of 0.425 cumec.

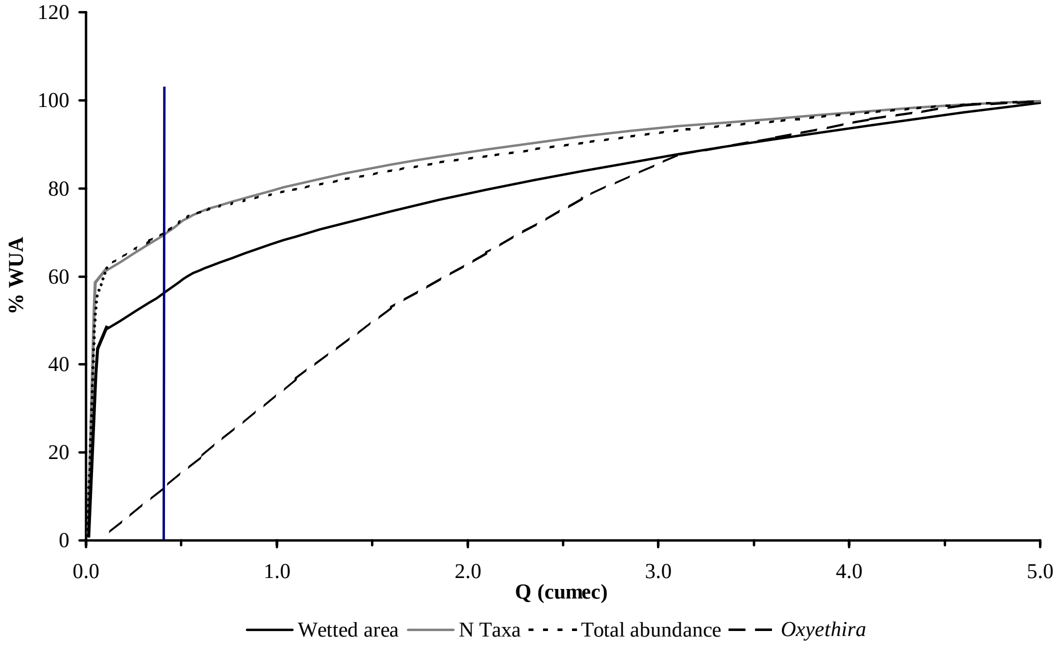


Figure 14: Percentage of area wetted and percentage of maximum available habitat area for maximum taxon richness and macroinvertebrate abundance, as well as for *Oxyethira mienica*, over a range of low discharges in Cataract Gorge. The vertical line indicates the dominant flow of 0.425 cumec.

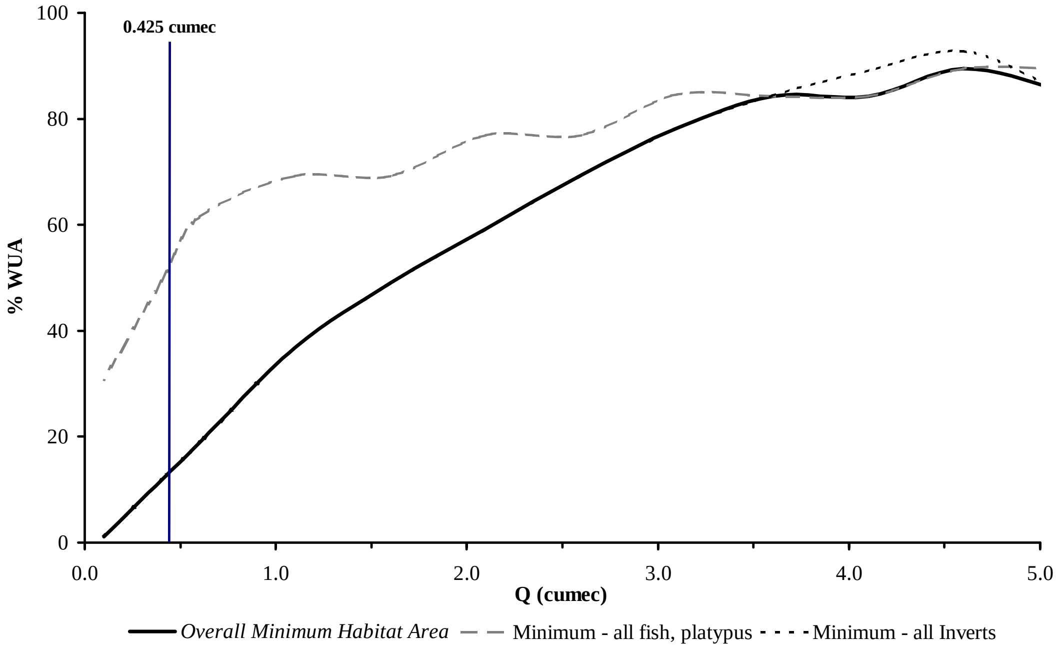


Figure 15: Plots of overall minimum of the maximum percentage of available habitat area for vertebrates (fish and platypus) and macroinvertebrates (all taxa listed in Table 3), over a range of low discharges in Cataract Gorge. The solid curve defines the overall minimum % habitat area available to all aquatic taxa studied, peaking at 4.6 cumec. The vertical line indicates the existing dominant flow of 0.425 cumec.

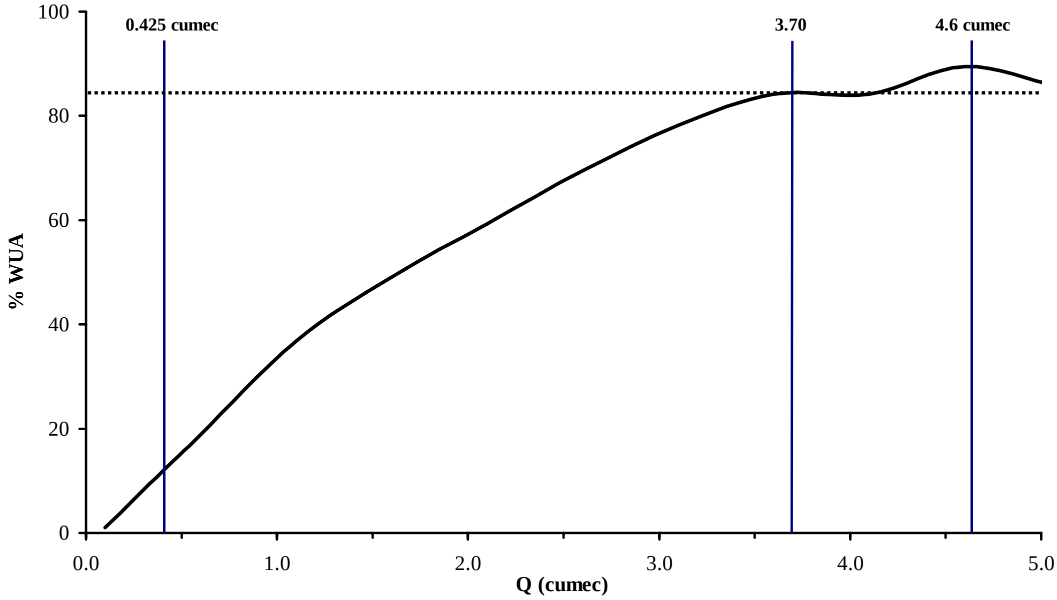


Figure 16: Plots of the minimum relative available habitat area for all aquatic taxa, over a range of low discharges in Cataract Gorge. Note the peak at 4.6 cumec, and the minimum defined by the threshold of 85% of Weighted Useable Area (shown as the horizontal dashed line). The left-hand vertical line indicates the existing dominant flow of 0.425 cumec.

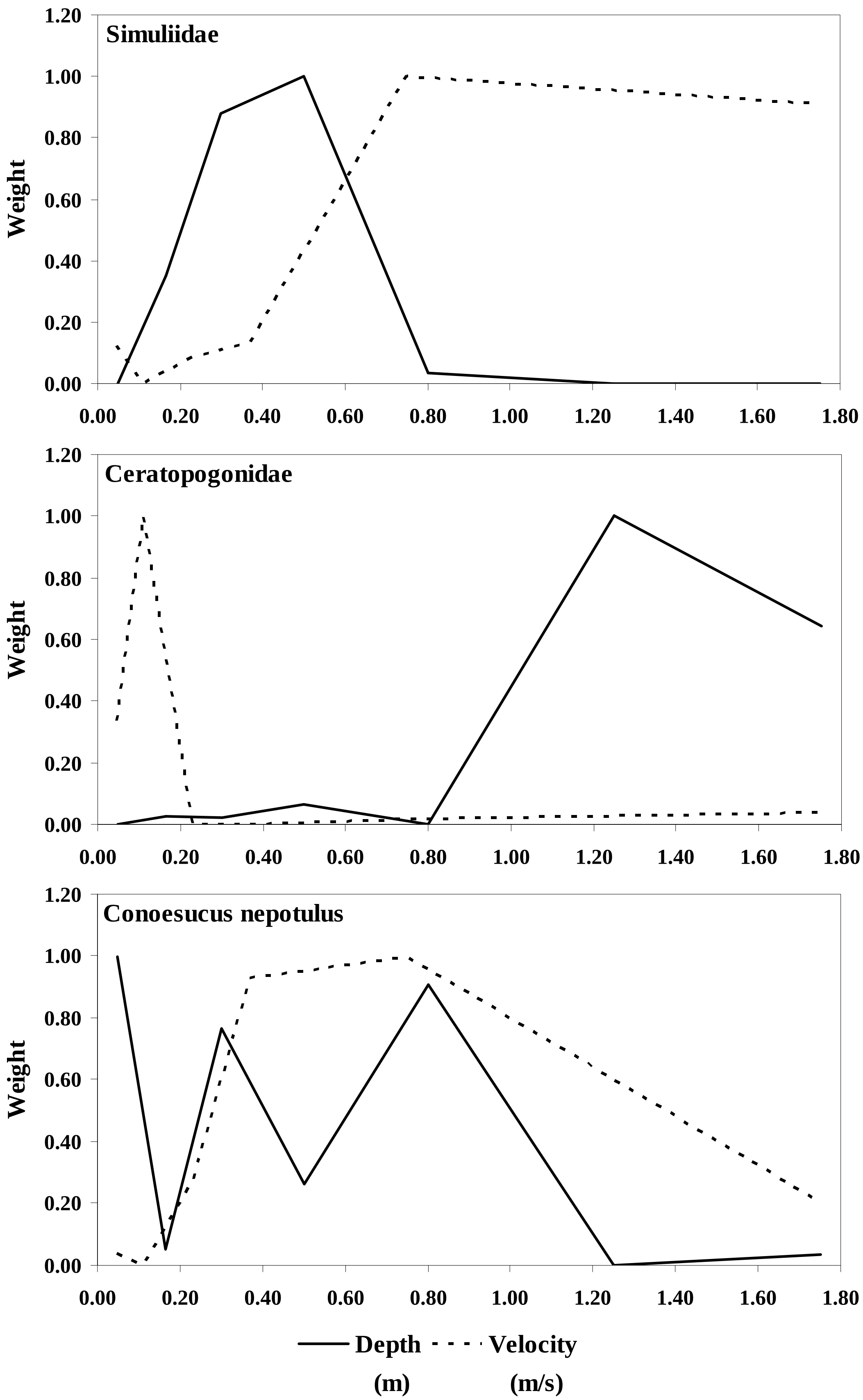


Figure 17: Habitat preference curves for three taxa found to be highly sensitive to flow changes in Cataract Gorge for flows between 0 and 10 cumec.

Table 6 shows the results of applying the risk criteria to the habitat area outputs of the RHYHAB simulation for all biological variables and taxa. A marked decrease in risk is observed for all taxa over this flow range, with the exception of *Beddomeia launcestonensis*, for which risk rises above 3.1 cumec, largely due to increasing velocities.

	Q	5.1	4.6	4.1	3.6	3.1	2.6	2.1	1.6	1.1	0.6	0.4	0.1
Physical													
Relative to 8 cumec natural baseflow													
	Wetted area	I	I	I	I	I	II	II	II	II	II	III	III
Biological													
Habitat available (no reference flow used)													
Family	**Species**												
	Platypus (*O. anatinus*)	I	I	I	I	I	I	I	I	I	II	II	II
	Anguilla australis	I	I	II	II	I	I	I	I	I	I	I	II
	Geotria australis (amm.)	I	I	I	II	II	II	II	II	II	II	III	III
	Galaxias maculatus	I	I	I	I	I	I	I	I	I	II	II	III
	G. truttaceus	I	I	I	I	I	I	I	I	I	II	II	III
Hydrobiidae	*Beddomeia launcestonensis*	II	II	II	II	I	I	I	I	I	I	I	II
Hydrobiidae	*Austropyrgus spp.*	I	I	I	I	I	I	I	I	I	II	II	III
Sphaeriidae		I	I	I	I	I	I	I	II	II	II	II	II
Ancylidae		I	I	I	I	I	II	II	II	II	III	III	III
Hydracarina		I	I	I	I	I	I	I	I	II	II	II	II
Gripopterygidae		I	I	I	I	II	II	II	II	III	III	III	III
Caenidae	*Tasmanocoenis* sp. B	I	I	I	I	I	I	I	II	II	II	II	II
Chironominae		I	I	I	I	I	I	I	I	I	II	II	II
Orthocladiinae		I	I	I	I	I	I	II	II	II	II	II	III
Simuliidae		I	I	I	I	I	I	I	II	III	III	III	III
Tipulidae		I	I	I	I	I	I	I	II	II	II	II	III
Ceratopogonidae		I	I	I	II	II	II	II	II	II	II	III	III
Empididae		I	I	I	I	I	II	II	II	II	II	III	III
Dipteran pupae		I	I	I	I	I	II	II	II	III	III	III	IV
Conoesucidae	*Conoesucus nepotulus*	I	I	I	I	II	II	III	III	III	IV	IV	IV
Ecnomidae		I	I	I	I	I	I	I	I	I	II	II	II
Hydroptilidae	*Hydroptila acinasis*	I	I	I	I	I	I	II	II	II	II	II	II
	Hellyethira simplex	I	I	I	I	I	I	I	I	I	I	II	II
Elmidae	Elmidae (adults)	I	I	I	I	I	I	I	I	II	II	II	III
	Kingolus aeratus	I	I	I	I	I	II	II	II	II	II	II	III
	Simsonia sp. L12E	I	I	I	I	I	I	I	II	II	II	II	III
Number of taxa		I	I	I	I	I	I	I	I	II	II	II	II
Total abundance		I	I	I	I	I	I	I	II	II	II	II	II
Highest risk, invertebrates only		II	II	II	II	II	II	III	III	III	IV	IV	IV
Proportion in risk band II		0.04	0.04	0.04	0.09	0.13	0.3	0.39	0.65	0.78	0.91	0.96	1
Highest risk, fish and platypus only		I	I	II	II	II	II	II	II	II	II	III	III
Proportion in risk band II		0	0	0.25	0.5	0.25	0.25	0.25	0.25	0.25	0.75	0.75	1
Overall Risk		**Low to Moderate**					**Moderate**			**High to Severe**			

Table 6: Risk levels associated with a range of flows between 0.1 and 5 cumec in Cataract Gorge for wetted area and instream biota. Values for individual taxa and variables are shown first, while risk values are summarized below.

Flood Flows

Channel morphology within Cataract Gorge is largely unresponsive to small to intermediate floods, since the Gorge is bedrock constrained and the major substrate elements are large boulders.

However, the existing spill-generated flood flow sequence is important in several respects:

- it flushes fines which are deposited during periods of sustained baseflow (sourced from the Gorge walls, small tributaries and upstream land-use activities);
- it occasionally flushes and/or regenerates biofilms and accumulations of exotic plants – the latter particularly downstream of Dalrymple Creek where local accumulations of *Lemna, Azolla* and a variety of other exotic aquatic or semi-aquatic plants occur, sourced from and/or facilitated by inputs from Dalrymple Creek catchment;
- it mobilizes smaller substrate size classes, particularly gravels and small cobbles which act as substrates for some macroinvertebrate taxa; and
- it acts as a stimulus for a degree of fish migration into the Gorge from the Tamar estuary.

Table 7 summarises the sequence of flood events that have occurred in the Gorge between 1990 and 2000. To fulfil many of the requirements listed above, a sequence of flood flows of various sizes should be allowed to pass through the Gorge. These are listed in Table 7 as medium-term averages (over a 10 year period). All of these floods currently pass as spills from Trevallyn Dam. Any future development of the site should allow this minimum flood sequence to be maintained.

Q	N floods per year		
(cumec)	Mean	Range	Recommended
0-50	2.18	1 - 5	2 per year
50-200	3.18	0 - 5	3 per year
200-500	1.36	0 - 3	1 per year
>**500**	0.55	0 - 3	1 per 2 years

Table 7: Mean and range of floods occurring in Cataract Gorge between 1990 and 2000, along with recommended average flood sequences required for maintaining aquatic values.

Discussion of Potential Environmental Flows

A minimum environmental baseflow for Cataract Gorge should be designed to reduce existing risks to instream biota, while maintaining recreational uses of the Gorge. In the absence of any new strategy to manage recreational use of the Gorge in relation to flows, a flow release of between 1.5 - 3 cumec from Trevallyn Dam would be appropriate. This flow range results in at least 50 – 80 % (respectively) of the possible habitat area available to macroinvertebrate taxa within the Gorge (including *Beddomeia launcestonensis*), and at least 70 – 85 % (respectively) of available habitat area for fish species. This can be delivered as a continuous release from Trevallyn Dam, as there is little evidence of the need for seasonal variation in this baseflow.

The results discussed in this section suggest a response in the Cataract Gorge fauna to both a change in flow regime and a decline in water quality. The significantly greater decline in Stream Invertebrate Grade Number Average Level (version 2) score in Cataract Gorge compared to the North Esk River at Cora Linn suggests that the changes in water quality in Cataract Gorge are both more acute and/or different in nature. The overall impact on the biota is due to the major reduction in base-flows which are also likely to be coupled with increases in temperature particularly during summer, as well as any likely changes to dissolved oxygen levels which might occur with low flows and high summer temperatures.

A related issue is the potential for enhanced fine sediment deposition on boulder surfaces in Cataract Gorge due to the lack of flushing flows, particularly during summer. This will interact with enhanced biofilm development associated with greater insolation of the substrate due to the existing prevalent shallow water depths. Well-developed, silt-rich biofilms constitute a modified habitat, which is a significant factor altering macroinvertebrate community composition. A shift from a diverse mayfly, stonefly and caddisfly to a midge-dominated macroinvertebrate community has occurred. Conditions downstream are further degraded by the influence of the wastewater treatment plant contaminated inflow from Dalrymple Creek, which produced nutrient enrichment and consequential blooms of green and potentially toxic blue-green algae.

Flood events are also an important feature of the flow regime, which should be maintained for environmental purposes in the Gorge. The recommended average sequence shown in Table 7 should be maintained into the future, managed as specific environmental flows, along with the recommended minimum flow.

Future studies may investigate options for controlling the rate of flow decline following flood peaks, and the possibility of providing ramped rates of recession of spill events commensurate with the requirements of instream fauna.

Recreational Uses and Flow

The recreational uses of the Gorge are intensive and varied. Within the Gorge and basin channel areas, it includes intensive use for sightseeing, bathing (swimming, paddling etc), community picnic facilities, and less intensive uses such as angling and canoeing. Water-associated safety is a key factor in recreational management of the Gorge and the following issues are of relevance:

- water velocity;
- water depth;
- water temperature;
- water quality (bacterial); and
- water quality (toxicological).

Both water depth and velocity are directly affected by flow within the Gorge. Temperature and water quality are also affected by flow but have a number of secondary controlling influences such as season, and management of point source discharges such as storm and waste waters. These are not addressed in this assessment.

The focus of this component of the study was on the flow requirements for maintaining safe conditions for bathing (i.e. swimming and paddling). Flow needs for canoeing are met by other, special arrangements with Hydro Tasmania, and are usually focused on single sporting events and/or commercial operations, and are not discussed further here.

For this assessment, no specific field observations were made of recreational use, other than casual observations of patterns of use during summer of:

- the First Basin for bathing;
- the lower sections of the Gorge immediately upstream of the First basin for bathing; and
- all sections of the Gorge for walking and/or paddling.

We have made an assessment of flow requirements for bathing using water velocity as the primary factor influencing suitability (safety/risk) for swimming/paddling within the Gorge under conditions of suitable water temperature.

In order to conduct this assessment we have used the hydraulic data from the transects used to assess flow conditions in the Gorge (see Figure 12) and the First Basin.

Use of 'swimming/paddling' suitability data in an 'Instream Flow Incremental Methodology-style' RHYHAB analysis was not suitable, as this kind of simulation does not take into account the need for consistent safe swimming conditions across the entire channel.

We therefore used the criterion that the entire channel width must be below a velocity threshold of 0.1 m/sec for risk to be considered low. This is a deliberately conservative velocity threshold, to ensure minimal risk from the analysis, and is based on the estimated swimming speed of a child aged 9-12 years with poor swimming ability. If any part of a transect had velocities > 0.1 m/sec, then the risk was considered moderate to high.

We simulated cross-channel velocity distributions for all transects at discharges between 0.1 and 5 cumec and visually inspected profile at each velocity increment of 0.5 cumec.

For the Gorge (Trevallyn Dam to upstream of the First Basin), we then assessed the number of transects (out of a total of 12) for which the above criteria were satisfied.

For the First Basin, we assumed that the upstream and downstream ends of the basin pool were similar in velocity profiles to the Gorge transects, and that the rest of the Basin had much lower velocities. Thus, if Gorge transects satisfied the criteria (i.e. were at low risk) then the rest of First Basin was assumed to be at low risk also.

The results of the simulations and applying the threshold criteria are shown below in Table 8. Threshold discharges vary widely depending on whether the channel is predominantly pool or rapid, and with changes in channel slope and substrate type. In order to develop an indication of flow-risk for the whole Gorge, threshold discharges were estimated based on the proportion of the Gorge which failed/satisfied the low risk threshold criterion. This was calculated using the proportion of the number of study transects whose threshold discharges failed/met the criterion, as the set of transects was assumed to be representative of the Gorge as a whole. The results are shown in Table 9.

Transect	Threshold discharge (cumec)
T1	1.6
T2	5.1
T3	0.2
T7	5.2
T8	0.6
T11	5.1
T12	1.6
T13	0.1
T14	0.4
T15	0.2
T16	5.1
T17	0.4

Table 8: Threshold discharges above which conditions for bathing failed the criteria (spot water velocity >0.1 m/sec) and were therefore considered to be of moderate to high risk. Discharges at or below the levels shown here are judged to be of low risk for bathing at these locations, provided temperatures are suitable. See summary in Table 4.

Flows must be maintained at a very low level (ca 0.1 cumec) if the entire Gorge is to have a low risk for bathing. Current baseflow levels (0.425 - 0.5 cumec) result in low risk conditions in all of the First Basin, but only 50 – 75% of the Gorge. Only a third of the total Gorge reach would be at low risk for bathing at flows higher than 2 cumec, while only the First Basin would be at low risk at flows up to about 3 - 4 cumec. These flows are likely to result in moderate to high-risk conditions for swimming at the upstream and downstream channels of the First Basin pool, however.

<table>
<tr><td colspan="2">Q :</td><td>5.1</td><td>4.6</td><td>4.1</td><td>3.6</td><td>3.1</td><td>2.6</td><td>2.1</td><td>1.6</td><td>1.1</td><td>0.6</td><td>0.4</td><td>0.1</td></tr>
<tr><td colspan="14">Recreational - swimming/paddling</td></tr>
<tr><td>1st Basin</td><td><u>% of area</u></td><td colspan="12"></td></tr>
<tr><td></td><td>Approx. all</td><td colspan="4">Low to Moderate</td><td colspan="8">Low</td></tr>
<tr><td></td><td>75%</td><td colspan="12">Low</td></tr>
<tr><td>Gorge</td><td><u>% of area</u></td><td colspan="12"></td></tr>
<tr><td></td><td>Approx. all</td><td colspan="11">Moderate to High</td><td>Low</td></tr>
<tr><td></td><td>75%</td><td colspan="10">Moderate to High</td><td colspan="2">Low</td></tr>
<tr><td></td><td>50%</td><td colspan="7">Moderate to High</td><td colspan="5">Low</td></tr>
<tr><td></td><td>33% or less</td><td colspan="12">Low</td></tr>
</table>

Table 9: Flow ranges for bathing in Cataract Gorge (Gorge and 1st Basin shown separately) at different risk levels. Flow ranges are shown separately for different proportions of the Gorge area.

It becomes obvious from inspecting these figures that a considerable trade-off must be made between recreational and biological values in determining a minimum environmental flow for Cataract Gorge. This is discussed in the final section of this document.

The Cataract Snail - *Beddomeia launcestonensis* – Status, Management and Critical Habitats

The following section is a summary of results of a study conducted by Freshwater Systems, commissioned by Hydro Tasmania, to investigate issues related to the endemic and listed freshwater snail – *Beddomeia launcestonensis*.

Background

B. launcestonensis is one of 47 species of the uniquely Tasmanian snail genus *Beddomeia* described to date (Ponder *et al*. 1993). These authors suggest that there may be over 80 species, many of which are yet to be described. All of these species are endemic to the state, and many are highly localised in their distribution. Many, including *B. launcestonensis*, are formally listed as 'rare' under Tasmanian *Threatened Species Protection Act* (1995), although a number of these listings are in need of review.

It is believed that *B. launcestonensis* is restricted to Cataract Gorge on the South Esk River. However, no dedicated surveys had been conducted prior to this work to assess either its true distribution or its status either within the Gorge or outside it. There was also no understanding of its habitat requirements, other than it having been observed on:

- the underside if large rocks adjacent to the channel margins in the pool formed by the weir at Deadman's Hollow (Ponder pers. comm.);
- still water in communication with the South Esk and in caverns in the Cataract Gorge, Launceston (Johnston, 1879);
- First Basin Launceston (Kershaw, unpub. data, 1988);
- under stones in running water, ca 1.2 k downstream of Trevallyn Dam (41 27 57S, 147 06 09 E), under stable rocks in 0.2 – 0.5 m, and not in flow (this is station TA667 in Ponder *et al*. 1993); and
- under large stable slabs of rock in pools and side channels off the main bed of the river (Ponder *et al*. 1993).

The aim of this component of the study was to enhance existing knowledge of the distribution and habitat requirements of this species, with the objective of identifying potential threats to the long-term survival of the species and potential options that will provide some protection for this species.

The methodology for collecting this information consisted of active searching for *B. launcestonensis* in cryptic habitats at a number of locations in Cataract Gorge, around Lake Trevallyn, in the South Esk River upstream of lake Trevallyn and in the North Esk at Corra Linn. *B. launcestonensis* was only consistently found in cryptic habitats, and these included:

- the underside of boulders, lifted by hand and/or crowbar;
- in sheltered backwaters and/or channels adjacent to the main channel;
- on rock surfaces in crevices between large boulders or bedrock slabs; and
- in water-filled scour holes adjacent to the channel.

While attempts were made to standardise sampling, by use of quadrat-based counts, the wide variety of habitats and range of snail densities precluded recording snail densities by area. Instead, the emphasis was on observing the presence of *B. launcestonensis* and recording whether densities were relatively high or low. In addition, the presence of other snail species was recorded. For all boulder habitats, a minimum of 10 (typically 15 – 30) boulders were surveyed, with inspection of all surfaces (occasionally requiring use of crowbars).

Surveying within Cataract Gorge involved foot access by a team of two people actively searching all suitable cryptic habitat within the channel. *B. launcestonensis* was recognised by eye. A number of samples of *B. launcestonensis* and other snail species were returned to the laboratory for confirmation of identification during the study. Access to sites on the Lake Trevallyn shoreline was by boat.

Surveying within the large pools upstream of Deadmans Hollow and in the First Basin was by means of snorkelling and/or scuba diving.

Distribution and Abundance

The locations where *B. launcestonensis* were observed during the survey (conducted in the summer of 2001/02) are listed in Table 10. The overall distribution of *B. launcestonensis* in Cataract Gorge is shown in Figure 18. Locations of sampling sites in Lake Trevallyn are shown in Figure 19. *B. launcestonensis* was highly patchy in its distribution and where present, consistently occupied, or were closely adjacent to cryptic habitat features.

In Cataract Gorge, low densities of *B. launcestonensis* (typically 1 to 2 individuals per rock) were observed on the underside of boulders or on the slopes of bedrock slabs in still or calm water on the channel margins. No *B. launcestonensis* were observed on or under any rock surface within flowing water in the main river channel, anywhere within the gorge.

B. launcestonensis were found in high densities in only three habitats:

1) Scour holes around 2 m above low water (0.425 cumec release) elevation, typically close to the 'flood line' indicated by the limit of moss growth on bedrock surfaces, both in the gorge between Deadmans Hollow and Duck Reach and between the Dam and the head of the Deadmans Hollow weir pool. The presence of *B. launcestonensis* was not consistent among scour holes at similar elevations. The shape and depth of scour holes with high *B. launcestonensis* densities suggested that only those scour holes that provide low stress hydraulic conditions during high flow events are able to sustain *B. launcestonensis* populations. These holes had depths and widths ranging from 0.5 to 1.5 m and 0.5 to 1 m, respectively. Numerous other scour holes were observed with a range of densities of other snail species (austropyrgid and pulmonate snails), or no snails. Algal food resources in scour holes were apparently not limiting, as most holes without snails had abundant epiphytic or filamentous algal growth. Scour holes close to the low water mark, within 0-1 m, consistently did not contain *B. launcestonensis*.
2) On small rocks deep within crevices between large (1-2m high) boulders in First Basin. Occasional *B. launcestonensis* were observed on the main boulder surfaces, but densities were very low (with over 30 boulders being searched). Densities were very high on a number of small (ca 10 – 15 cm) rocks found in deep crevices between these boulders, with between 8 and 36 individuals counted per rock (of 9 observed).
3) On the underside of large rocks (boulders) adjacent to the north-eastern shoreline of First Basin, or on small rocks beneath them. Densities ranged from 1 to 38 per rock, with an overall mean of 7.4 per rock. These densities were highly skewed (see Figure 20), with a highly clustered distribution at small spatial scales.

Areas with low *B. launcestonensis* densities included the mouth of First Basin adjacent to the causeway, where a mean density of 0.33 individuals per rock was recorded (and a median of 0). The large pool immediately downstream of First Basin had a lower density, with a mean of 0.105 per rock (median = 0). Both of these sites have a higher exposure to flows during flood events than benthos and shore of the eastern part of First Basin. Again, areas adjacent to the First Basin and upstream within the Gorge in the main, flowing channel did not appear to support any *B. launcestonensis*.

The eastern shore of First Basin adjacent to the lawns and swimming pool supported a low density of *B. launcestonensis*. Searching on the western and southern shores of First Basin failed to reveal any *B. launcestonensis*. Exposure to high flows during floods is high on the western shore and near the inlet to First Basin. High levels of silt were observed on rock surfaces on the eastern and southern shorelines and benthos, which are in a depositional eddy during the prolonged periods of low flow. Most rock surfaces in this area did not support other snail species.

Site Name	Grid references where *B. launcestonensis* observed	Comments
South Esk River		
1st Basin	Within area defined by rectangle formed by diagonals at 509775 5411575 509900 5411525	Observed in eastern corner of Basin from 0 to 3 m depth in locally high abundance under boulders or on small rocks in deep crevices. Absent on northern, western and southern shores.
Dam to Deadmans Hollow	507273 5411150	Low densities in shallow backwater pool, under boulders on channel margin, depths from 0.1 to 0.25 m. High densities in isolated scour hole 2m above 0.425 level. Absent in fast flowing shallow and deep main channel.
	507316 5411016	Low densities under boulders in side-channel margin, 0.5 m depth.
	507802 5410665	Very low densities in weir pool margin under boulders in still water, 0.4 m depth.
Deadmans Hollow to Duck Reach Bridge	Main channel	None found in main channel or under boulders, despite active searching.
	508139 5409933 508147 5409912	Locally high densities in scour holes at ca 2m elevation above low water mark.
Lake Trevallyn	506148 5407200 505990 5407661 505414 5408404 505410 5409127	Present in low densities at four locations (1 to 3 per 20 min searching) under boulders.

Table 10: Locations are which *B. launcestonensis* were observed.

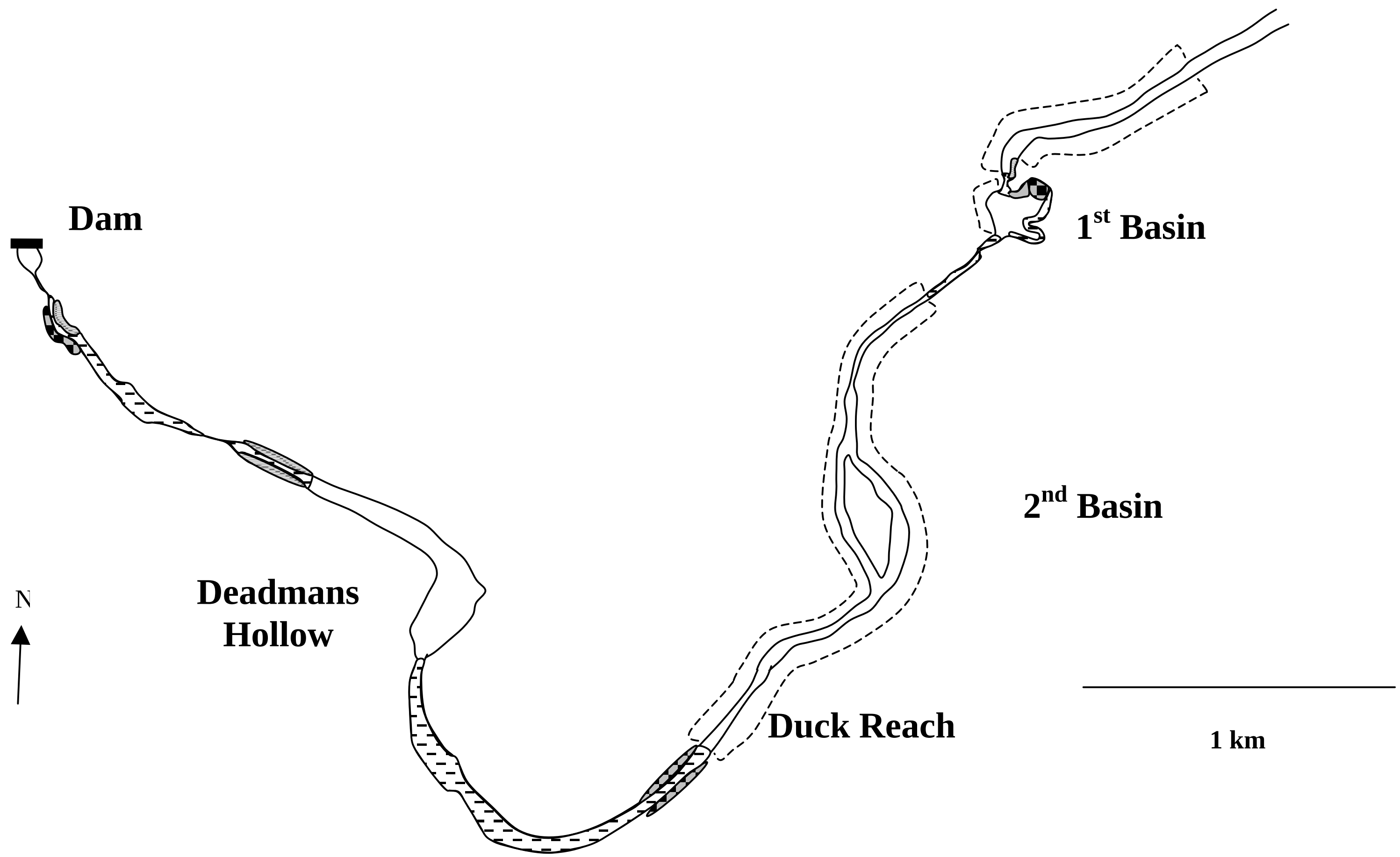


Figure 18: Locations in Cataract Gorge where *B. launcestonensis* was recorded, in low densities (grey shapes) and high densities (dotted shapes) and was absent (horizontal dashed areas). Dashed lines indicate channel margins with habitats similar to those in which no B. launcestonensis were recorded. These areas were only searched in specific locations.

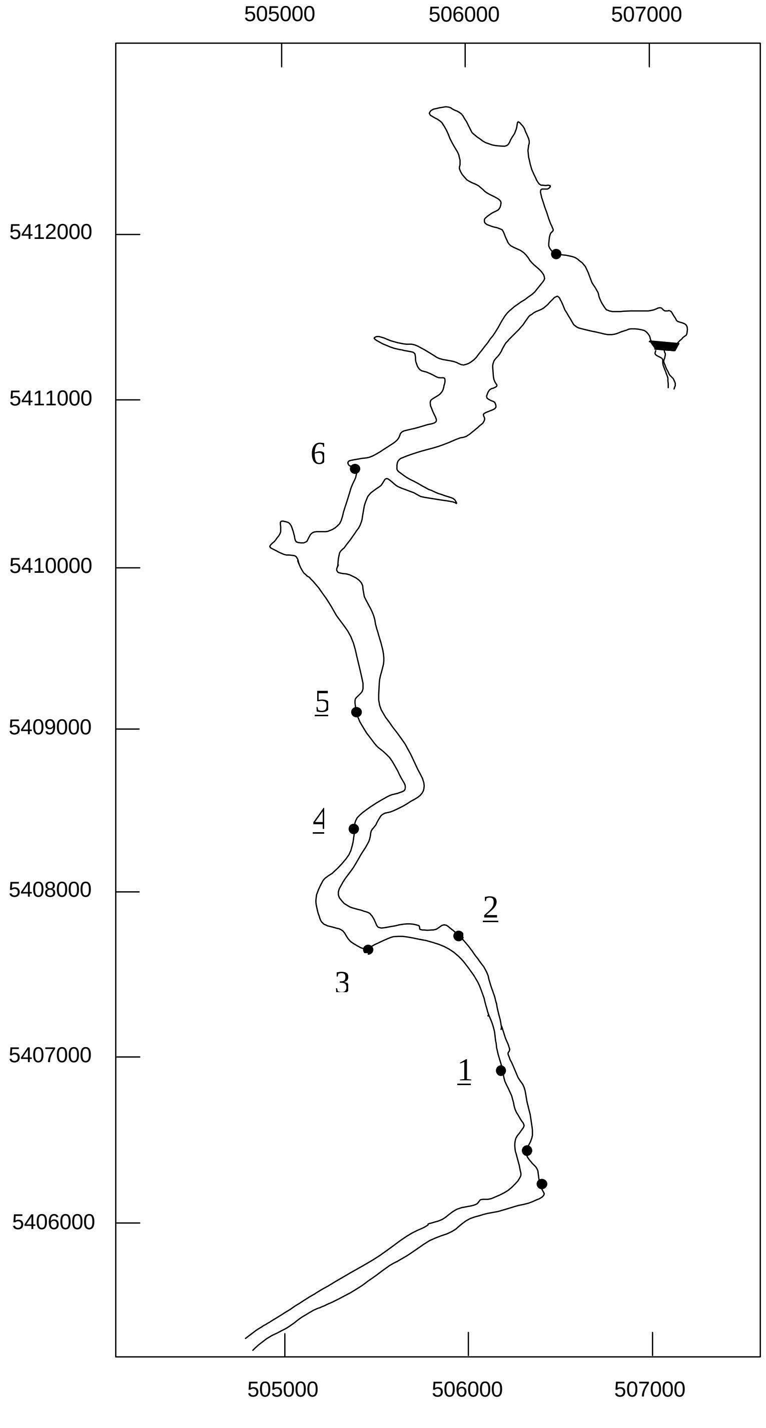


Figure 19: Sites in Lake Trevallyn identified as having potentially suitable habitat for *B. launcestonensis*. Numbers indicate intensively sampled sites. Underlined numbers indicate sites with *B. launcestonensis* present (at very low densities). Solid bar indicates Trevallyn Dam.

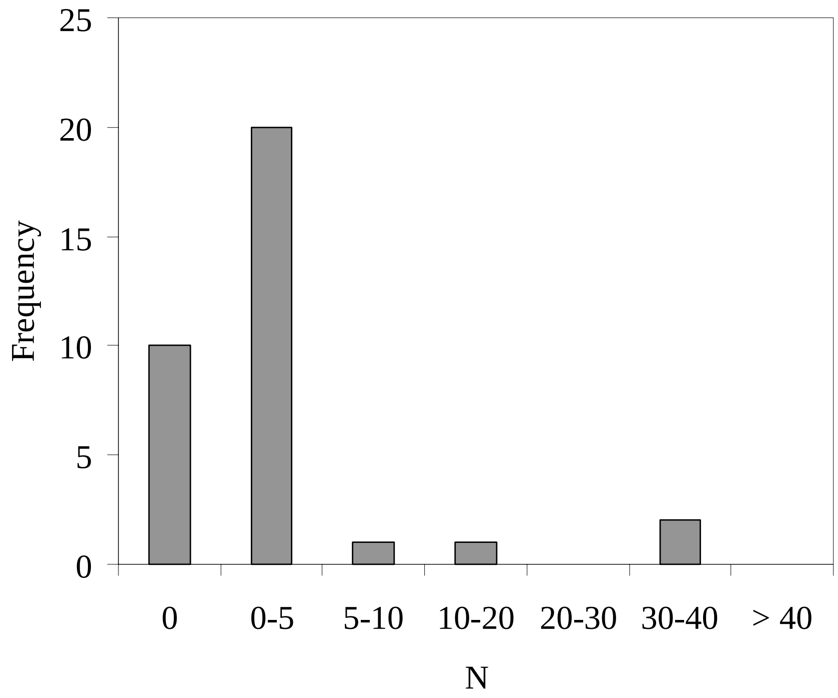


Figure 20: Frequency distribution of *B. launcestonensis* densities (n/boulder) observed on boulder undersides on the 1st Basin shoreline. Boulder dimensions typically 30 - 45 by 20 - 40 cm.

No *B. launcestonensis* were found in the North Esk River at Corra Linn gorge, despite intensive searching. The presence of dense populations of austropyrgid snails, ancylid limpets and abundant (but not eutrophic) epiphytic algae, combined with the generally good ecological condition of this gorge (as indicated by macroinvertebrate community composition), indicates that the absence of *B. launcestonensis* is unlikely to be due to poor environmental conditions.

No *B. launcestonensis* were found in the lower reach of the South Esk River above where it enters Lake Trevallyn. In this reach, few locations were found which had suitable 'cryptic' habitat features.

B. launcestonensis was observed at a number of locations associated with large boulders along the shoreline of Lake Trevallyn, although at very low densities. Only 8 *B. launcestonensis* were observed despite searching six locations on the lake shoreline between the inflow of the South Esk River and the dam (see Figure 4). Sites 5 and 6 were characterised by high densities of *Potamopyrgus antipodarum*. All sites were rocky, with sites 3 and 5 having a superficial silt layer.

Status and Habitat Preferences

This survey confirmed that *B. launcestonensis* is a highly local endemic snail found only in the lower South Esk River in Lake Trevallyn (at very low densities) and in Cataract Gorge. Searches of similar gorge habitats in the neighbouring North Esk River failed to reveal the presence of *B. launcestonensis,* and none were found in the South Esk River upstream of Lake Trevallyn.

The species is sympatric with a dense and diverse community of native and exotic freshwater snails. Very to extremely high densities of austropyrgid snails were evident throughout Cataract Gorge (up to 1100/m^2 on some boulder surfaces), the identities of which are yet to be confirmed (the taxonomy of the autropyrgids is currently under review). In addition, a further five snail species were identified within the gorge:

- the introduced hydrobiid *Potamopyrgus antipodarum*;
- three species of planorbid snails – *Gyraulus tasmanica*, *Physastra gibbosa* and *Isidorella hainesii*; and
- the ancylid limpet *Ferrissia petterdi* and the lymnaeid *Austropeplea tomentosa*.

The high densities of these snails, especially of the planorbids, *A. tomentosa* and *P. antipodarum*, are considered indicative of a severely disturbed riverine environment. Very high levels of algal production were evident especially in the lower sections of the gorge below Duck reach. Extremely high densities of snails were evident across the First Basin which was characterised by a high density of epiphytic algae, and substantial interstitial deposits of fine organic silt were observed, which on inspection was found to be snail faeces.

High levels of insulation, exacerbated by the consistent low water levels during summer, coupled with warm temperatures (recorded up to 23 °C in January 2002) and enhanced nutrient levels as a result of wastewater treatment plant releases into Dalrymple Creek, appear to be stimulating high levels of algal production and high densities of grazing snails.

Densities of *B. launcestonensis* however are generally low. Most *B. launcestonensis* observed in Cataract Gorge were found on cryptic rock surfaces, typically the underside of boulders and/or on small rocks deep in crevices. These habitats were not associated with high algal density, and were commonly clean and dark brown in colour. *B. launcestonensis* while sympatric with other snail species, shows distinct habitat separation from them, with high densities only occurring when other snails are either absent or at very low densities. This was true of all habitats in which *B. launcestonensis* was found and may be evidence for some level of competitive interaction. It is therefore possible that a biological interaction, tied to the presence of a suitable food resource is controlling the mutual distribution of *B. launcestonensis* and other snail species within suitable habitat patches in Cataract Gorge.

In addition, all habitats in which *B. launcestonensis* is found are similar in their capacity to act as hydraulic refuges under high flow events. A primary control of the distribution and abundance of *B. launcestonensis* within Cataract Gorge therefore appears to be the avail ability of refuges during floods. This hypothesis is supported by:

- the pattern of *B. launcestonensis* density within the First Basin, with high densities occurring at locations with the lowest current velocity and turbulence during floods, provided these locations are not subject to siltation under periods of prolonged low flows (this pattern appears to be mimicked, though at much lower densities, within Lake Trevallyn);
- the distribution of *B. launcestonensis* within scour holes – with high densities only occurring in wide, deep scour holes which are high in the channel profile and thus generally protected from major flushing and turbulence during floods;

- the absence of any *B. launcestonensis* within channel sections which flow at low flows (ie in the absence of spills). These sections would experience the greatest current velocities during floods; and
- the presence of *B. launcestonensis* adjacent to the main channel in the Gorge only in backwaters or under boulders.

Overall, then, it appears that the distribution and abundance of *B. launcestonensis* within Cataract Gorge is firstly determined by the availability of refuges from high flows, provided that these refuges do not suffer from siltation during low flows. Within these habitats, the abundance of *B. launcestonensis* may be limited by interaction/competition with other, highly abundant snails, most of which are 'pollution tolerant' and appear to be favoured by the environmental conditions which predominated under the existing low flow regime.

Habitat preferences for *B. launcestonensis* in terms of water velocity, depth and substrate appear to be as follows:

- water velocity - all *B. launcestonensis* observations were at water velocities <0.1 m/s, and generally close to zero;
- depth - the majority of depths at which *B. launcestonensis* was observed were between 0.5 and 1 m, but with occasional observations up to 2.5 m depth; and
- substrate - all observations of *B. launcestonensis* were on boulders or bedrock. No *B. launcestonensis* were observed on mobile material (cobbles, pebbles, gravel or silt/sand).

B. launcestonensis were prevalent on boulder undersides in crevices or in highly elevated scour holes. It is therefore not possible to completely describe the species' habitat requirements in terms of depth, or substrate alone. Therefore, results of simulation of *B. launcestonensis* habitat availability in Cataract Gorge can only be indicative when using the habitat simulation approach used to derive minimum flows (see earlier section). However, provided these requirements are met, a crude, comparative assessment of flow availability can be made across a range of flows. Habitat preference curves for *B. launcestonensis* derived for habitat simulation are below shown in Figure 21.

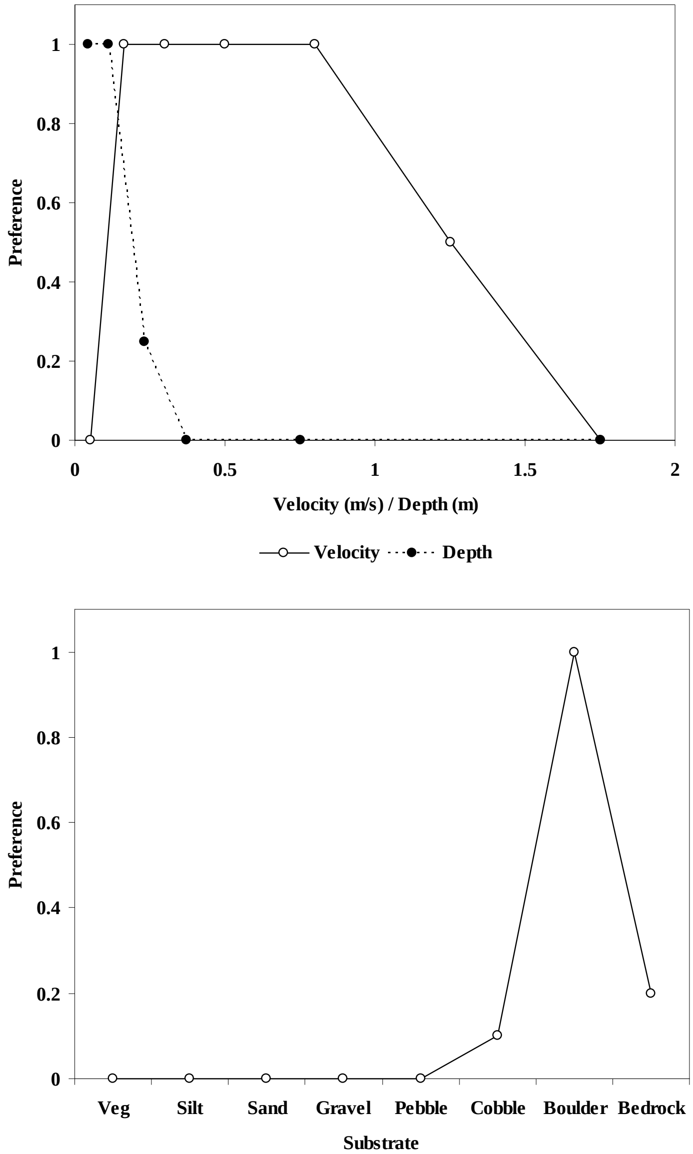


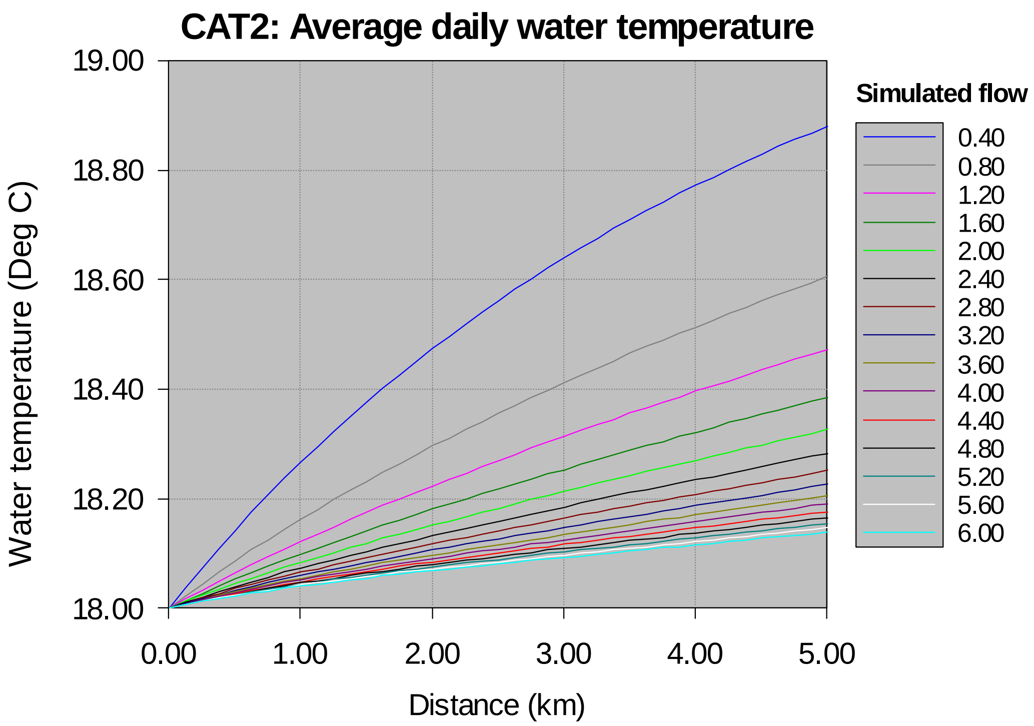
Figure 21: Habitat preference curves used for comparative habitat simulation and risk analysis for derivation of minimum environmental flows in Cataract Gorge (see Davies and Cook 2002).

Temperatures are anticipated to be higher under lower flows. While there are no data on temperature preferences of Australian hydrobiid snails, Beddomeid snails are generally considered to prefer cool, shaded streams and rivers (Ponder *et al.* 1993), and are frequently absent from disturbed, warmer agricultural streams (Ponder unpub data, Davies pers. obs.). Simulation of water temperatures in Cataract Gorge was conducted using the RHYHAB package. Results for a warm, cloudless summer's day, under typical conditions for the Gorge (see below) are shown in Figure 22.

<u>Conditions used for modelling summer water temperatures in Cataract Gorge:</u>
Slope = 0.1
Elevation = 20 m
Mean daily temp = 20
Mean ground temp = 18
Max daily temp = 25
Wind = 0.1
Day length = 14 hr
% sun hours = 98 (0.98)
Solar radiation = 30 J/m^2/sec (value for sunny day on 29/1/02),
Shade = 0.1
Lateral flow = 0
Humidity = 0.75 (Launceston in Jan-Mar at 9am is 0.7 to 0.8).
Inflowing temp (ie release from Trevallyn) = 16 or 18

While the magnitude of temperatures may not be highly accurate, the trend with flow is considered realistic. Flows around 0.4 cumec (the current baseflow) result in a relatively large downstream increases in temperature, which are substantially reduced at flows of about 1.5 cumec and larger.

A



B

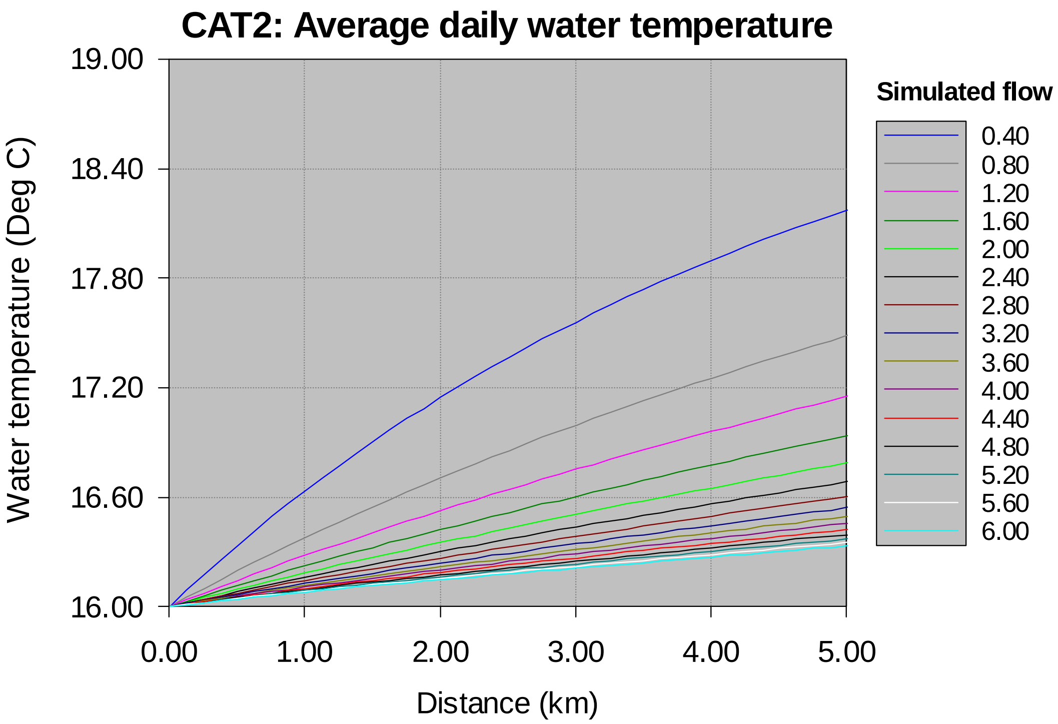


Figure 22: Modelled water temperatures (using the RHYHAB package) in Cataract Gorge, plotted against distance from Trevallyn Dam, at a range of baseflows. A, B = Trevallyn releases of 18, 16 degrees respectively.

Influence of Hydro Developments on B. launcestonensis

Early collections (1880's to 1930's) of *B. launcestonensis* lodged with museums contain large numbers of specimens, and notes associated with them do not suggest that collection was laborious (Ponder *et al*. 1993, Ponder pers. comm.). This may indicate that either *B. launcestonensis* was generally more abundant historically or that it was more widespread within the First Basin than is currently the case (the main site of these collections). This evidence, though circumstantial, does suggest a decline in the status of the species sometime between the 1930s and 1980s. While this may have been caused by the single major change within the Gorge over that time (the construction of the Trevallyn Dam), the competition from more 'tolerant' and exotic snails species cannot be discounted as another major influence on the apparent decline of this species.

The primary changes of interest are:

- the reduction in baseflows from a seasonal range of ca 5-10 cumec in summer and 20-40 cumec in winter, to a flat 0.425 cumec release all year round; and
- a reduction in the frequency and intensity of intermediate sized flood events.

The reduction in baseflows has undoubtedly led to changes in sediment transport, water temperature and habitat availability within Cataract Gorge, and for some may have led to increases in abundance of some 'tolerant' taxa (eg pulmonate snails). In addition, the impacts from low flows have been exacerbated by the organic and nutrient enrichment resulting from the discharge of water into Dalrymple Creek, which enters the river upstream of Duck Reach. This has resulted in a decrease in water quality (see below), particularly in the lower reaches of the Gorge. All of this could be seen to act as additional stressors on the status of the *B. launcestonensis* population. Enhancement of minimum flows within the Gorge has the benefits of both improving habitat availability and improving water quality by dilution. Management actions to reduce wastewater treatment plant discharges into the Gorge environment must also be pursued by local authorities.

The changes in higher flows do not appear to have had any radical impact on the physical environment of the bedrock-controlled Gorge. It is likely that floods >100 cumec influence the status and distribution of *B. launcestonensis* within the Gorge and First Basin. This is based on simulated relationships between near-bed velocities within the Gorge channel, and the discharge at which scour holes are flooded.

It is therefore probable that historical changes in the flood regime are unlikely to have led to a major decline in the status of *B. launcestonensis*. However it will be important to maintain a flood sequence within the Gorge that is not substantially different from that occurring now if further decline of *B. launcestonensis* is to be prevented.

Water Quality Data from the Current Study

Water quality data was collected from 4 locations within Cataract Gorge (see Figure 23) between November 2000 and April 2001 to improve knowledge about the spatial variation in water quality during the summer months. Hydro Tasmania collected the majority of these data with additional data being supplied by the Launceston City Council.

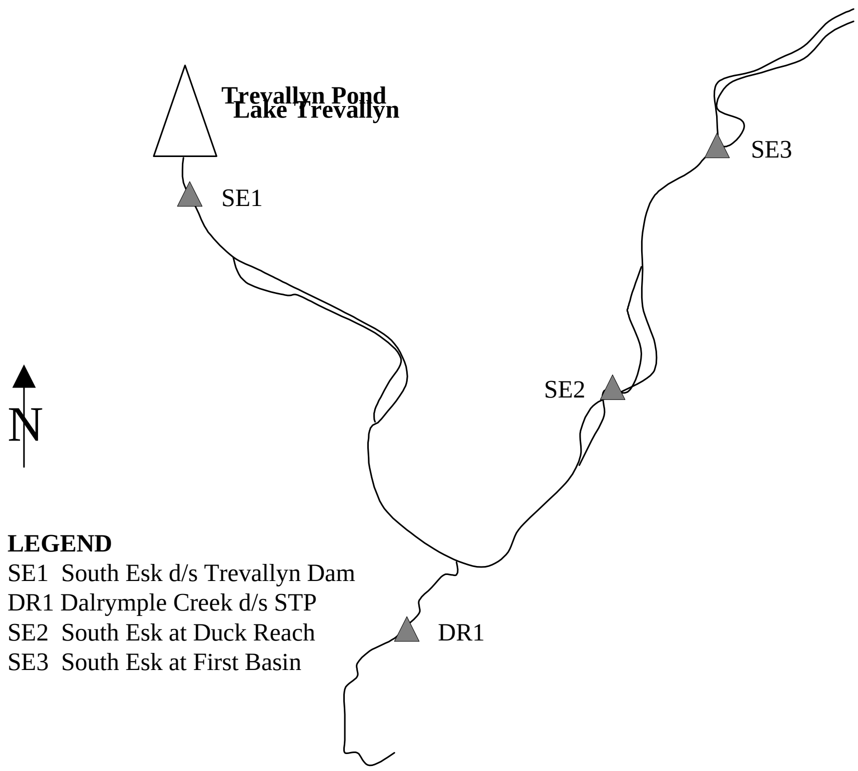


Figure 23: Schematic map showing locations of monitoring sites in Cataract Gorge.

Algal Monitoring

An algal bloom was declared and signs erected on 11th January 2001 warning the public of the health risks associated with contact with water in the Gorge downstream from Duck Reach. Data collected by the Launceston City Council showed that the bloom, which persisted until late March, was composed of two species, *Planktothrix* and *Microcystis*. The former species is classified as potentially toxic, while the latter is generally regarded as a species that always contains harmful toxins. Counts done during the Launceston City Council sampling program showed that the dominant species in Dalrymple Creek (downstream of the sewerage treatment plant ponds where the bloom originated) was *Planktothrix*, peak counts of which exceeded 190,000 cells/mL. This species was the main cause of concern in the South Esk River at Duck Reach, downstream. Peak counts of *Microcystis* in Dalrymple Creek were 86,000 cells/mL, which is also very high.

Dissolved Oxygen

The data on dissolved oxygen at all sites is shown in Figure 24. It clearly demonstrates the impact sewage effluent discharge from Prospect Vale Sewerage Treatment Plant is having on biochemical oxygen demand (BOD) in Dalrymple Creek; with substantially lower oxygen saturation levels than all other sites tested. The primary cause of this is likely to be due to the biological oxygen demand caused by the organic load discharged to the creek. Oxygen levels at sites within the South Esk River are above the range typically found in the lower reaches of larger rivers and indicative of a healthy environment. This is probably due to the gradient and structural characteristics of the river in this area (large boulders and prevalence of riffles and pools), which increase turbulence and aeration potential.

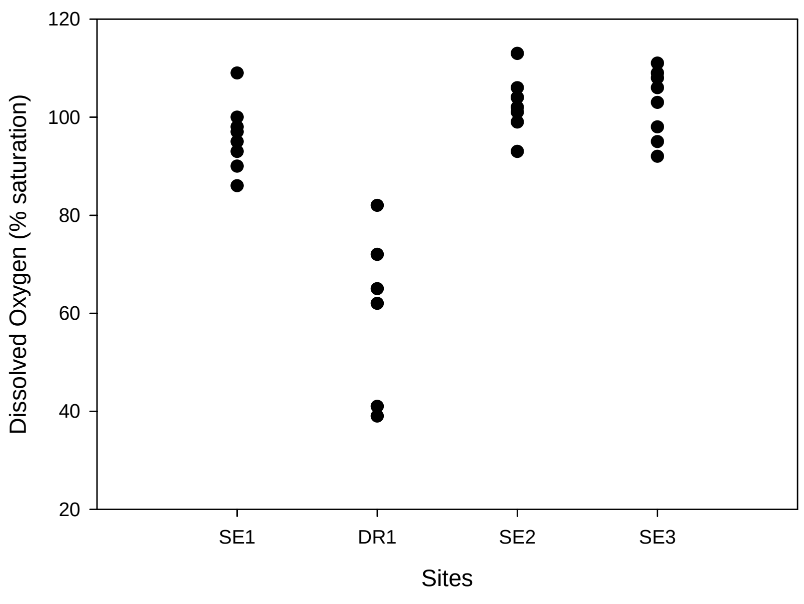


Figure 24: Dissolved oxygen measured at the four monitoring locations within Cataract Gorge. Oxygen levels recorded as percent saturation.

Temporal trends in variation between sites were consistent, with lowest oxygen levels recorded across all sites in February when water temperature was highest and flow was lowest. With the exception of the November and April sampling rounds, dissolved oxygen levels were consistently lowest (by between 10-20 %) at SE1, directly downstream of Trevallyn Dam.

During additional sampling in December 2000, greater diurnal variation in dissolved oxygen was measured at SE2 (Duck Reach), where saturation levels fell from 113 % (measured at midday) to 93 % (measured at 5 am following day). In comparison, levels of oxygen saturation measured at SE1 were 95 % and 98 % respectively. These are much more stable and indicate the influence of Trevallyn Pond on oxygen levels in the river downstream of the dam.

Field pH

Environmental pH can be quite variable, depending on the nature of land use impacts and instream environmental characteristics such as the growth of algae. In Cataract Gorge, pH was found to be most variable at sites in the South Esk River downstream of Dalrymple Creek (see Figure 25). Unlike SE1, both of the lower South Esk sites showed evidence of prolific algal growth during the late summer and autumn seasons. The very high pH reading at SE2 (Duck Reach) was taken during the December visit and may have been linked to the extensive cover of filamentous algae at this site at the time. It is interesting to note that a visit to the site very early the following morning showed that the pH and dissolved oxygen had fallen significantly (8.8 - 7.45 and 113 % - 93 % respectively) in line with respiratory consumption of oxygen by algae at night. It is likely that a substantial standing crop of filamentous and planktonic algae in the First Basin (SE3) is responsible for the variation in pH at that location.

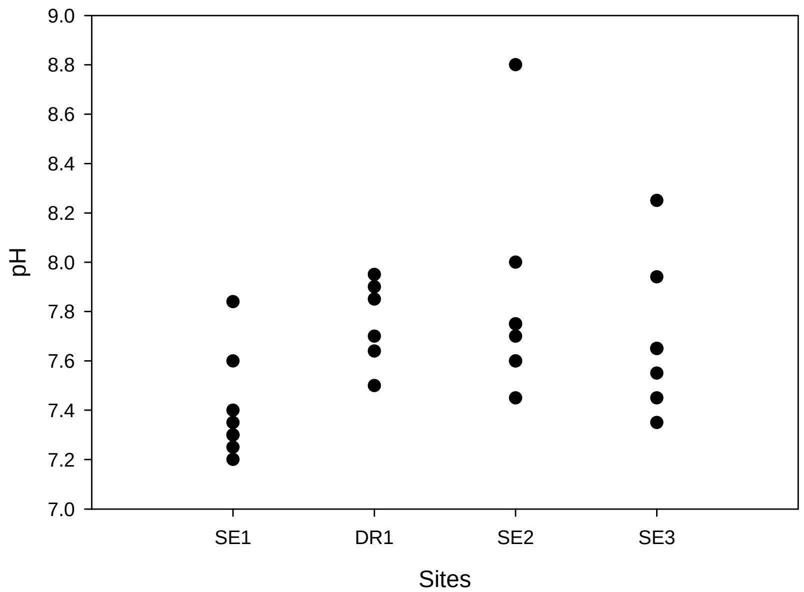


Figure 25: Field pH measured at the four monitoring locations within Cataract Gorge.

Nutrients

The results of sampling for nutrients in the Gorge during the current study clearly show that Dalrymple Creek is much more degraded than the South Esk River. For all the major parameters, concentrations in Dalrymple Creek are an order of magnitude or more higher than are found in the South Esk River downstream of Trevallyn Dam (see Figure 26 and Figure 27).

Despite the potential for dilution of inflows by discharge from the riparian valve from Trevallyn Dam, the input from Dalrymple Creek has a statistically significant (*t-test* of means; P<0.005) impact on nutrient concentrations in the South Esk River downstream (SE2 and SE3) under normal baseflow conditions. During periods when the dam is on spill (9/11/2000 sampling trip), water quality at all South Esk River sites is similar and there is no evidence of impact from Dalrymple Creek. The range of total phosphorus concentrations at sites in the South Esk River downstream from the junction with Dalrymple Creek are within the upper range of concentrations found in similar lowland rivers in Tasmania (DPIWE WQ Database) and are well in excess of the recently revised trigger concentrations for rivers in Tasmania as published in ANZECC (2000).

Faecal Coliforms

Monitoring of bacteria during this program also clearly illustrates the impact of Dalrymple Creek on water quality in the South Esk River downstream (see Figure 28). The concentration of faecal bacteria in Dalrymple Creek was consistently elevated during the entire summer and on two occasions appeared to have a definite impact on bacterial concentrations in Duck Reach, immediately downstream. In comparison, bacterial concentrations in the South Esk River directly below Trevallyn Dam were consistently low.

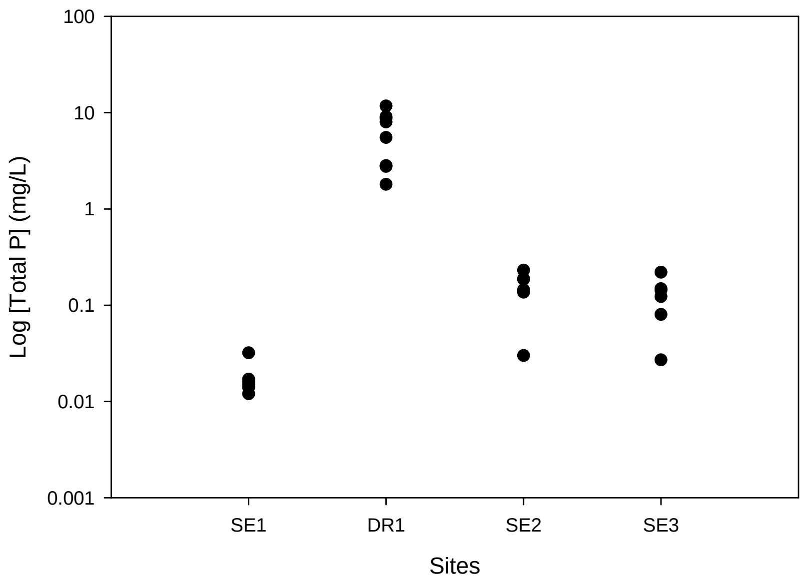


Figure 26: Total phosphorus concentration as measured at sites within Cataract Gorge (Note: log scale of y-axis).

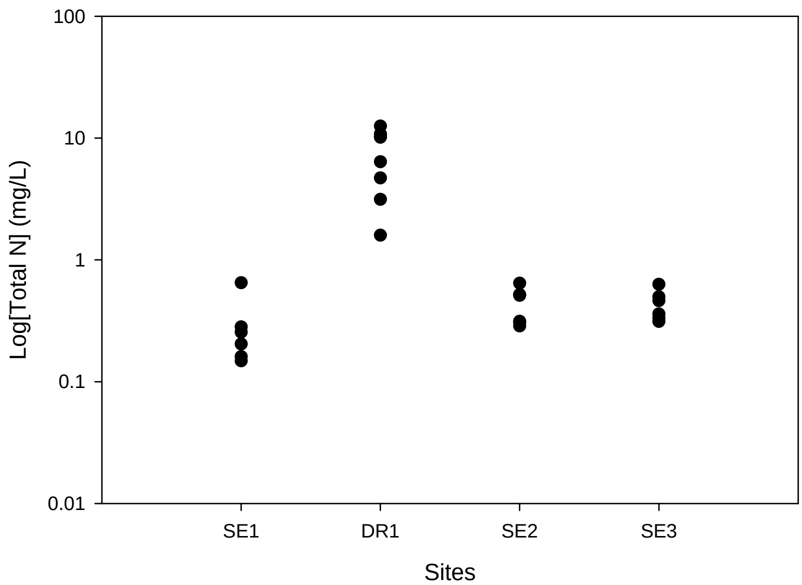


Figure 27: Total nitrogen concentration as measured at sites within Cataract Gorge (Note: log scale of y-axis).

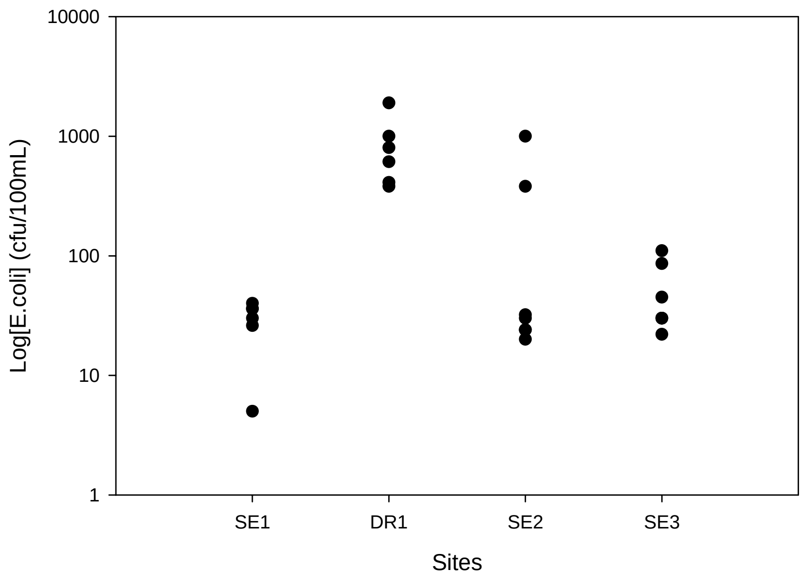


Figure 28: Faecal coliform concentrations as at sites within Cataract Gorge. Data is for the summer period only and has been supplied by the Launceston City Council (Note: log scale of y-axis).

The data from monitoring conducted during this study confirms the conclusions made from previous historical data and provides conclusive evidence that water quality deterioration within the lower reaches of Cataract Gorge during the summer months is caused by discharge of sewage effluent into Dalrymple Creek. During normal summer flows in the Gorge, the nutrients and faecal bacteria entering the South Esk River from this source are clearly having some impact, especially in the area of Duck Reach (located about 1 km downstream). Faecal bacteria and toxic blue-green algae originating from Dalrymple Creek are causing public health risks to users of the South Esk River downstream during the summer months. Nutrient enrichment from this creek is also likely to be a factor contributing to the prolific growth of filamentous green algae in the South Esk River, although the removal of flushing flows from the river by Trevallyn Dam and insufficient flow release from the dam for dilution also contributes to this problem.

4. Environmental Management Options for Cataract Gorge

Instream Biota

There is evidence to indicate that the poor aquatic health of aquatic biota in Cataract Gorge is related to the major reduction in discharge associated with the establishment and ongoing use of Trevallyn Dam. This includes the decline in status of the endemic snail, *Beddomeia launcestonensis*, and while nutrient pollution from Dalrymple Creek is also likely to be having some impact on the health of the aquatic community, an increased flow release from Trevallyn Dam should be initiated to sustain the population of this and other aquatic species in the Gorge in the long term.

Options include:

- reduce or remove excessive nutrient inputs from the Prospect Vale Wastewater Treatment Plan (an issue for Meander Valley Council and the Launceston City Council); and
- increase baseflow discharge from Trevallyn to improve water quality (dilution of contaminant input and reduced temperatures) and increase habitat area for aquatic biota in Cataract Gorge.

Minimum Environmental Flows

The habitat-flow analysis conducted here indicates that the existing 0.43 cumec flow is insufficient to maintain sufficient habitat area for many taxa. Recreational use of the Gorge, especially the First Basin is intense, and is accompanied during the summer and autumn by a high level of bathing activity. It is important that a minimum environmental flow, which optimises habitat conditions for instream biota also ensures that recreational values and safety are not compromised.

Table 11 illustrates the flow ranges that produce varying levels of risk for both instream biota and recreational use (bathing). The green highlights a flow range (ca 1.5 to 3 cumec), which reduces risks for instream biota to a moderate level while maintaining low risk for bathing in the First Basin and in at least 33 – 50 % of the Gorge. A new minimum environmental flow should fall within this range.

Options include:

- retain current level of baseflow discharge from Trevallyn Dam;
- increase level of discharge from Trevallyn Dam to 1.5 cumec to provide additional habitat for aquatic biota while not impinging on recreational users (bathers); and
- increase level of discharge from Trevallyn Dam to 3.0 cumec to provide optimum habitat area for aquatic biota and dilution of contaminant input from Dalrymple Creek, but elevated risk to bathers in Cataract Gorge.

	Q :	5.1	4.6	4.1	3.6	3.1	2.6	2.1	1.6	1.1	0.6	0.4	0.1
Biological													
Overall Risk		**Low to Moderate**					**Moderate**			**High to Severe**			
Recreational - swimming/paddling													
1st Basin	% of area												
	Approx. all	**Low to Moderate**				**Low**							
	75%	**Low**											
Gorge	% of area												
	Approx. all	**Moderate to High**											**Low**
	75%	**Moderate to High**										**Low**	
	50%	**Moderate to High**							**Low**				
	33% or less	**Low**											

Table 11: Flow ranges for instream biota and bathing in Cataract Gorge (Gorge and 1st Basin shown separately) at different risk levels. Flow ranges for bathing risk are shown separately for different proportions of the Gorge area. Yellow and green highlights represent current baseflow and recommended trade-off environmental flow range.

High/Flood Flows

Evidence has been presented that a substantial flood regime is still maintained within the Gorge environment. In addition, the instream fauna has adapted to the regulated flood regime. It is recommended that no major change to flood (spill) flow management at Trevallyn Dam, or the relative magnitude and frequency of spills, should occur, especially as the status and distribution of *Beddomeia launcestonensis* may be closely tied to the existing flood regime.

Any future changes to the configuration of Trevallyn Dam, and associated structures, as well as to the magnitude of off-takes for the Trevallyn power station should consider potential risks to downstream values associated with any changes to the pattern of spills and flood response.

Studies to further enhance environmental values in the Gorge might also consider the potential for managing spills using ramping techniques as flood levels recede order to further reduce impacts on instream biota.

Beddomeia launcestonensis

A number of management actions are need in order to provide ongoing protection for *Beddomeia launcestonensis*, and these fall in the area of flow, water quality and physical management. Some further research should be done to clarify the basic hypotheses that are proposed concerning the distribution and presence of competitive interactions with other snail species.

Options include:

- increase the minimum environmental flow in order to improve habitat availability along channel margins, reduce possible stress to the snail species caused by high temperature, and reduce threats posed by water quality;
- remove all nutrient inputs to Cataract Gorge so as to minimise the potential for prolific growth of filamentous algae, which appears to favour other aquatic snail species;

- pursue opportunities for local population enhancement; particularly through local translocation within areas rich in scour holes; and
- sponsor university scholarship to investigate the influence other snail species may be having on restricting the abundance of *Beddomeia launcestonensis*.

Summary

An increased release of flow from Trevallyn Dam is likely to have a multitude of benefits, both environmental and social. An increase in water levels throughout the reach of the river downstream of Trevallyn Dam will result in increased habitat area for aquatic biota, and should in turn result in increased abundance and numbers of taxa. Through increased dilution, water quality should improve and the risk of algal blooms (of both nuisance filamentous and potentially toxic blue-green algae) should be less. There would also be obvious benefits in terms of recreational use and aesthetics, particularly in the narrower sections of the Gorge.

The magnitude of these benefits is dependent on the magnitude of the increase in discharge, however while greatest environmental and aesthetic benefits might be gained from releasing larger volumes of water, increasing the risk of high water velocity in areas frequented for swimming and bathing during the summer months must be avoided. This being the case, a minimum environmental flow of 1.5 cumec would appear to be most appropriate.

Regardless of what volume of water is released, it is also important that biological monitoring to assess the adequacy of this flow is undertaken to ensure that the environmental benefits that are envisaged are in fact achieved.

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