Impact of bulk water transfers in the Cordeaux River, Sydney, on availability of habitat suitable for aquatic fauna

P. E. Bacon*, T. Berryman** and C. Gippel***

*Woodlots & Wetlands Pty Ltd, 67 David Road, Castle Hill, 2154, NSW, Australia (Email: woodlots@optusnet.com.au)
**Sydney Catchment Authority, PO Box 323 Penrith, 2751, NSW, Australia (Email: tim.berryman@sca.nsw.gov.au)
***Fluvial Systems Pty. Ltd, PO Box 49, Stockton, NSW, 2295, Australia (Email: chris.gippel@bigpond.com)

Abstract
The Sydney Catchment Authority (SCA) is a statutory authority established under the *Sydney Water Catchment Management Act 1998*. SCA is responsible for protection and management of Sydney's drinking water catchments and for provision of bulk raw water supply.

The SCA utilises natural stream channels to deliver water to offtake points that lead to online storage and distribution points. Currently the releases are largely determined by urban needs, so the flows are adjusted to balance anticipated demand and to balance the levels in all SCA storages. The combination of long periods of steady flow followed by rapid fluctuation would not occur naturally, and may impact on stream health.

This study quantified physical changes in the Cordeaux River with change in flow. Stream velocity, depth and substrate were measured at 6 transects over a 5 km reach of river below Cordeaux Dam. Transects were undertaken when the dam discharge was 4, 54, 104 and 304 ML/day.

Flow variation between 54 and 304 ML/day had little effect on availability of preferred habitat for either macro-invertebrate diversity or platypus activity. It was concluded that as far as practical, flows should be maintained in this range during the critical breeding period of mid-spring to mid-summer.

Keywords

PHABSIM; platypus, aquatic macroinvertebrates, regulated flow, physical habitat

INTRODUCTION
The Sydney Catchment Authority (SCA) is a statutory authority established under the *Sydney Water Catchment Management Act 1998*. The primary tasks for the SCA are the protection and management of Sydney's drinking water catchments and to provide a bulk raw water supply to its customers.

Water stored in Cordeaux Dam is released into the natural river course below the dam. The water proceeds for some 18 km to Pheasants Nest Weir. An offtake at the weir enables a maximum of 380 ML/day to be diverted into a Sydney water supply tunnel.

Bulk water discharge rates from Cordeaux Dam are adjusted to balance anticipated demand and supply, and to balance the levels in all SCA storages. Flow rates are sometimes kept constant for several months then changed significantly over a few minutes. This combination of long periods of steady flow followed by rapid fluctuation would not occur naturally, and may impact on stream health.

As a result of recognising these possible impacts, the SCA undertook a study to assess the environmental effects of using natural river courses to convey bulk water. An important component of the impact assessment was a detailed study of four regulated flows on the Cordeaux River and their influence on in-stream physical conditions. Change in physical conditions may then be related to habitat suitability for a variety of stream biota.

The concept that physical conditions in streams could be used to assess potential habitat has been developed considerably over the past 30 years (eg Bovee, 1982, USGS, 2001). In recent times Physical Habitat Simulation Systems have been used to describe functional relationships between flow and stream habitat availability for a wide range of aquatic attributes (USGS, 2001).

Originally these simulation systems were largely concerned with habitat availability for different life stages of fish (see for example, Nehring and Anderson, 1993). More recently the approach has been used to quantify habitat for a wider variety of stream biota, including platypus (*Ornithorhychus anaticus*), macro invertebrates, fish and flora (Grant and Bishop, 1998, Davies and Cook, 2001).

The physical habitat modelling approach has been criticised for its inability to provide strong correlation between habitat availability and biological abundance (Pusey, 1998). The correlation is especially difficult to establish for mobile, shy species such as fish (Scott and Shirvell, 1987) and platypus (Serena et al, 2001). Additionally there is currently insufficient evidence to allow for interaction between attributes such as depth and velocity (Growns, 1998).

King and Tharme (1994) suggest the habitat availability scores be expressed as habitat suitability, rather than habitat availability. This is similar to the concepts of probability of use (Richardson, 1986) or habitat preference (Arthington, et al, 1992). In the current paper we have used the term ‘preference’ to emphasise the gradational rather than abrupt change in habitat that occurs with change in flow rates.

SITE CONDITIONS AND METHODOLOGY

Cordeaux River

The Cordeaux River arises on the western side of the Illawarra Escarpment, approximately 70 km south of Sydney, NSW Australia. It passes through a confined valley prior to entering the main Cordeaux Dam. The dam is an effective sediment trap and the erosion rate of the sandstone is less than the transport ability of the river, so there is relatively little sediment accumulation. The river enters sandstone gorges below the dam. In this reach the river consists of a series of rock steps, cascades and rapids and elongated pools. Some 62% of the Cordeaux River length consisted of pools. The average distance between the pools was 100 m, while average pool length was 192 m.

Flow rate selection

SCA has a requirement to release 4 ML/day as an environmental flow. This water is discharged from a fixed outlet. Other flows can be adjusted to approximately suit demand. Examination of discharge information indicated over 90% of daily flow rates varied between 50 and 300 ML/day. The 300 ML/day was similar to the highest non-flood discharge rate, so it was therefore selected as the highest flow used in this study. Physical habitat was also measured at flows of 4, 54, and 104 ML/day. These flows reflect typical regulated discharge rates. The measurements were undertaken following a least a week of constant discharge. No rain occurred during this period.

Transect selection

Six transects were initially selected for assessment of change in physical habitat with change in flow rate. However Transect 3, which consisted of a bare sloping rock step, had extremely turbulent flow when discharge exceeded 100 ML/day. This made the site unsafe for sampling so it was eliminated from further investigation.

The other five sites had the range of macro habitats typical of those found in this stretch of the river, with three transects being across pools and two being across riffles and glides.

Field measurements

Water depth and average velocity was measured at 1m intervals across each transect and each sampling time (USGS, 2001). The substrate was also sampled and assessed at one metre intervals.

Aquatic macroinvertebrate habitat preference

Growns (1998) reviewed use of habitat preference curves to determine the habitat availability for macro invertebrates. He emphasised the need to carefully consider the limitations of the system, especially the level of local knowledge concerning interaction between biota and habitat. However, Growns (1998) conceded that the curves could be used to form a generalised relationship between changes in habitat with change in discharge.

In this study of the Cordeaux River, the preference curves of Davies and Cook (2001) were used to identify relative changes in habitat conditions with change in flow. The approach uses the number of macro-invertebrate taxa as the measure of habitat. This avoids specifying conditions for specific biota to the potential detriment of non-target species. The curves of Davies and Cook (2001) were derived from sampling of Tasmanian rivers. These are typically 2 - 3°C cooler than the Cordeaux River, so the suite of species may be different (Growns, 1998). Table 1 shows the weighting scores used for total number of macro-invertebrate taxa.

Platypus habitat preferences

Grant and Bishop (1998) reviewed the in-stream habitat preferences of platypus. More recently, Davies and Cook (2001) summarised platypus habitat preferences as:

- Preferable depth for feeding is <2 m;
- Platypus will swim and feed in currents of 0 to 0.5 m/sec;

- Currents >1 m/sec are unsuitable;
- Platypus actively feed in substrates composed of coarse organic matter, silt, sand, and pebbles. Occasional feeding occurs in coarse gravels, but rarely among boulders or on bedrock, and;
- Riffles are important for macro-invertebrate food sources.

Pools and habitat diversity are important. Serena et al (2001) concluded that platypus especially favoured undercut banks and large woody debris (LWD). Grant (2002) commented on the need for earth banks suitable for burrowing. He also emphasised the need for maintaining suitable habitat for benthic invertebrates, the main food source for platypus.

In this study of the Cordeaux River the habitat preference curves shown in Davies and Cook (2001) were slightly modified to include information from Grant and Bishop (1998) and Serena et al (2001) to assess relative change in habitat suitability for platypus with change in discharge rate.

Table 1: Habitat preference weighting scores for total number of taxa of macro invertebrates. (From Davies and Cook, 2001).

Depth (m)	*Preference score*	*Mean velocity of the water column (m/sec)*	*Preference score*	*Substrate on base of river*	*Preference score*
0.1	0.75	0.05	0.8	Silt	0.52
0.2	0.9	0.1	0.87	Sand	0.94
0.3	0.97	0.2	0.96	Gravel	0.81
0.4	1	0.3	1	Pebble	0.8
0.5	1	0.4	0.98	Cobble	0.91
0.6	1	0.5	0.9	Boulder	0.95
0.7	1	0.6	0.81	Rock	0.6
0.8	0.99	0.7	0.74		
0.9	0.98	0.8	0.67		
1	0.97	0.9	0.62		
1.1	0.96	1	0.64		
1.2	0.95	1.1	0.67		
1.3	0.94	1.2	0.69		
1.4	0.93	1.3	0.71		
1.5	0.92	1.4	0.75		
1.6	0.88	1.5	0.75		
1.7	0.85	1.6	0.75		
1.8	0.82	1.7	0.72		
1.9	0.79				
2	0.75				
2.1	0.72				
2.2	0.69				
2.3	0.66				

Table 2. Habitat preference weighting scores for platypus (Derived from Davies and Cook, 2001, Grant and Bishop, 1998 and Serena et al, 2001).

Depth (m)	*Preference score*	*Mean velocity of the water column (m/sec)*	*Preference score*	*Substrate on base of river*	*Preference score*
0.1	0.1	0.05	1	Organic Matter	0.6
0.2	0.15	0.1	1	Silt	0.7
0.3	0.3	0.2	1	Sand	0.8
0.4	0.6	0.3	1	Gravel	1
0.5	0.7	0.4	0.8	Pebble	1
0.6	0.75	0.5	0.6	Cobble	1
0.7	0.8	0.6	0.5	Boulder	0.2
0.8	0.85	0.7	0.4	Rock	0.1
0.9	0.9	0.8	0.3	LWD, live vegetation CPOM	1
1	1	0.9	0.2		
1.1	1	1	0.1		
1.2	1	1.1	0.08		
1.3	1	1.2	0.06		
1.4	1	1.3	0.04		
1.5	1	1.4	0.02		
1.6	1	1.5	0		
1.7	1				
1.8	0.95				
1.9	0.92				
2	0.9				
2.1	0.89				
2.2	0.86				
2.3	0.824				
2.4	0.78				
2.5	0.75				
2.6	0.7				
2.7	0.65				
2.8	0.6				
2.9	0.55				
3	0.5				

Preferred habitat availability, expressed as m^2 per m of stream length was based on stream width and stream velocity, depth and substrate at 1 m intervals. The score for each 1 m wide unit was calculated as:

Preferred habitat availability $index_i = (Velocity_i * Depth_i * Substrate_i)^{0.333}$

RESULTS

Macro invertebrates

Table 3 shows that the preferred habitat availability for number of taxa of aquatic macro-invertebrates increases between 4 and 54 ml/day at all transects. This is due to a combination of increased stream width and increased average velocity of the water column. However, there was little change in habitat availability between 54 and 304 ML/day. That is, according to the preferred habitat availability criteria, the total habitat suitability did not change greatly in the typical range of regulated discharge.

Table 3: Change in preferred habitat availability (m^2 per m of river length) for aquatic macro-invertebrate taxa number with change in discharge rates.

Transect	*Type of macro habitat*	*Preferred habitat availability for 4 ML/day*	*Preferred habitat availability 54 ML/day*	*Preferred habitat availability for 104 ML/day*	*Preferred habitat availability for 304 ML/day*
1	Glide	5.3	11.4	13.1	14.3
2	Pool (shallow)	8.3	11.9	12.3	12.5
4	Riffle/run	4.7	6.6	6.5	6.4
5	Pool (near inlet)	10.1	13.1	13.8	12.8
6	Pool (deep)	12.3	12.8	14.3	13.4
Average		8.1	11.2	12.0	11.9

Table 4 shows the habitat availability varied significantly with both transect and the flow. The deep pools had significantly higher habitat availability, while reducing the flow to 4 ML/day significantly reduced the habitat availability.

Table 4: Statistical analyses of change in preferred habitat availability for macro-invertebrates with transect and flow.

Source of Variation	*Sum of Squares*	*Degrees of Freedom*	*Mean Square*	*F value*	*Probability of difference not being real*	*Critical F value*
Transects	125	5	25.0	16.15	1.42E-05	2.90
Flow rates	59	3	19.7	12.72	0.000212	3.29
Error	23.24	15	1.55			

Platypus Habitat

Preferred habitat availability for platypus varied considerably between transects. For example, Table 5 shows transects 2 and 4 have little preferred habitat. This is due to the dominance of bare rock substrate at these locations. Suitable substrate at these two transects was confined to a narrow strip of sand and organic matter near the edge of the stream. The pool transects had more preferred habitat area per metre of stream length. This reflected a combination of deeper water and the presence of organic substrate at these transects. Table 6 shows the differences between habitats are statistically significant.

Table 5: Change in preferred habitat availability (m^2 per m of river length) for platypus with change in discharge rate.

Transect	*Type of macro habitat*	*Preferred habitat availability for 4 ML/day*	*Preferred habitat availability 54 ML/day*	*Preferred habitat availability for 104 ML/day*	*Preferred habitat availability for 304 ML/day*
1	Glide	2.5	9.2	10.9	12.3
2	Pool (shallow)	3.5	5.6	6.3	7.2
4	Riffle/run	2.4	3.3	3.5	3.0
5	Pool (near inlet)	7.1	10.4	11.9	9.4
6	Pool (deep)	6.5	9.2	8.5	10.1
Average		4.4	7.5	8.2	8.4

The impact of changing discharge rates on preferred habitat availability for platypus is also shown in Table 5. Average preferred habitat availability almost doubles between 4 and 54 ML/day. This difference is statistically significant (Table 6). The increase is largely in response to increased water depth. For example at Transect 1 the average depth increased from 0.13 to 0.33 m when the flow was increased from 4 to 54 ML/day. Table 2 shows the habitat preference triples over this increase in depth.

Table 6. Statistical analyses of change in preferred habitat availability for platypus with transect and flow.

Source of Variation	*Sum of Squares*	*Degrees of Freedom*	*Mean Square*	*F value*	*Probability of difference not being real*	*Critical F value*
Transects	120.01	4.00	30.00	11.36	0.000477	3.26
Flow rates	51.86	3.00	17.29	6.55	0.007162	3.49
Error	31.68	12	2.64			

Change in preferred habitat availability with change in flow was greatest in riffle/glide areas and least in pools. For example the preferred habitat availability for transects 1 and 4 across riffles/glides increased from 2.5 to 7.7 m^2/m of stream length as the flow increased from 4 to 304 ML/day. The corresponding preferred habitat availability increase in the pool transects was from 5.7 to 8.9 m^2/m of stream length. The results demonstrate that the shallower portions of the stream are more likely to have marked change in physical habitat suitability with change in flow than do the pools.

There was a small decrease in average preferred habitat availability for platypus when the flow was increased from 104 to 304 ML/day. This was due to higher stream velocities and to increased scouring of the stream base at the higher flow. The scouring removed some sand and organic debris, exposing bare rock. This was most obvious at transect 5 where velocity in the centre of the stream exceeded 1.7 m/sec. That is, the 304 ML/day flow removed some of the organic debris that had accumulated at transect 5 during the lower flows.

DISCUSSION AND CONCLUSIONS

Preferred habitat availability for aquatic macro-invertebrate diversity and platypus activity in the Cordeaux River did not change greatly with discharge over the range 54 to 304 ML/day. This result suggests the current normal operating range of flow in the Cordeaux is not posing an environmental risk to the biota examined in this study. As far as practical, flows should be maintained in this range during the critical breeding period for stream fauna, that is, between mid spring and mid summer.

There was a statistically significant fall in preferred habitat availability between 54 and 4 ML/day. The fall was related to shallowing of the water. Reduction in water depth to below 0.2 m for much of the riffle/run transects markedly reduced habitat suitability, especially for platypus.

Bare rock steps provide poor habitat for platypus: At low flows the water is only a few centimetres deep, while at high flows the velocity exceeds 1 m/sec. It is therefore likely that the platypus largely rely on the pools rather than the rock steps for habitat and food (Grant, 2002). While reduction in flows from 54 ML/day to 4 ML/day reduces pool habitat for both macroinvertebrate diversity and platypus, there is still sufficient pool volume to provide substantial refuge at the lower flow.

There is a possibility of standing immobile species if the discharge rate is adjusted too quickly. Other areas that should be examined include:

1. The impact of constant flows on stream biota;
2. The habitat requirements and preferences of other stream dependant biota, and;
3. Methodology to adjust environmental flows to mimic natural variations;

REFERENCES

Arthington, A. H., King, J. M., O'Keefe, J. H. , Bunn, S. E., Pusey, B. J., Bludhorn, D. R., and Tharme, R. (1992). Development of an holistic approach for assessing environmental flow requirements of riverine ecosystems. IN: *Proceedings of an International Seminar and Workshop on Water Allocation for the Environment*. J. J. Pigram and B. P. Hooper (eds), Centre for Water Policy Research, Armidale, NSW Australia.

Bovee, K. D. (1982). *A guide to stream habitat analysis using the instream flow assessment methodology*. US Fish and Wildlife Serv. FWS/OBS-82/26. 248 pp.

Davies, P. E., and Cook, L.S.J. (2001). Appendix 7: Gordon River macroinvertebrate and aquatic mammal assessment. Basslink Integrated Impact Assessment Statement-Potential Effects of Changes to Hydro Electric Generation. Hydro Tasmania Hobart, Tas.

Grant, T. R. (2002). Platypus studies in the Wingecarribee River and Glenquarry-Doudles Folly Creek-Nepean River System-Monitoring. April-May 2002. Final Report to SCA. 33 pp.

Grant, T. R., and Bishop, K. A. (1998) In-stream Flow Requirements for the Platypus (*Ornithorhychus anaticus*): A Review. *Australian Mammalogy* 20: 267-280.

Growns, I.O. (1998). Methods addressing the flow requirements of macroinvertebrates. Chapter 6. IN *Comparative Evaluation of Environmental Flow Assessment Techniques: Review of Methods*. A.H. Arthington and J.M. Zalucki. (eds.), Land and Water Res and Dev. Corp. Occasional Paper 27/98 pp. 115-140.

Nehring, R. G., and Anderson, R. M. (1993). Determination of population-limiting critical salmonid habitats in Colorado streams using the physical habitat simulation system. *Rivers* 4 (1): 1-19.

Pusey, B. J. (1998). Methods addressing the Flow Requirements of Fish. IN C*omparative evaluation of environmental flow assessment techniques: review of methods*. Land and Water Res and Dev. Corp. Occasional Paper Series 27/98. pp. 66-105.

Richardson, B. A. (1986). Evaluation of instream methodologies for freshwater fish in New South Wales. In: S*tream protection. The management of rivers for instream uses.* I. C. Campbell (ed.), Water Studies Centre, Chisholm Institute of Technology, East Caulfield, Victoria.

Scott, D., and Shirvell, C.S. (1987). A critique of the Instream Flow incremental Methodology and observations of flow determination in New Zealand. In: *Regulated Streams: Advances in Ecology*, J. F. Craig and J. B. Kemper (eds.), Plenum Press, New York, pp. 27-43.

Serena, M., Swinnerton, M., Worley, M., and Williams, G. A. (2001). Attributes of Preferred Foraging Habitats of Platypus (*Ornithorhynchus anatinus).* In *Third Aust. Stream Management Conf*. I Rutherfurd, F. Sheldon, G. Brierley and C. Kenyon. (eds.), Brisbane Qld. 27-29 Aug 2001 pp. 565-570.

USGS (2001). *PHABSIM for Windows*. Report 01-340. 288 pp. Mid-continent Ecological Science Center. US Dept Interior US Geological survey.