National River Health Program - Environmental Flows

Impacts of hydrological disturbance on stream communities.

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Abstract

The tendency for lotic research to focus on particular rivers has made it difficult to extrapolate findings from one river to another or to develop the predictive models of ecosystem structure and functioning that ecologists and managers crave. For Australian rivers, the problem is exacerbated by the distinctively wide range of different flow regimes found. We investigated how flow-generated disturbance affects benthic communities in 10 rivers with contrasting flow regimes. From a classification of south-eastern Australian rivers, we identified rivers with "constant" flow regimes and rivers with "highly variable" flows. At 3 sites on each river we used portable in-stream weirs to examine the resistance of benthic invertebrates to a 48 hour period of both a 300% increase and a 70% decrease in discharge. The 48 hour period of increased flow significantly reduced species richness changed community structure as densities of Chironomids declined while Simuliids increased. The reduced flow treatment had little impact over 48 hours, and also after the experiments were maintained for 8 days. The observed patterns of invertebrate resistance to hydrological disturbance were broadly consistent across rivers, regardless of hydrological classification, suggesting our results may apply under a broad range of conditions and be of general value to the management of isolated flow releases and flow stoppages.

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Project Title: Impacts of hydrological disturbance on stream communities
Principal Investigators: Dr S Brooks & Dr PS Lake
Project Duration: 1/7/1994 - 31/5/1998
Due Date for Final Report: 31/8/1998
Original Project Objectives:

1. We will assess how artificially imposed flow variation structures invertebrate communities which have evolved under different natural disturbance regimes.
2. We will test the hypothesis that *interactions between the hydrological regime and substratum stability determine the impacts of hydrological disturbance on stream communities.*
3. We will construct an empirical model that predicts the resistance of stream communities to disturbance by increased and decreased discharge based on hydrological and geomorphological variables. This model will then be independently tested to assess it's value as tool for water resource managers and water authorities at a national level.
4. We will identify taxa which are sensitive to flow variation for potential use as bio-indicators of hydrologically disturbed systems.

Introduction

There is little doubt that natural hydrographic patterns are substantially altered by human activity in river catchments. River regulation for town water supply, irrigation and power generation often replace the natural flow regime of protracted high amplitude fluctuations (floods and drought), with rapid fluctuations of smaller amplitude as river flow is managed for the supply and demand of human use (Walker *et al.* 1992).

The study of impacts of short-term hydrological variability on benthic invertebrate communities world wide has been dominated by “one off” studies characterised by poor experimental design and poor provision of the basic data required to synthesise results into a general framework for management (e.g. Radford and Hartland-Rowe 1971, Blythe *et al.* 1984, Gaschignard and Berly 1987, McEvoy *et al.* 1993). These deficiencies hamper the development of general theories and the generation of reliable predictions. Our knowledge is gleaned almost exclusively from studies conducted in North America and Europe and no studies designed to test hypotheses targeting short-term flow variability have been conducted in Australia. While it is understandable that most ecological studies focus on particular streams, this level of research focus has made it difficult to extrapolate findings from one stream to another or to develop predictive models of ecosystem structure and functioning. This problem is particularly acute in Australia where flow regimes are distinctively variable when compared with the rest of the world.

We aimed to derive an understanding of how flow generated disturbance affects invertebrate assemblages in streams with contrasting flow regimes, to obtain <u>general</u> results that can be used by water managers and regulatory authorities that have a broader focus than a single river. We focused on patterns of invertebrate resistance to experimental increases and decreases in flow. Recovery from disturbance (resilience) was beyond the scope of this project because our experiments were conducted at a limited spatial scale, leaving artificially high numbers of potential colonists when compared to natural, whole stream channel disturbances. Our experimental treatments were designed to mimic the hydrological variability associated with irrigation pumping cycles, hydroelectric power (esp. hydropeaking), inter-basin transfers and flushing flows released from dams for environmental maintenance of the channel.

Methods

Analysis of Hydrological Data and Selection of Study Rivers

Flow data were obtained for all stream gauging sites in Victoria, NSW and the ACT. These data were made available through collaboration from the NSW Dept. Water Resources, Cooperative Research Centre for Catchment Hydrology and Victorian Rural Water Corporation. Data were filtered to eliminate sites with poor records (<20 years), highly disturbed catchments, and also those sites where the river is not of a size appropriate to the experimental flow manipulations (mean daily flow Jan-Apr > 50 Ml.day^{-1}, mean daily flow over 20 years < 1500 Ml.day^{-1}) leaving 145 rivers for analysis. Hydrological Flow regime descriptors were calculated for each river over a range of temporal scales (Table 1).

Table 1. Flow regime descriptors calculated from 20 year series of mean daily discharge. Parameters with the temporal scales in parentheses were calculated for inclusion into later modelling efforts, but were not used for the selection of study rivers.

General Indices		**Temporal Scale**
Mean Daily Flow		Daily, Monthly, (Annual)
Standard error of Mean Daily Flow		Daily, Monthly, (Annual)
Coefficient of Variation:		Daily, Monthly, (Annual)
Coefficient of Skewness:		Daily, Monthly, (Annual)
Autocorrelation:		Daily, Monthly, (Annual)
Colwell's Predictability Indices:	Constancy	Monthly
	Contingency	Monthly
Total Base Flow Index (BFI)		20 years
HIGH FLOW INDICES		
Spell Duration Index for high flows		Summer, Winter, (Annual)
Slope of Rising Hydrographs		(Summer), (Winter), Annual
Recedence coefficient of falling hydrograph		(Summer), (Winter), Annual
LOW FLOW INDICES		
Spell Duration Index for low flows		Summer, Winter, (Annual)
Recedence coefficient of falling hydrograph		(Summer), (Winter), Annual
Slope of Rising Hydrographs		(Summer), (Winter), Annual

An ordination was performed on the hydrological parameters (Table 1) for 145 rivers using non-metric multidimensional scaling (NMDS) (Figure 1). Correlating each of the calculated hydrological parameters with the axis scores obtained in the NMDS for each river indicated that the ordination is primarily driven by patterns of flow variability. Rivers with low scores on axis 1 have consistent flows between days and months with a high base flow component. Rivers scoring highly on axis 1 have highly variable flows between days and months, a low base flow component, and rise and fall rapidly during floods. Five study rivers were randomly chosen from each end of this flow variability spectrum for our examination of the impact of hydrological disturbances in rivers with contrasting natural discharge regimes (Figure 1).

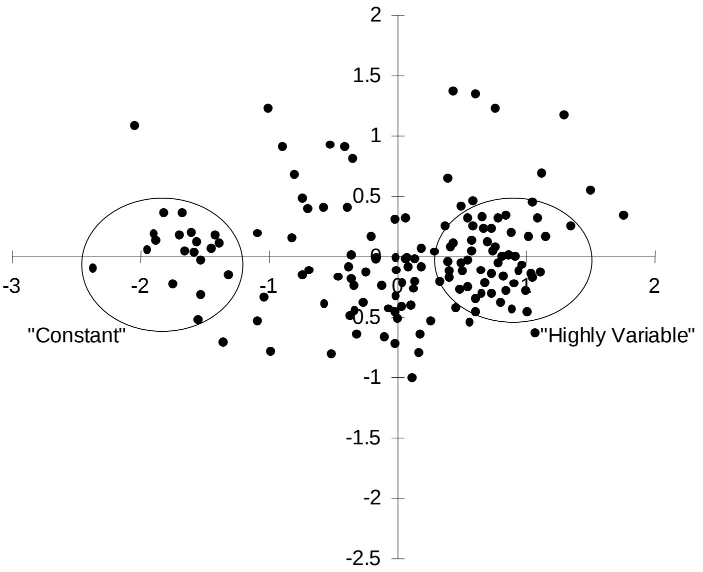

Figure 1. Ordination of 145 stream gauging stations using calculated hydrological parameters. Ellipses bound groups of gauging stations in each flow category ("constant" and "highly variable"). Study rivers chosen randomly were:

"Constant"
- Gibbo R. Vic
- Goobaragandra R. NSW
- Nariel Ck Vic
- Snowy Ck Vic
- Murrindindi R Vic

"Highly Variable"
- Numeralla R. NSW
- Tuross R. NSW
- Shoalhaven R. NSW
- Queenbeyan R. NSW
- Avon R. Vic

<u>Field Methods</u>

At three sites on each river (all within 10km of the gauging station), portable weirs were set up to rapidly increase discharge over a section of streambed while concurrently reducing discharge over another (Figure 2). Each weir is made from rip-stop vinyl and is held in place using metal tri-star pickets and galvanised wire cable. Three randomly distributed benthic samples were collected using a 20 cm square suction sampler (Brooks 1994) before the experimental disturbances were applied in each of the high flow, low flow and background areas. Discharge was increased to 300% of the current discharge in the high discharge treatment, and reduced to 30% of the current flow in the low discharge treatment. These values were near the physical limitations of our experimental setup. The flow manipulations were held for two days, following which a set of post-disturbance samples were collected. Background samples were taken from unaffected areas of streambed either upstream and downstream of the weirs, before and after the experiment. In all, 27 benthic samples were collected from each site.

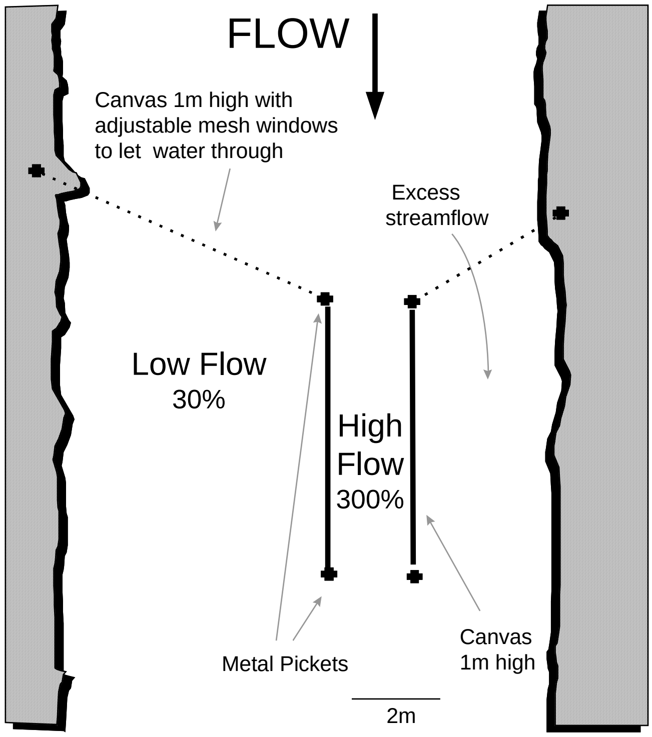

Figure 2. Schematic of a portable weir used to simultaneously increase discharge by 300% over one area of streambed while reducing discharge by 70% over another. Invertebrates were sampled from both flow manipulation areas, as well as from an undisturbed upstream or downstream site both before and after the flow manipulation.

Site geomorphology was described using a variety of techniques. Permanent quadrats of streambed were photographed before and after the experiment using glass bottomed box 60 cm x 45 cm. Pre/post disturbance photo pairs were then digitised to measure the streambed particle size distribution and stability under high flow. At each site, 10 randomly placed roughness profiles were taken using a profiler consisting of 100 adjacent pins, each 1 cm diameter, held in a 1 m long frame. The pins are lowered on to the streambed and photographs were taken of the resulting profile. These were digitised for measures of streambed roughness and depth. Ten randomly located turbulence readings (variance in 30 consecutive 1 second flow readings). Site width, depth, slope and discharge were measured, along with an index of reach stability assessed at each site using inventory sheets (Pfankuch 1975). In total, 21 variables were measured, or derived, to describe each sites geomorphology and hydraulics for possible use as predictors of biological responses to the experimental disturbance treatments.

Statistical Analyses

Invertebrates were classified and enumerated in the laboratory to family level. "Common" taxa were defined as those taxa comprising more than 1% of the invertebrate assemblage at a site, for at least one site in each river. The differences in taxonomic richness, total number of invertebrates, and densities of common taxa before and after the flow manipulation were analysed as estimates of resistance to hydrological disturbance. The experimental design was a split plot analysis of Variance (ANOVA) (Neter *et al.* 1990). This design allows the concurrent identification of sources of variation in the data at river reach (site), entire river, and hydrological regime scales, and enables us to test the hypothesis that the natural flow regime influences the impacts of hydrological disturbances (increased and decreased flow) on stream communities (Neter *et al.* 1990). Replication was maximised at the river level, to provide the most powerful test of differences between rivers with different hydrological histories. The Bray-Curtis (dis)similarity index was calculated for the pre/post disturbance sample pairs as a measure of community change associated with the experimental treatments and analysed using the same ANOVA model. Single degree of freedom contrasts were then conducted to test the hypothesis that the observed change in a dependant variable (=resistance) was greater in the flow manipulation treatment, than in the background samples over the same time period (2 or 8 days).

Multiple linear regression was then used to see if hydrological variables (calculated from a 20 year daily flow series), substratum characteristics (eg. particle size, streambed roughness, stability), hydraulic variables (eg. sheer stress, turbulence, Reynolds number), or site parameters (eg. latitude, river width, depth, discharge) could predictors of the patterns of invertebrate resistance to the experimental flow disturbances. Principal components analysis was used reduce the data set of co-correlated variables (eg. Reynolds number, velocity, depth), to orthogonal axes that were then used as independent variables in the multiple regressions (Neter *et al.* 1990). In addition, a subset of uncorrelated variables were also assessed for predictive potential using multiple regression.

Modification to Project Objectives - Incorporating Disturbance Duration

Drought prevented sampling of many sites in 1995 and so experiments were spread across two years, with 5 rivers being completed in 1995 and a further 5 rivers in 1996. After analysing this data set it became apparent that the 2-day reduced flow treatment had little effect on the benthic fauna (see below), while the elevated discharge treatment had some, but not catastrophic, impacts. At this time we hypothesised that 2 days may not be long enough to detect detrimental effects of reduced flow (a *"press"* disturbance), while the impact of high flow was virtually instantaneous (a *"pulse"* disturbance). We restructured our project goals to include a test of the influence of the *duration* of disturbance. Experiments were repeated in three rivers in 1997 with samples collected after 2 days, and then after the flow manipulation had been maintained for 8 days. Thus we could assess the influence of disturbance *duration* on our results, as well as examine the consistency of results for the 2-day experiments conducted in the same rivers 1 and 2 years apart.

Results and Discussion

Impacts of Disturbance and the Influence of River Hydrology

A total of 540 benthic samples were collected from 10 rivers (5 in each flow category), containing over 478,000 invertebrates from 82 taxa. Of these, only seven taxa were defined as common (see Statistical Analyses). Simuliids were also analysed along with the common taxa and this dipteran family is known to respond rapidly to changes in flow and to disturbance (Maitland and Penny, 1967, Downes and Lake, 1991). Resistance of taxonomic richness, total numbers of individuals, the seven most common taxa, Simuliids and organic matter (CPOM and FPOM) to our flow manipulation treatments did not differ significantly between the two classified hydrological regimes, or among rivers. Thus, the overall effects of our flow manipulations were consistent across all rivers, regardless of hydrological history. This result vindicates our use of rivers as our units of replication for this experiment.

Two days of elevated flow (flow increased by 300%) overturned 44% of the streambed on average, resulting in a significant reduction in the number of taxa (Table 2). This change was relatively small, being an elimination of 4 taxa from a mean of 22.3 taxa before the disturbance. Total numbers of invertebrates did not change, perhaps because a because a significant reduction in densities of Chironomids, was balanced by significant colonisation by Simuliids in the high flow treatments (Table 2). Five of the seven common taxa were highly resistant to the flow treatment, and their densities did not change in response to two days of elevated flow (Table 2). The Bray-Curtis dissimilarity index (using all taxa) was significantly greater for the elevated flow treatment when compared to background samples ($P<0.001$) indicating that the high flow treatment caused significant overall changes in benthic community structure. This may be explained, in part, by the changes in densities of Chironomids and Simuliids.

The 48 hour decrease in discharge (flow reduced by 70%) led to an increase in the densities of Leptophlebiid mayflies and chironomids (Table 2) across all rivers. Apart from this, the flow reduction had little impact on the benthic invertebrate assemblage. There was no significant change in taxonomic richness, number of individuals, or in the abundance of the remaining 5 common taxa when compared to the natural variation in background densities. Overall, there was a significant change in community structure as described by the Bray-Curtis dissimilarity index that may be partly due to the increases in densities of Leptoplebiid mayflies and chironomids.

	Discharge Increased 300%	Discharge Reduced by 70%
Taxon Richness	0.002 (-)	-
Total Individuals	-	-
Structure (Bray-Curtis Dissimilarity.)	<0.001 (+)	0.020 (+)
Tubificidae/Phreodrillidae	-	-
Leptophlebiidae	-	<0.001 (+)
Baetidae	-	-
Chironomidae	0.019 (-)	0.021 (+)
Hydropsychidae	-	-
Elmidae (Larvae)	-	-
Simuliidae	0.006 (+)	-
CPOM	-	-
FPOM	-	-

Table 2. Statistical *P*-values for significant tests ($P < 0.05$) of the hypotheses that changes in taxonomic richness, total numbers of individuals, community structure, seven common taxa, Simuliids and organic matter in the flow manipulated treatments over two days (=resistance), were greater than changes observed in background samples over the same period. The direction of change is in parentheses.

Levels of benthic organic matter, both fine (FPOM) and coarse (CPOM) did not change significantly when compared to background levels (Table 2). This result is somewhat surprising given that 44% of the streambed was overturned in the high flow treatment and reflects a low statistical power of our test caused by an extremely patchy distribution interstitial organic matter. We observed substantial deposition of FPOM in the reduced flow treatments at most sites, forming a fine layer over the tops of the stones. While the total amount of organic matter on the tops of the stones was small when compared to interstitial levels, this may be of considerable biological importance if it smothers algal production. Primary productivity was not measured in this study.

Reproducability of Results

Experiments in 1997 were conducted in 3 "constant" rivers that had been used previously in 1995 (Nariel Ck and Snowy Ck) and 1996 (Goobaragandra R). These rivers were chosen at random from the ten original rivers, since the classification of hydrological regime was shown to be insignificant in determining patterns of resistance to disturbance. There were significant river*treatment interactions in the ANOVA model comparing results across 3 rivers and two times. Therefore separate ANOVA models were tested for each river to elucidate specific patterns (Table 3). Results from experiments conducted in 1995 and 1997 in Snowy Creek were almost identical (in direction and magnitude) (Table 3). However, the same experiments conducted in the Goobaragandra R. 1 year apart, and in Nariel Ck over two years, yielded disparate results, both within, and among rivers (Table 3). The mechanisms underlying these differences are not clear, however in Snowy Creek, the experiments were repeated in 1997 at exactly the same site in the river as in 1995. For the Goobaragandra R. and Nariel Ck, floods in the intervening years had restructured the riverbed at some sites, scouring pools that made those sites unsuitable for experimentation. In these two rivers, at two of the three sites were different riffles, than those used in 1995. This suggests strong local control on patterns of resistance to disturbance.

Comparison of 2-Day and 8-Day Flow Manipulations

We could not support our hypothesis that hydrological disturbances of 8 days duration were more "severe" than 2-day disturbances. The invertebrate assemblage was seemingly oblivious to reduced flow, whether the experiment was conducted for 2 days or for 8 days with only one taxon, Hydropsychid caddisflies, showing a significant decline in Nariel Ck after 8 days (Table 4). This filter feeding family relies on high currents for food delivery, and it is possible that food limitation under low flow caused their decline. We expected that the significant impacts of 2 days of elevated discharge would be amplified after the disturbance was maintained for 8 days. This was clearly not the case in the Goobaragandra R and Nariel Ck, as many significant changes after 2 days were not significantly different to background variation over the 8 day experimental period (Table 4). In Snowy Ck, there were no significant changes in the benthos after 2 days, and only a significant decline of Leptophlebiids, and an increase in Hydropsychids in the elevated treatment, and a decline of Hydropsychids in the reduced flow treatment after 8 days, and these differences were not sufficient to alter overall community structure dynamics as measured by taxonomic richness, numbers of individuals, or Bray Curtis (Table 4). This suggests that the fauna is extremely resistant to flow manipulations of the magnitude and duration we imposed.

Predicting the Impacts of Elevated and Reduced Flow

Independent variables were divided into river-scale hydrological variables calculated from the long term flow record (24 variables), and geomorphological variables that described local site conditions (16 substratum variables, 4 hydraulic variables, 5 channel morphology). PCA reduced these data sets to readily interpretable orthogonal axes (Table 5), however none of theses axis could predict the significant differences in the benthic assemblage that were observed in response to elevated or reduced flow treatments. Given the lack of significant "river" or "hydrological regime" main effects in the split plot ANOVA, it is not surprising that hydrological variables could not predict the experimental outcomes. The hydrological parameters did differ considerably among rivers (Figure 1), and indeed, our design was constructed to maximise this spectrum of hydrological variability. The lack of significant multiple regression models for flow variables supports the conclusions from the split plot ANOVA that the experimental results were consistent across all rivers, *regardless of hydrology*.

Table 3. Reproducability of results across years at the same sites. The table reports statistical *P*-values for significant tests ($P < 0.05$) of the hypotheses that changes in taxonomic richness, total numbers of individuals, community structure, eleven common taxa, Simuliids and organic matter in the flow manipulated treatments (=resistance), were greater than changes observed in background samples over the same period.

Discharge Elevated 300%	Goobaragandra R		Nariel Ck		Snowy Ck	
	1996	1997	1995	1997	1995	1997
Taxon Richness	0.036	-	-	-	-	-
Total Individuals	0.003	-	-	-	-	-
Structure (Bray-Curtis)	<0.001	-	-	0.002	<0.001	<0.001
Naididae	0.024	-	-	-	-	-
Tubificidae/Phreodrillidae	0.041	-	-	-	-	-
Hydracarina	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-
Baetidae	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-
Chironomidae	-	0.002	-	-	-	-
Hydropsychidae	-	-	-	-	-	-
Conoesucidae	-	-	-	-	-	-
Elmidae (Larvae)	0.029	-	-	0.009	-	-
Elmidae (Adults)	-	-	-	-	-	-
CPOM	-	-	-	<0.001	-	-
FPOM	-	-	-	-	-	-

Discharge Reduced 70%	Goobaragandra R		Nariel Ck		Snowy Ck	
	1995	1997	1995	1997	1995	1997
Taxon Richness	-	-	-	-	-	-
Total Individuals	-	0.025	-	0.048	-	-
Structure (Bray-Curtis)	-	-	0.036	-	0.034	0.030
Naididae	-	-	-	0.019	-	-
Tubificidae/Phreodrillidae	-	-	-	-	-	-
Hydracarina	-	-	-	-	-	-
Leptophlebiidae	-	0.036	0.014	0.038	-	-
Baetidae	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-
Chironomidae	-	-	0.002	0.023	-	-
Hydropsychidae	-	-	-	-	-	-
Conoesucidae	-	-	-	-	-	-
Elmidae (Larvae)	-	-	0.002	-	-	-
Elmidae (Adults)	-	-	-	-	-	-
CPOM	-	-	0.006	<0.001	-	-
FPOM	-	-	-	-	-	-

Table 4. Comparison of results after 2-day and 8days of flow manipulation. The table reports statistical *P*-values for significant tests ($P < 0.05$) of the hypotheses that changes in taxonomic richness, total numbers of individuals, community structure, eleven common taxa, Simuliids and organic matter in the flow manipulated treatments (=resistance), were greater than changes observed in background samples over the same period.

Discharge Elevated 300%	Goobaragandra R.		Nariel Ck		Snowy Ck	
	2day	8day	2day	8day	2day	8day
Taxon Richness	-	-	-	0.048	-	-
Total Individuals	-	-	-	-	-	-
Structure (Bray-Curtis)	-	-	0.027	-	-	-
Naididae	-	-	-	-	-	-
Tubificidae/Phreodrillidae	-	-	-	-	-	-
Hydracarina	0.007	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	0.048
Baetidae	-	-	-	-	-	-
Simuliidae	-	-	-	0.008	-	-
Chironomidae	0.011	-	-	-	-	-
Hydropsychidae	-	-	-	-	-	0.021
Conoesucidae	-	-	-	-	-	-
Elmidae (Larvae)	-	-	0.046	-	-	-
Elmidae (Adults)	-	-	-	-	-	-
CPOM	-	-	0.027	-	-	-
FPOM	-	-	-	-	-	-

Discharge Reduced 70%	Goobaragandra R		Nariel Ck		Snowy Ck	
	2day	8day	2day	8day	2day	8day
Taxon Richness	-	-	-	-	-	-
Total Individuals	-	-	-	-	-	-
Structure (Bray-Curtis)	-	-	-	-	-	-
Naididae	-	-	-	-	-	-
Tubificidae/Phreodrillidae	-	-	-	-	-	-
Hydracarina	-	-	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-
Baetidae	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-
Chironomidae	-	-	-	-	-	-
Hydropsychidae	-	-	-	-	-	0.021
Conoesucidae	-	-	-	-	-	-
Elmidae (Larvae)	-	-	-	-	-	-
Elmidae (Adults)	-	-	-	-	-	-
CPOM	-	-	0.035	-	-	-
FPOM	-	-	-	-	-	-

Table 5. Explanation of PCA axes calculated to reduce correlated independent variables to orthogonal axes for use in multiple regression models predicting patterns of resistance to elevated and reduced discharge.

		%Variance Explained	Contributing Variables (loading > 0.7)	Explanation
Hydrological Variables				
	PCA axis 1	46.7	Day CV, Month AutoCorr, Baseflow, Slope of rising/falling hydrographs, Day Skew	High Flow Variability
	PCA axis 2	13.75	Slope of Low Spell duration curve	Low Flow Variability
	PCA axis 3	18.9	Mean Daily, Monthly and Annual Flow	Size of River
Substratum/Hydraulic				
	PCA axis 1	17.7	%Stable area, Stable Particle Width	Streambed Stability
	PCA axis 2	16.8	Streambed Roughness	Hydraulic environment
	PCA axis 3	11.8	Riffle Width, Depth	Channel Morphology

Site level geomorphological variables were similarly unsuccessful in predicting the outcomes of the experimental manipulations. The only significant regression coefficient was for PCA axis 3 (channel morphology) to explain 22% of the variance in change in community structure defined as the Bray-Curtis dissimilarity measure between pre- and post-manipulation samples. This result was somewhat surprising, given that our repeated experiments in 1997 suggested that local site conditions may alter the experimental outcomes. However, this finding does make sense if the observed significant differences in the split plot ANOVA model for densities and species richness were relatively consistent among sites, as well as among rivers and hydrological regimes. Indeed, independent variables are not required to predict consistent outcomes because they are known with some certainty *a priori*. The lack of significant regression coefficients does indicate that the variables we measured were unable to explain any more of the residual error variation in our ANOVA model. An alternative explanation for a lack of predictive power using multiple regression is that the variables may not be related in a linearly, however, a "fishing exercise" of calculating all possible combinations of non-linear polynomial models for n! combinations of n variables is impractical and statistically invalid.

We decided *a priori*, to test the hypothesis that *interactions between the hydrological regime and substratum stability determine the impacts of hydrological disturbance on stream communities.* We tested this hypothesis for our elevated discharge treatment only, using the interaction of **Stable Area of Streambed * Coefficient of Variation for Daily Discharge**. The CV for daily discharge was highly correlated with other measures of hydrological variability (Pearson correlation coefficient > 0.9 for autocorrelation of mean monthly flows, baseflow Index, slope of rising/falling hydrographs), and was chosen as the single variable representing the range of hydrological variability. This interaction was only a significant predictor of overall changes in community structure measured by the Bray Curtis dissimilarity index ($P = 0.003$), with the regression model accounting for 24% of the variation in this factor.

Conclusion

This work provides a powerful test of the impacts of short duration hydrological fluctuations in south-eastern Australia. It is rare in the field of ecology for experiments to be repeated either in space or time, despite the fact that this is the only way to determine if results have general applicability beyond a single study. For this project we conducted the same experiment at 30 sites, throughout 3 years, spanning an extreme range of environmental variability, and over a large geographic area. Given the range of environmental variability we incorporated in our design, the results were remarkably consistent across rivers and times. Our experiments suggest that a single short duration (2-8 day) decrease in discharge have little measurable affect on benthic invertebrate assemblages of rivers in south eastern Australia. Elevated discharge consistently, but not always, results in the loss of taxonomic richness, and a shift in community structure as some taxa decline in density (e.g. Chironomids) and others increase (e.g. Simuliids).

The classification of hydrological regime using variables derived from long term gauging data were not useful in predicting biotic responses to our treatments, but this is not to say that these data are unimportant. These data provide a vital description of the environment under which studies are conducted, and may provide a habitat template (*sensu* Southwood 1977, Poff 1997) to facilitate integration of results from separate smaller studies and the reporting of basic flow description in the stream literature should be encouraged.

The results of this study can not be taken out of context. We can never be certain how the results from our experiments of restricted spatial extent (a portion of a single riffle) will translate to the real situation when the entire channel in disturbed. We believe that it is likely that these results may be transferable to isolated river level disturbances of similar magnitude to our experiments. Unfortunately, isolated events are rarely associated with river flow management. No studies have been conducted to examine the impacts of *repeated* flow disturbances on lotic assemblages, and we know very little about the influence of long term natural flow variability in Australian streams. Our study has the broadest focus of any experimental study conducted in Australian rivers, and possibly world-wide. The results are encouraging that general ecological patterns do exist, that once resolved can form a basis for intelligent adaptive management.

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Technology Transfer Activities

Presentations

Brooks S.S. and Lake P.S. 1998. "Impacts of hydrological disturbance in streams with contrasting disturbance histories". Ecological Society of America, Baltimore, USA.

Brooks S.S. and Lake P.S. 1998. "Impacts of floods in imbricated systems: defining flood disturbance at the appropriate scale". North American Benthological Society, Prince Edward Island, Canada.

Brooks S.S. and Lake P.S. 1997. "Hydrological Classification and Disturbance: Effects of disturbance on the biota of rivers with contrasting flow regimes.". CRC for Freshwater Ecology River Health Workshop Canberra.

Brooks S.S. 1997. "Assessing the impacts of river flow management." Department of Biology, University of Maryland, Maryland, USA

Brooks S.S. and Lake P.S. 1997. "Impacts of hydrological disturbance". North American Benthological Society, San Marcos, Texas, USA.

Brooks S.S. 1997. "Flow manipulation: ecological disturbance or hydrological agitation". Dept Ecology and Evolutionary Biology, Monash University, Vic.

Brooks S.S. and Lake P.S. 1997. "Impacts of hydrological disturbance". Australian Society for Limnology Annual Congress, Albury, NSW

Brooks S.S., Lake P.S., Reich P., Warfe D. and Honan P. 1996. "Determining the impacts of hydrological disturbance". Australian Society for Limnology Annual Congress, Berri, S.A.

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Print Media

"Shane's Holy Grail" Ripples Newsletter. May 1996 CRC for Freshwater Ecology.

"Bugged by question of stream flows, scientist turns to Queanbeyan River." June 1996 Press Release for Queenbeyan print media NSW.

"Scientists Get Bug-Eyed Over Flow Needs For Upland Rivers" July 1996 Watershed Newsletter. CRC Freshwater Ecology

Once approved by L.W.W.R.D.C., copies of this report will be published by the CRC for Freshwater Ecology and distributed to management agencies in NSW, ACT, and Vic. The report will also be available word-wide on the CRCFE internet homepage. A manuscript is being prepared for publication in the international journal "Ecological Monographs". This manuscript is not yet complete and is likely to be another six months in preparation. Dr Shane Brooks left his position on this project in December 1997, and is completing the manuscript in his own time. Salary savings from his departure were used to keep Mr Paul Reich employed until the end of the year (6 months longer than originally budgeted for) to complete the sample processing and assembly of the empirical data, and to cover new mandatory severance payments that were not budgeted for in the original proposal.