A QUANTITATIVE STUDY OF BUSHFIRE IMPACTS ON THE BUFFALO AND KING RIVERS: FIRST YEAR FINDINGS

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1 INTRODUCTION

On 8 January 2003, lightning storms ignited bushfires that burned over 1.3 million hectares of north-eastern Victoria. These, alongside the fires of Ash Wednesday in 1983 and Black Friday in 1939, stand as the largest bushfires seen in Victoria (Government of Victoria 2003).

The severity of this event prompted a cooperative effort in assessing the impact and recovery following the bushfires, including research into the effects of fire on the natural environment. An important impact of bushfires on our water catchments is the erosion and delivery of ash and sediments from burnt hill slopes. The effects of this has been seen in rivers like the Buckland River, where a massive sediment slug caused loss of native River Blackfish, stream insect species and a decline in river health (EPA Victoria 2004).

Elsewhere in the Ovens catchment, bushfires burned areas where sampling for a study had recently been completed by EPA (*The development of ecosystem guidelines for sedimentation and suspended particulate matter for rivers and streams (SPM*), EPA Victoria/Cooperative Research Centre for Freshwater Ecology (Unpublished)).

One river monitored in the study (the Buffalo River) was affected by fire while others were not. This provided the opportunity, by continuing the study, to make a controlled comparison of sediment effects before and after the bushfires, something that was not possible in assessing impact on the Buckland River.

This preliminary report provides the outline of a quantitative study into the effect of bushfire sediment slugs on stream ecosystems, part of the State Bushfire Recovery Program. Preliminary results are presented that address effects of the 2003 bushfires.

2 THE STUDY

2.1 Study sites

The Buffalo and King rivers rise in the alpine region of north-east Victoria and flow into the Ovens River, an important tributary of the Murray–Darling Basin (Figure 1).

Two study sites were chosen on these rivers to compare change on the Buffalo River after the bushfires with conditions on the King River unaffected by fires. Using these two sites we aimed to separate fire effects from other changes in the environment such as seasonal effects and flow.

Blades Picnic Ground is on the Buffalo River, 6 km upstream of Lake Buffalo, surrounded largely by undisturbed sclerophyll forest (Figure 2). Edi Cutting is located on the larger King River, 31 km downstream of Lake William Hovell (Figure 3). Land use within the broader catchment consists of agriculture and viticulture, with headwaters of the river mostly forested. Other characteristics of the river catchments are shown in Table 1.

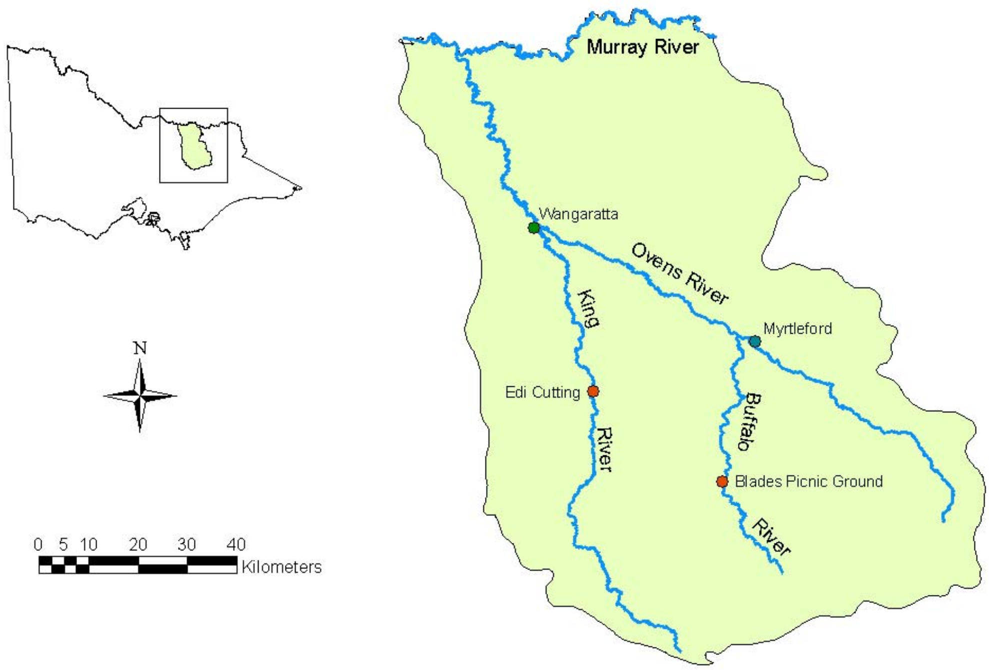

Figure 1: Ovens River Catchment showing sampling sites

Figure 2: The Buffalo River at Blades Picnic Ground pre-bushfire, autumn 2002

Left: Pool sampling area. Right: Riffle sampling area

Figure 3: The King River at Edi Cutting, autumn 2002

Left: Pool sampling area. Right: Study reach

Table 1: Characteristics of the Buffalo and King Rivers sampling sites and catchment.

Site	King River at Edi Cutting	Buffalo River at Blades Picnic Ground
Latitude	-36° 39' 9"	-36° 49' 00"
Longitude	146° 25' 29"	146° 39' 36"
Altitude (m)	195	275
Catchment Area (km²)	797	495
Average stream width (m)	12	8
Channel width (m)	25	16
Distance from source (km)	89	49

2.2 Study design

The study aims to understand the effects of sediment delivery to a river on its aquatic life. We anticipated that, with significant rainfall, ash and soil on unstable burnt slopes would easily be washed into streams. With fires creating hydrophobic soils, reduced infiltration would lead to greater runoff and risk of stream bank erosion. Newly formed firebreaks would also provide a ready source of sediment when placed close to streams.

Sediment delivery poses an important risk to stream ecosystems. High concentrations of sediment and ash reduce the amount of oxygen available for fish and insects to breathe (Eriksen 1963; Wilbur & Clark 2001; EPA Victoria 2004). High turbidity reduces light penetration for plant and algal growth (Kirk 1985), reducing also the feeding success of visual predators (Vogel & Beauchamp 1999; Shaw and Richardson 2001). Once sediment is deposited on the streambed it smothers fish breeding sites and the habitat of many stream insects (Metzeling, Doeg & O'Connor 1995). It also reduces the quality and quantity of algae as food resources for insects and fish (Quinn et al 1992).

Sediment impacts were assessed using diatoms and macroinvertebrates (insects, snails and worms). These biota represent the base of the aquatic food chain, an important food resource for fish. Change in their abundance and community structure can create changes throughout the ecosystem. Macroinvertebrates are commonly used indicators of stream health due to their abundance, ubiquity, ease of sampling and differing sensitivities to pollution and other sources of disturbance.

Macroinvertebrates were measured in two ways. A quantitative technique was used to assess change in communities including abundance, diversity and loss and gain of sediment-sensitive taxa. Rapid bioassessment was used to compare change in stream health between the rivers and to allow comparison with statutory objectives for the region. Diatoms were sampled quantitatively to assess change in relative abundance and community composition and to apply indices developed to measure sediment impact.

Sampling occurred in autumn and spring 2002, before the bushfires, as part of the original (SPM) study, providing a prior comparison of condition. The rivers were sampled soon after fire in March 2003, but prior to significant rain. A subsequent sampling trip took place after the first significant storm event.

In spring and autumn of the two subsequent years recovery continues to be monitored, with analysis to be completed. Stream health and water quality will continue to be assessed from 2002 till 2005 under the project timeline shown in Figure 4.

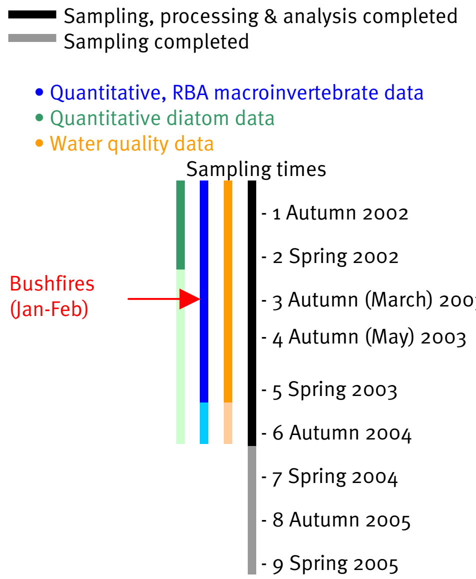

Figure 4: Project timeline

In summary, comparing stream communities of the Buffalo River and King River before and after the bushfires provides a Before-After-Control-Impact (BACI) study of bushfire effects using different quantitative and semi-quantitative measures of change.

2.3 Sampling

On each sampling occasion, five replicate macroinvertebrate samples were collected using a Surber sampler, from both slow-flowing pools and faster-flowing riffle environments. Diatom samples were collected in a similar manner using a quantitative sampler. Each sample was accompanied by measures of depth, velocity and substrate composition.

Macroinvertebrate kick and sweep samples were also collected using EPA's Rapid Bioassessment Method (EPA Victoria 2003). This also allowed assessment of other factors that may influence stream communities such as the quality of available stream habitat, woody debris, riparian vegetation and land use influences using data collected under the RBA sampling methodology.

Biological sampling was accompanied by assessment of water quality, including nutrients, and channel and catchment characteristics. The extent of fine sediment deposition was visually estimated for the reach and transects of the streambed were made to profile rocky substrate. Turbidity, suspended sediment and particle size were measured from water samples taken at each site.

2.4 Analysis

This report presents preliminary results one year prior to and post-bushfire, with all autumn and some spring macroinvertebrate data presented. Descriptive analysis of quantitative macroinvertebrate data includes abundance, diversity and loss and gain of sediment-sensitive taxa. Change in community composition was explored by ordination of macroinvertebrate data using multidimensional scaling within PRIMER 5 (Clarke & Gorley 2001). The indices AUSRIVAS, SIGNAL, EPT, and Number of Families were calculated from rapid bioassessment data and compared to the biological objectives for this region in the State Environment Protection Policy (Waters of Victoria).

Full analysis of diatom and macroinvertebrate data will be reported at the end of the complete study.

3 OBSERVATIONS AND PRELIMINARY RESULTS

3.1 Fire damage

Fire damage in the Buffalo River catchment was patchy in nature. Forty-five per cent of the catchment above the Buffalo River sampling site was affected by fire, with only a small proportion (15 per cent) experiencing severe crown burn. Approaching from the east, the fire only reached the stream bank or jumped the river in a few places. Riparian vegetation remained almost entirely intact, protecting the stream from severe erosion.

Burnt patches were characterised by blackened tree trunks holding singed orange leaves. Where previously there was a dense understorey of native shrub and fern, a bed of bare ash lay under the trees (Figure 5). A firebreak had been cleared close to the stream in an effort to contain the fires, as shown in Figure 5. It forded the river a few kilometres upstream of our site on the Buffalo River and ran alongside the river (5 to 20 m from the river's edge) for more than 11 km upstream, creating a source of loose, readily eroded sediment.

When the Buffalo River was visited on 12 March 2003 following the fires, there was no evidence of recent rain or hill slope erosion. Returning on 8 May 2003 after rain, the firebreak ford had been stabilised by hay batters to reduce erosion. Burnt areas in the catchment upstream of the sampling site showed little change, nor evidence of either stabilisation or recovery.

By spring 2003, the river and surrounding catchment showed significant signs of recovery. Trees budded with new epicormic growth and grass had stabilised burnt hill slopes, although there was still little recovery of the understorey.

3.2 Flow and sedimentation

The Buffalo and King rivers are historically low in sediment with similar flow regimes. The bushfires came during a period of severe drought. After a dry winter in 2002, there was little winter recharge of the Buffalo and King rivers and flow remained low from spring to the following winter (Figure 6). The Buffalo River dropped to less than 1 ML/day from 18 January to 26 February 2003 and remained below 5 ML/day to mid-April (Figure 7).

Low summer flows appear to be a natural characteristic of the Buffalo River. In 14 of the last forty years, flow has dropped below 5 ML/day over the summer–autumn period, commonly for more than 20 days. Only twice before in this time period, however, in 1998 and 1983, has flow of this low magnitude persisted for longer than three months. On the King River, irrigation releases from Lake William Hovell maintained an average base flow of 80–100 ML/day over the summer–autumn period.

Figure 5: Bushfire damage on the Buffalo River – fire damage in the catchment surrounding the Buffalo River (above), firebreak and ford (below), March 2003

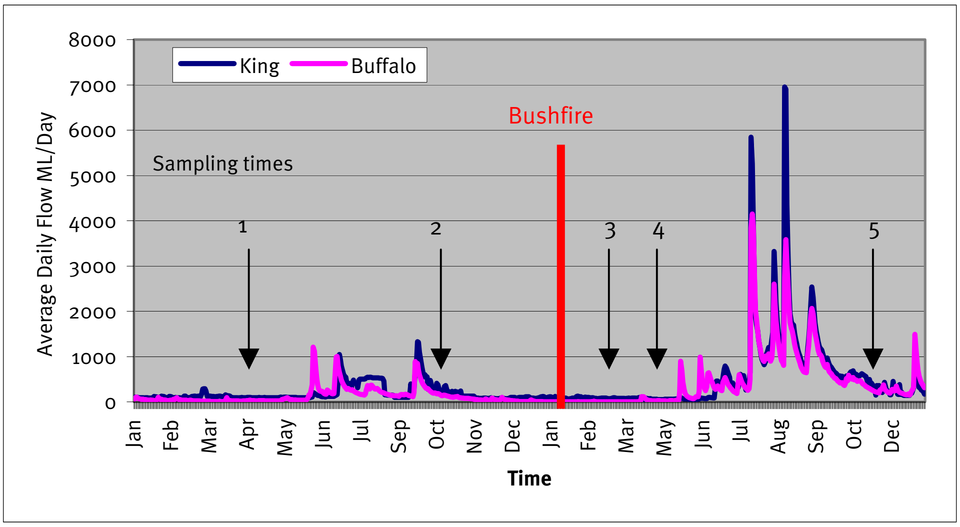

Figure 6: Flow rates of the Buffalo and King rivers during the study of fire effects, 2002–03. See enlargement of time around bushfire below

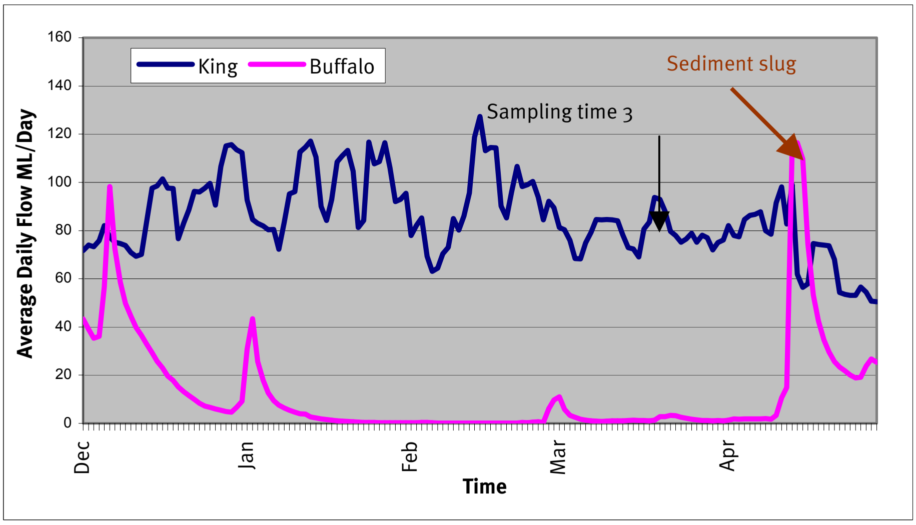

Figure 7: Flow rates of the Buffalo and King rivers during the summer drought and bushfire period, December 2002 to April 2003

Figure 8: Buffalo River, March 2003 – low flow conditions

Figure 9: Buffalo River sediment slug, Blades Picnic Ground, 16 April 2003

Figure 10: Buffalo River, May 2003 – sediment covering pools

When the Buffalo River was sampled in March 2003 following the fires, filamentous algae choked pools and was found in faster-flowing riffles (Figure 8). Slow-moving water, warm temperatures and nutrients provided perfect conditions for algal growth. In the King River at this time, filamentous algae were present in pools, although to a lesser extent than the Buffalo River. Dam release flows appeared to buffer effects of the drought.

A rain event increased flow on the Buffalo River (to 100–115 ML/day) between 13 and 16 April 2003, delivering a slug of sediment, pictured in Figure 9. The turbid waters were reasonably low in suspended sediments (140 mg/L), suggesting the slug was composed predominantly of fine colloidal matter. The fine silt appeared low in organic matter and relatively high oxygen levels were observed (96 per cent oxygen saturation), suggesting that ash and inorganic sediment created less demand for oxygen than for the Buckland River slug (EPA Victoria 2004).

Biological sampling occurred three weeks later (8 May 2003). At this time, flows on the Buffalo River were again low (18 ML/day), although filamentous algae had been cleared somewhat from the substrate. Pools were entirely smothered by a thin layer of fine silt 1–4 cm deep (Figure 10). Riffles also contained areas covered by 1–2 cm of silt and sand, although there were still significant areas of scour and clean substrate remaining. Flow in the King River at this time (56 ML/day) was lower than during summer releases and had not been affected by the rain that caused the slug in the Buffalo River.

By spring 2003, winter flows had largely scoured riffles in the Buffalo River. The streambed was clear of algae and the river was similar in appearance to spring of the previous year, although some coarser sediment deposition was evident in pool areas. Flows were higher than in the previous spring, with the Buffalo and King Rivers carrying around 450 ML/day and 575 ML/day, respectively.

3.3 Water Quality

Like other forested, middle to upland rivers the Buffalo and King rivers possess good water quality, naturally carrying low levels of salts, suspended sediments and nutrients, as seen in Table 2.

Waters in both rivers were slightly more acidic in spring 2002 prior to fire, for reasons that are unknown. In March 2003 after the fires and before rain, the Buffalo River experienced an increase in alkalinity, and salinity, possibly associated with extremely low flows and greater contribution of groundwater base flow during the drought. These increases were not mirrored in the King River, which maintained a relatively high base flow over the drought period.

Dissolved oxygen levels were slightly lower in both the Buffalo and King rivers in March 2003, although without any likely ecological consequence. Total nitrogen, including organic nitrogen (TKN), was also elevated on both rivers at this time, reflecting partly an increased abundance of algae.

Little change in water quality was observed in May 2003 after the sediment slug in April. Overall, water quality results were not greatly different before and after the fires.

Table 2: Water quality data

	Buffalo River					King River				
	1 Autumn 2002	2 Spring 2002	3 Autumn 2003 (March)	4 Autumn 2003 (May)	5 Spring 2003	1 Autumn 2002	2 Spring 2002	3 Autumn 2003 (March)	4 Autumn 2003 (May)	5 Spring 2003
Alkalinity (mg/L)	25	25	50	25	15	20	25	20	25	15
Electrical conductivity (µs/cm)	45.6	38	72.5	51	36	33.7	28	36.1	38	28.5
Dissolved oxygen (mg/L)	9.5	10.7	8.4	11.6	10.8	9	9.1	8.15	9.8	10
Percentage saturation oxygen (%)	98.2	98	88.7	103	99	97.6	88	89	94	95.7
Nitrate/nitrite (µg/L)	7	12	5	3	22	10	89	80	39	70
Total Kjeldahl nitrogen (µg/L)	110	100	400	180	90	60	110	130	130	90
Total phosphorus (µg/L)	6	21	6	21	7	<5	20	6	9	10
pH	7.6	6.5	8	7.3	7.4	7.29	5.9	7	7	7.1
Temperature (° C)	17.8	11.8	19.1	9.7	11.5	18.4	13.7	19.6	13	12.2
Turbidity (NTU)	1.2	0.7	1.2	1.2	0.9	1.1	0.75	1.2	0.8	1

3.4 Quantitative macroinvertebrate data

Abundance and diversity

Following the impact of sedimentation a decrease in abundance and diversity of macroinvertebrates (measured as the number of families present or richness) may be expected, especially in EPT taxa, a group of animals commonly associated with healthy rivers.

Abundance, EPT abundance, richness and EPT richness all fell in riffles on the Buffalo River over the spring and autumn drought period prior to sediment impact, particularly in EPT families (Figure 11). For richness this was mirrored by a similar decrease on the King River, suggesting that seasonal effects drove changes rather than any effect of sediment. However abundance in riffles increased on the King River.

In May 2003, following sediment deposition and return of flows, riffle diversity and abundance recovered slightly on the Buffalo River, although not to levels observed in autumn 2002. This was particularly evident in EPT species. Abundance and diversity on the King River at this time more closely resembled that of the previous year, although EPT abundance had decreased somewhat.

Pools on the Buffalo River were less clearly affected by drought and sedimentation than riffles, as might be expected, since pool fauna naturally exist in slower-flowing, muddy environments. While pools lost abundance (particularly in EPT) in early autumn 2003, diversity fell only slightly.

In May 2003 following rain, pool abundance increased (in EPT only slightly) and diversity and EPT richness fell to lower than previously observed. This could reflect the effects of sedimentation, including the smothering of leaf packs. It may also reflect reduction in available vegetation habitat, as many plants that were submerged in autumn 2002 were exposed on the stream bank in autumn 2003 due to the low water levels.

Overall, the pattern of change in pools on the King River reflected a slight increase in abundance and diversity in spring and early autumn and decline in late autumn, with exception of pool EPT abundance, which declined over the study period.

While it is possible that sedimentation impeded the recovery of invertebrate abundance and diversity following drought and low flow, its effects, if present, appear to be less than those of seasonal change.

Individual species

As the streambed is smothered by sediment, sensitive animals, particularly in riffles, are lost from areas of sedimentation and confined to clear rocky areas or vegetation. Sediment-tolerant animals become more abundant, causing a change in macroinvertebrate community composition.

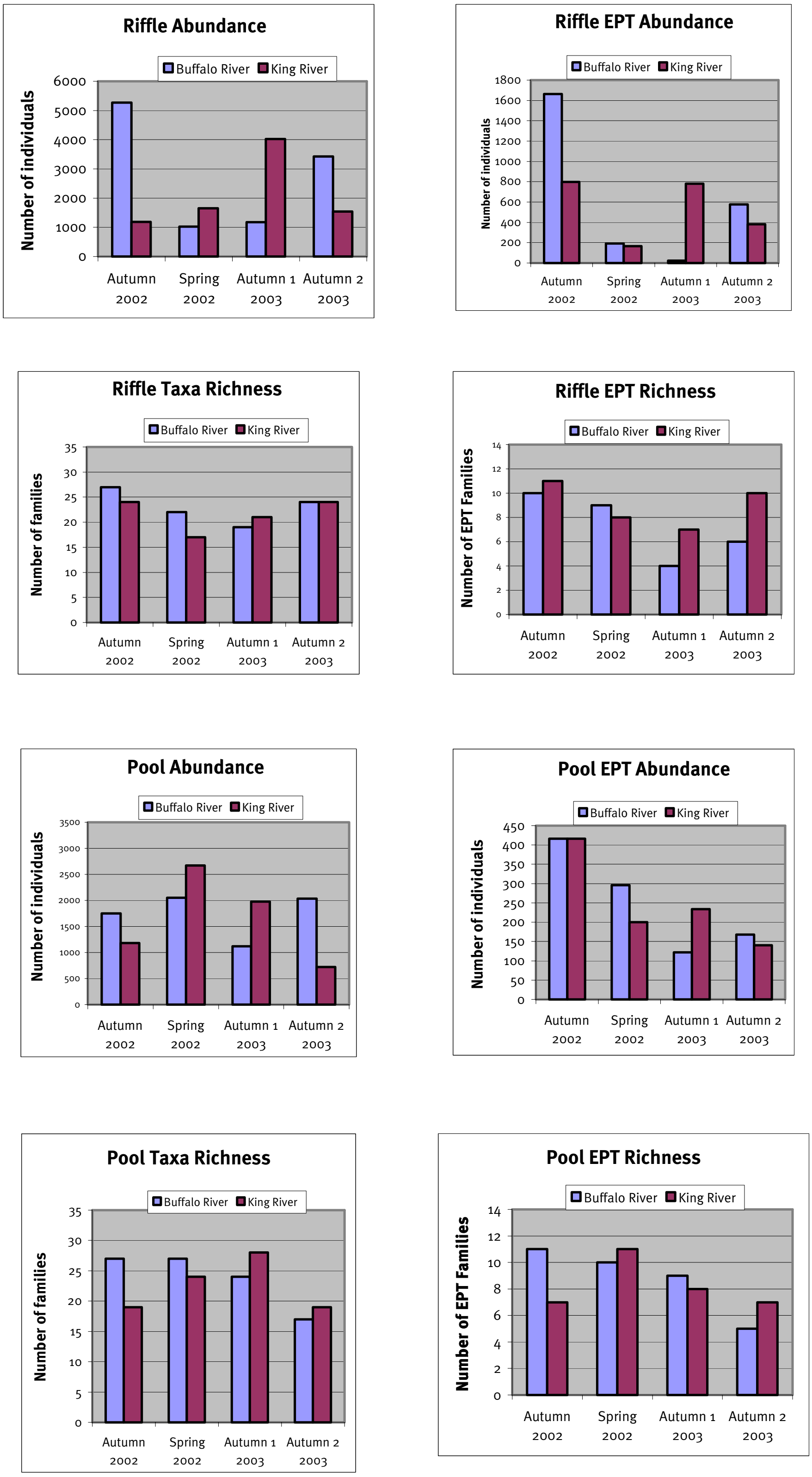

Figure 11: Change in riffle and pool macroinvertebrate abundance and diversity on the Buffalo and King Rivers – before (2002) and after (2003) bushfire

Two sediment-sensitive families – baetid mayflies (Ephemeroptera: Baetidae) and adult riffle beetles (Coleoptera: Elmidae) (Doeg & Koehn 1994 and others) – were lost from riffles following low flows and sedimentation respectively on the Buffalo River, while still found in consistent or larger numbers in the King River (Table 3).

Black flies (Diptera: Simuliidae), of a sediment-sensitive family that relies on stable substrate to attach and filter food from the water column (Wood & Armitage 1999, Gooderham & Tsyrlin 2002 p. 129), were greatly reduced in riffles on the Buffalo River during low flows in March 2003. Black fly numbers remained high on the King River over the study. In May 2003, when flows had returned to normal, black flies had increased in abundance, although not to levels observed the previous year, possibly because sediment had limited their recovery.

A similar pattern was observed in net-spinning caddisfly (Hydropsychidae). This sediment-sensitive filter feeder was in low abundance over spring 2002 and March 2003 and recovered only slightly following sedimentation. However, numbers were also quite variable on the King River.

Larvae of the sand fly (Diptera: Ceratopogonidae), an invertebrate commonly found burrowing in the mud at the edges of streams (Gooderham & Tsyrlin 2002 p. 119), were present in riffles in the Buffalo River during summer low flows and following sedimentation, where they were previously absent. This family was not found in riffles in the King River.

There was no clear pattern in relative abundance of sediment-liking (Chironominae) and sediment-loathing (Orthocladiinae) midge larvae, nor increase in caenid mayflies as might be expected following the introduction of sediment (Angradi 1999).

Sediment-liking worms (oligochaeta) increased abundance in both the Buffalo and King rivers.

Table 3: Change in sediment-sensitive and sediment-tolerant taxa; average abundance per sample

	Buffalo River				King River			
	Autumn 2002	Spring 2002	Autumn 2003	Autumn 2003	Autumn 2002	Spring 2002	Autumn 2003	Autumn 2003
	1	2	3	4	1	2	3	4
Baetidae	54	2	0	0	208	20	266	112
Elmidae	18	2	16	0	4	10	22	28
Simuliidae	2270	112	26	1266	118	594	2220	460
Hydropsychidae	946	6	2	32	444	30	356	160
Ceratopogodinae	0	0	2	4	0	0	0	0
Caenidae	156	8	6	14	62	4	96	40
Orthocladiinae	366	280	64	500	54	478	526	256
Chironominae	394	58	76	220	22	198	146	54
Oligochaeta	276	338	518	626	82	118	158	274

Community composition

Riffle community composition in the Buffalo River changed markedly in periods of low flow compared with autumn 2002 (Figure 12). When the site was sampled after sediment deposition (May 2003), composition was closer to that observed the previous year, potentially indicating a recovery to pre-existing conditions.

When compared to more severely sediment-impacted sites in the earlier SPM study, composition in the Buffalo River moved away from that associated with sedimentation. This suggests that the changes observed on the Buffalo River were more closely related to seasonal change (including flow) than sedimentation, despite loss of sediment-sensitive invertebrates. The effects of sediment on the riffle community were less than those experienced from the drought.

Riffle community composition of the King River, by comparison, remained similar when sampled during the drought and autumn 2003, since flows were maintained during this period. When the pool fauna were examined, composition in both the Buffalo and King rivers varied within and between sampling occasions without clear patterns.

These data show that macroinvertebrate community composition was adversely affected by sedimentation following the fires, although these effects are small when compared to effects of the drought.

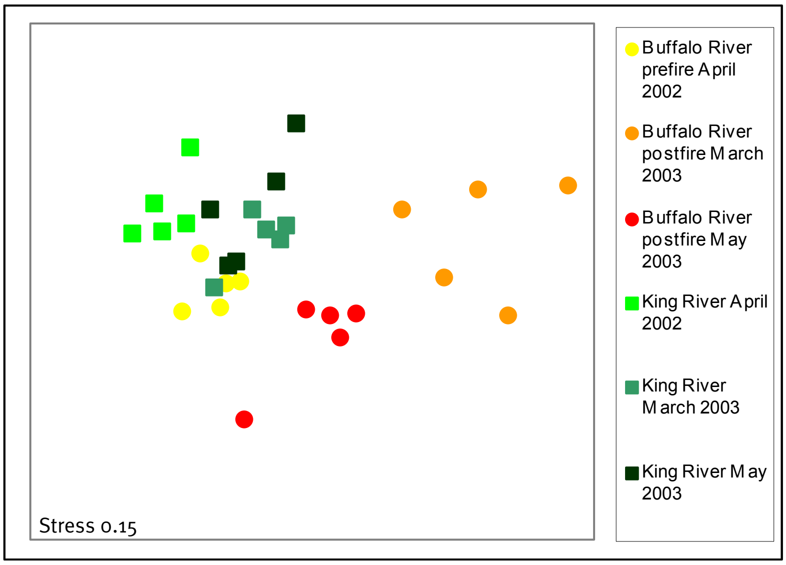

Figure 12: Change in riffle macroinvertebrate community composition on the Buffalo and King Rivers – Autumns prior to and post-bushfire 2002–03

This ordination provides a visual representation of similarity in community composition. Samples containing similar types and abundances of invertebrates are represented closer together in space, while samples with different composition are represented further apart.

3.5 Rapid bioassessment of macroinvertebrate data

River health declined in 2003 in both the Buffalo and King rivers, with most measures showing degradation (Table 4). River health therefore declined overall for reasons apart from the bushfires.

Riffle fauna are considered sensitive to the effects of sedimentation, as sediment smothers habitat and decreases food resources. However, in riffle environments, declines in general health indicators AUSRIVAS and SIGNAL were greater in th Decline in riffle number of invertebrate families and numbers of EPT taxa were greater in the Buffalo River following sedimentation than in the King River. The Buffalo River did not meet SEPP objectives for AUSRIVAS and EPT taxa, while the King River did not meet SEPP objectives for AUSRIVAS and SIGNAL in riffle environments. This demonstrates both rivers show stress from factors which include the influence of sediment but are not restricted to it.

A healthy edge environment reflects the quality of edge habitat, including riparian vegetation and macrophyte availability, and is less sensitive to the effects of sedimentation than riffle measures. Reduction in edge Number of EPT, AUSRIVAS and SIGNAL scores were greater on the Buffalo River following the bushfires than on the King River. Number of families also decreased in edge habitat on the Buffalo River but not on the King River.

These changes are likely to result from a number of influences, including reduction in vegetation habitat, low flow and sedimentation.e King River than the Buffalo River.

Table 4: River Health

		Buffalo River		King River		SEPP Objective
		Pre-fire 2002	Post-fire 2003	Pre-fire 2002	Post-fire 2003	
AUSRIVAS O/E Score (Band)	Edge	1.12	0.97	0.84	0.79	0.87–1.13 (A)
	Riffle	1.00	0.84	0.97	0.78	0.87–1.13 (A)
SIGNAL	Edge	6.4	6.1	5.9	6.0	5.8
	Riffle	6.4	6.3	6.1	5.8	6.0
Number of families	Edge	33	30	31	31	24
	Riffle	32	25	26	23	23
EPT Taxa	Edge	13	8	12	10	9
	Riffle	14	9	13	10	10

Measures of stream health are compared for the periods: Pre-fire (autumn and spring 2002) and post-fire sedimentation (autumn and spring 2003). Outcomes are compared to the Region 3 biological objectives from the State Environment Protection Policy (Waters of Victoria).

Meets SEPP Biological Objective	
Does not meet SEPP Biological Objective	

4 PRELIMINARY OUTCOMES

Following the 2003 bushfires, sediment erosion and delivery to the Buffalo River appears to have been less severe than in some other, more fire-affected streams. At the time of the fires, drought had severely reduced flows on the Buffalo River, changing the structure and likely functioning of invertebrate communities relative to the King River.

A slug of fire-related sediment delivered to the Buffalo River in April 2003 possibly slowed recovery of macroinvertebrate abundance and diversity following the drought. Change in community composition was evident but small in comparison to drought and other seasonal effects. An overall decline in river health was observed in both rivers during the time of the study. In all, the effects of low-level sedimentation on the Buffalo River were small in comparison to the effects of drought, and the system shows signs of recovery.

5 FUTURE DIRECTION

Following these preliminary results, the Buffalo and King rivers will continue to be monitored until spring 2005 as part of the State Bushfire Recovery Program. A full report will be prepared on its completion. With greater flows over the 2003 winter period and deposition of coarser sand in areas of the Buffalo River, different effects may be expected in quantitative data for spring 2003, which are currently being analysed.

Change in EPT and individual taxa have been useful in investigating the effects of sedimentation and drought and will continue to be studied in the future. Exploration of diatom data will also provide useful insight into the effects of sediment slugs following bushfires on river ecosystems.

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