

**Impacts of gold-dredging activities on benthic macro-
invertebrates of the upper Pomahaka River.**

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Introduction:

This study aims to assess the impact of a small gold dredging operation on stream benthic invertebrates. The resource consent for this operation covers a 27 kilometre stretch of the upper Pomahaka River in Southland (Figure 1). Gold dredging is carried out using a mobile suction dredge. The dredge uses a 16.5 cm inlet and operates in the top 20-30cm of stream sediments. Sediment is passed through the dredge, the heavier component is retained, and the remainder is discharged back into the stream. Operated in ideal conditions the dredge can process up to 10 m³ of sediment per day. In reality however, the operator tends to focus on patches of the bed that he considers likely to yield gold, but avoiding obvious areas of fine sediment and undercut banks.

The impacts of gold dredging on stream fauna have been described elsewhere (Pearson and Jones, 1975; Griffith and Andrews, 1981; Harvey, 1986; Hall, 1988). Such studies have shown short term impacts on stream invertebrates. The largest impacts on stream fauna are seen where the bed of the stream is tightly packed ('armoured') and has a high component of fine sediments. Disruption of bed armouring and mobilisation of fine sediment can have serious effects on both fish and invertebrates. Specifically, where there is an impact of dredging we can expect to see loss of species that are intolerant of fine sediment loading or bed disturbance. This will result in lower values for metrics of ecosystem health (e.g. Macroinvertebrate Community Index; [MCI] Stark, 1993). Impacts can be expected to be less severe in streams that have highly disturbed, mobile beds, as tends to be true of many New Zealand streams (Winterbourn, 1995). In these streams the fauna tends to be dominated by species able to deal with bed disturbance, and fine sediments are mobilised and removed from the system by natural disturbance.

This report follows on from an earlier study (Bagrie, 1998) in which two sites (one dredged, one undredged) were surveyed. Bagrie found higher numbers of invertebrate species and higher values for measures of ecosystem health (Macroinvertebrate Community Index [MCI]; Stark, 1993) at the dredged site, however there was high variation and some confounding factors present. This study builds on Bagrie's work and uses her data as background. The current study utilises a classical BACI (Before, After, Control, Impact) design to try and address the problems that Bagrie encountered with inter-site variability.

Methods:

Site Description:

The Pomahaka River at the site of dredging is a fourth order stream flowing through low intensity farmland (pasture interspersed with remnant tussock). The surrounding landscape is rolling hill country. Riparian margins of the stream are not fenced and there is abundant evidence of stock damage of banks. The riverbed is composed of bedrock sheets with a shallow (10-50cm) or absent covering of cobbles and pebbles. The nature of the bed is unstable and loosely consolidated. This area was extensively worked for gold last century, and in many places the river is reworking tailings from past gold mining activities. These contribute a significant amount of silt to the stream.

The study reach is comprised of a series of run-riffle/pool sequences that are unshaded by vegetation.

Sampling locations:

The river was sampled at two locations, a control site upstream of the intended dredging operations and a site that was dredged (Figure 1). Both locations were shallow riffles (30-50cm deep) with cobble/pebble substrate. The two locations were sampled twice, once (3/2/01) before dredging took place at the lower site (5/2/01), and once after the lower site had been dredged (10/2/01). By comparing the change at the upper site (the control, not dredged) with the change in the lower site (dredged) we can ascertain how much change has been due to the dredging operations and how much is due to natural variation.

Field Sampling:

At each location three kick-net samples (ORC, 1998) were taken. A 250 micron mesh net was placed downstream of an area of cobbles which was disturbed to a depth of 10cm until a sample of 400 mL of river fines and invertebrates was achieved.

In addition, some samples were taken during dredging operations in November (25/11/00). Measurements of water clarity were taken (using a Secchi disk) upstream of dredging operations, downstream 1m (directly in the dredge tailing flow and 1 m to the side of the dredge), 5m, 20m, 50m and 500m (in the centre of the stream). Water samples

were also taken upstream of the dredge, 1m downstream, 50m downstream, and 300m downstream and returned to the lab for further clarity analyses.

Sample Processing and Sample Analysis:

Invertebrate samples were sieved through a 250µ sieve to remove fine material and picked and identified live. Contents of the sieves were then placed in a white tray and macroinvertebrates removed. The macroinvertebrate samples were then identified under dissecting microscope (10-40X) and binocular microscopes (100-400X) using criteria from Winterbourn & Gregson (1989) and Towns and Peters (1996). Where necessary (as for Leptophlebiid mayflies and Chironomidae), permanent mounts of mouthparts were prepared to aid in identification.

To measure water clarity duplicate 10mL samples of water were taken from each water sample. Absorbance of samples at 665nm (measuring turbidity) were taken using a Shimadzu spectro-photometer.

Data Analysis:

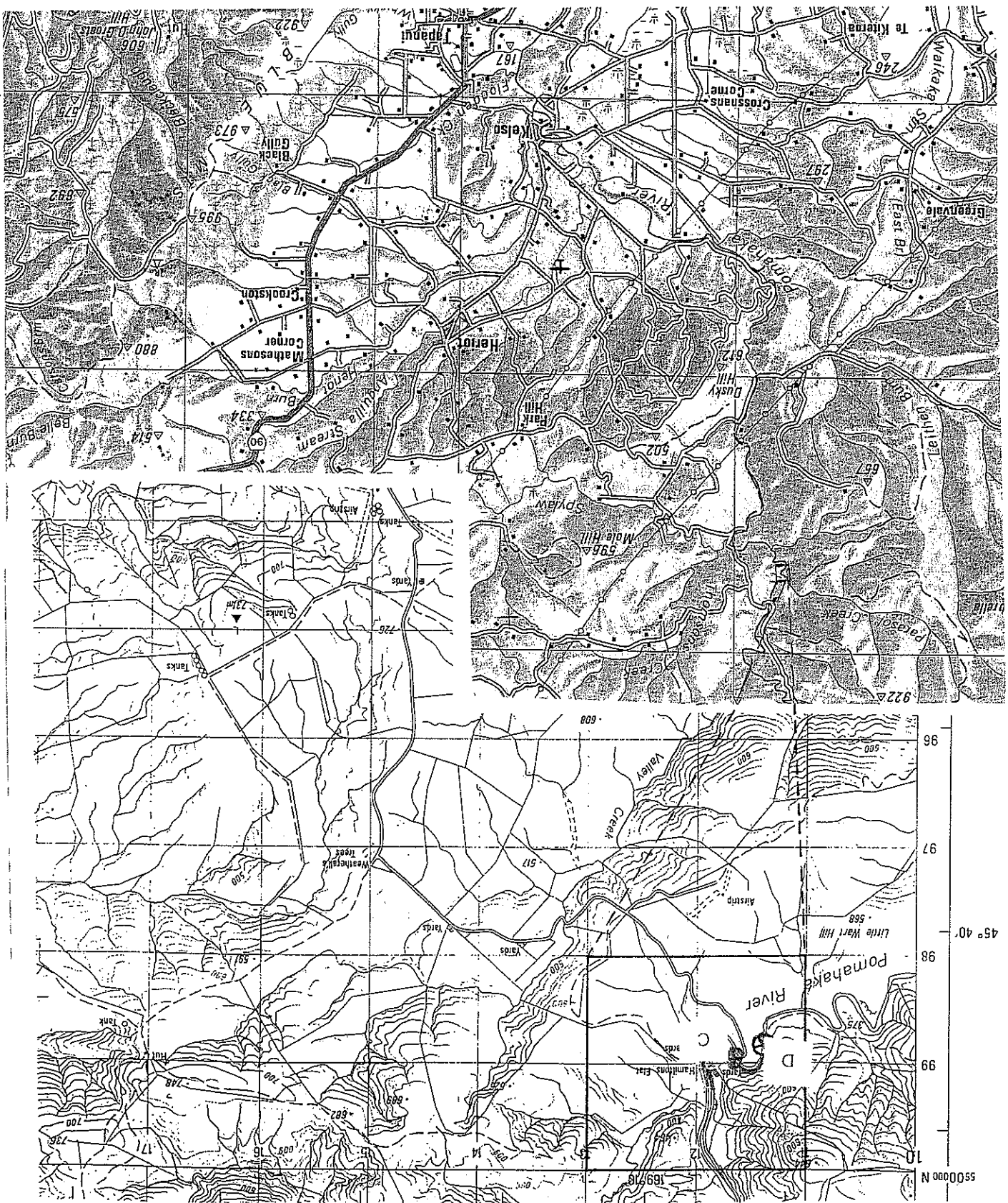
In addition to number of taxa, the Macroinvertebrate Community Index (MCI; Stark, 1993) and Open-ended MCI (OEMCI; ORC, 1998) were calculated. The MCI uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream.

$$MCI = \left(\frac{\sum \text{of taxa scores}}{\text{Number of scoring taxa}} \right) \times 20$$

A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site. Taxon scores are between 1 and 10, with low scores indicating high tolerance to organic pollution and high scores indicating the taxa that will only be found in “pristine rivers” (ORC, 1997).

The OEMCI is a derivative of the MCI that is abundance weighted. Invertebrates are classed as rare (<5/sample), common (5-19/sample) or abundant (20+/sample). The taxon scores are then multiplied by an abundance weighting (1=rare, 3=common, 5=abundant) before being summed in the same way as above.

FIGURE 1. Map showing location of sampling sites. The dredged site is marked 'D' and the control site is indicated with a 'C'.



Results:

Water clarity:

Dredging observed in November, 2000, resuspended significant amounts of fine sediment and disturbed the stream bed. Despite this, there were no obvious differences in bed consolidation or armouring between dredged and undredged areas. The bed was unstable, and large cobbles could easily be overturned. Fine sediment was obvious in the water column immediately behind the dredge but was not noticeable 10 metres downstream. Even immediately behind the dredge the streambed was still visible through the water.

Secchi depths were much greater than the depth of the stream. There was evidence of reduced Secchi depths in the 5m immediately behind the dredge but no change further downstream even after 1 hr of dredging activity (Table 1).

TABLE 1. Secchi depths in Pomahaka R. during dredging operations in November, 2000. d/s = downstream. Secchi depth describes the water depth at which a standard black and white disk is still clearly visible. Three measurements were taken, the mean is shown.

Distance d/s of dredge (m)	Location	Secchi Depth (mm)
1	Behind dredge	230
	1m to side of dredge	>500
5	Behind dredge	430
	1m to side of dredge	450
20	Mid stream	>500
50	Mid stream	>500
300	Mid stream	>500
Pre dredging	Mid stream	>500

Water clarity as measured by absorbance at 665nm was very high but was reduced 1m behind the dredge (Table 2). Differences were not detectable 20m downstream or 300m downstream.

TABLE 2. Absorbance of 665nm light by water samples taken during dredging of the Pomahaka R. in November, 2000. High values indicate high turbidity. Values shown are the means of two samples.

Location	Absorbance
Upstream of dredge	0.012
1m downstream of dredge	0.051
20m downstream	0.016
300m downstream	0.011

Invertebrate samples:

The number of taxa found in this study (7-14) was slightly lower than the average of 14 for New Zealand rivers (Quinn and Hickey 1990) (Table 3). The value was also much lower than the 14-26 taxa found by Bagrie (1998) (Appendix One). Species composition of the samples from this study and those of Bagrie's (1998) were broadly similar, although some rare species were absent for the 2001 samples. Several species indicative of very high quality habitat (e.g. *Stenoperla prasinia*) were present in the samples although in low abundances. Values for MCI were similar to Bagrie's (1998) and moderate to high. Both sites would be classified as high quality (MCI score >100) according to Otago Regional Council criteria (ORC, 1998). OEMCI values were lower than those recorded in the previous study, and would classify these sites as being of average quality. This is mainly due to the relatively low abundances of all invertebrates recorded in this study.

Sampling post-dredging revealed no clear differences (Table 4). Both the control site and dredged site samples contained similar numbers of species and had similar MCI scores (Figure 2), with no statistically significant differences evident (two-sample t-test). OEMCI values had declined slightly (Figure 3), although this difference was not

statistically significant for either site (two sample t-test). There were no apparent patterns in the presence or absence of species that could be correlated with dredging activities.

TABLE 3. Species present in kick-net samples from Pomahaka R. taken pre-dredging (3/2/01). R=<5 individuals/sample, C=5-19 individuals, A=20+ individuals. Taxon scores (ORC, 1998) for pollution tolerance are shown, low scores = high tolerance. Sites denoted BI are to be dredged, sites marked BC are controls.

Group	Species	Score	BI			BC		
Mayflies	<i>Deleatidium myzobranchia</i>	8	A	A	A	A	A	A
Stoneflies	<i>Megaleptoperla grandis</i>	9			R	R		
	<i>Stenoperla prasinia</i>	10		R		R	R	C
	<i>Zelandoperla fenestrata</i>	8					R	
Dobsonflies	<i>Archicauliodes diversus</i>	7		R	R	R	R	
Dipterans	<i>Aphrophila neozelandica</i>	5				R		R
	<i>Austrosimulium australense</i>	3			R		R	
	Empididae	3	R					
	<i>Mischoderus</i> sp.	4			R			
	<i>Paralimnophila skusei</i>	6		R	R		R	C
	<i>Pirara matakiri</i>	3			R			
	<i>Rhabdomastrix</i> sp.	5		R				
Coleopterans	<i>Hydora nitida</i> (adults & larva)	6	A	A	A	A	C	A
Caddisflies	<i>Aoteapsyche raruraru</i>	4	R	R	R	R	C	
	<i>Chostachorema xanthoptera</i>	7			R		R	C
	<i>Helicopsyche albescens</i>	10		R				
	<i>Hydrobiosis frater</i>	5	R		R	R	C	C
	<i>Hydrobiosis parumbripennis</i>	5						R
	<i>Neurochorema confusum</i>	6						R
	<i>Olinga feredayi</i>	9	C	C		C	C	C
	<i>Polyplectropus puerilis</i>	6				R		
	<i>Psilachorema bidens</i>	6		R	R	R	R	
Molluscs	<i>Potamopyrgus antipodarum</i>	4		C	R			
Oligochaeta	Oligochaete worms	1	C	C	C	C	C	C
	Number of Taxa		7	12	14	12	11	11
	MCI		103	123	104	127	145	124
	Average MCI		110			132		
	OEMCI		294	242	187	253	295	364
	Average OEMCI		241			304		

TABLE 4. Species present in kick-net samples from Pomahaka R. taken 10/2/01. R=<5 individuals/sample, C=5-19 individuals, A=20+ individuals. Taxon scores (ORC, 1998) for pollution tolerance are shown, low scores = high tolerance. Sites denoted AI were dredged on the 5/2/01, sites marked AC are controls.

Group	Species	Score	AI			AC		
Mayflies	<i>Deleatidium myzobranchia</i>	8	A	A	A	A	C	A
	<i>Nesameletus scita</i>	9	R			R		
Stoneflies	<i>Stenoperla prasinia</i>	10			R		R	R
	<i>Zelandobius confusus</i>	5			R			
Dobsonflies	<i>Archicaultiodes diversus</i>	7		R	R	R	R	R
Dipterans	<i>Aphrophila neozelandica</i>	5		R	R	R		R
	<i>Austrosimulium australense</i>	3		R				
	Empididae	3					R	
	<i>Mischoderus</i> sp.	4		R				
	<i>Paralimnophila skusei</i>	6	R	C	C	C	C	C
	<i>Pirara matakiri</i> .	3					R	
	<i>Rhabdomastrix</i> sp.	5		R				
Coleopterans	<i>Hydora nitida</i> (adults & larva)	6	A	A	A	A	A	A
Caddisflies	<i>Aoteapsyche raruraru</i>	4	R	R	R	R	R	R
	<i>Chostachorema xanthoptera</i>	7		R	R		R	
	<i>Hydrobiosis frater</i>	5	R		R	R	R	R
	<i>Hydrobiosis parumbripennis</i>	5	R				R	
	<i>Olinga feredayi</i>	9	R		C	C	R	C
	<i>Psilachorema bidens</i>	6	R	R	R	R	R	
	<i>Pycnocentrodes</i> sp.	5				R		
Oligochaeta	Oligochaete worms	1	R	R	C		C	C
	Number of Taxa		10	12	13	11	14	10
	MCI		118	103	122	127	114	122
	Average MCI		114			121		
	OEMCI		230	217	257	284	191	298
	Average OEMCI		235			258		

FIGURE 2. MCI scores for impact (dredged) and control sites before and 5 days after dredging. Results shown are a mean of three samples.

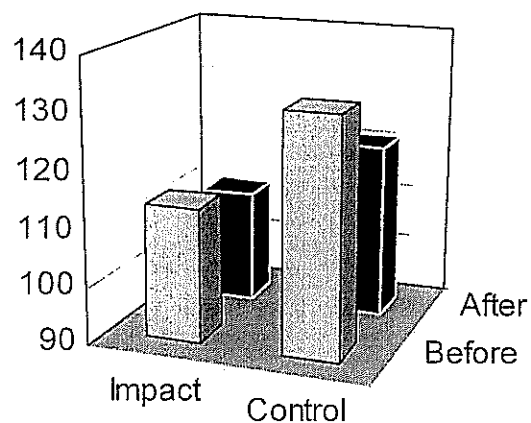
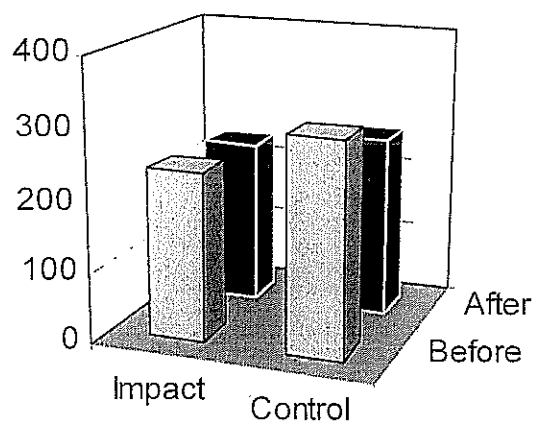


FIGURE 3. OEMCI scores for impact (dredged) and control sites before and 5 days after dredging. Results shown are a mean of three samples.



Discussion:

This study clearly shows impacts of dredging on water clarity in the immediate vicinity of dredge operations, and there are clearly disturbance effects on the streambed. However the lack of any clear evidence of detrimental effects on benthic macro-invertebrates suggests that this effect is relatively short term. Invertebrates found included species that are considered indicative of high quality habitat. In this area these species are present because of a lack of organic pollution, and may not be good indicators of any detrimental effects of physical disturbance of the streambed. Therefore interpretation of MCI and OEMCI values from a single sampling occasion is likely to be less meaningful. However comparisons of species richness, MCI and OEMCI before and after disturbance will provide an index of the impact of dredging operations.

In a stable environment, where the stream bed is armoured and disturbance events are rare, disturbance intolerant taxa may come to predominate. Disturbing these environments may cause species to be lost. The Pomahaka River however has a loose bed and can be classified as a high disturbance system. The fauna is dominated by species that display traits that infer disturbance resistance (Townsend et al. 1997). These species are adapted to a high disturbance environment and some may even be capable of physically passing through the dredge without damage (Griffith and Andrews, 1981). Where localised detrimental effects occur it is likely that the diffuse and patchy nature of the disturbances will allow invertebrates to re-colonise quickly (Hall, 1988). Dredging operations on the scale taking place for this study are not of comparable scale or intensity to natural high flow events.

This study can find no evidence of medium term impacts on stream macro-invertebrates due to gold-dredging activities. This is probably due to the disturbed nature of the habitat, which has resulted in the presence of a disturbance resistant fauna. The effects of dredging operations, as compared to the effects of a flood or spate are likely to be extremely small. The effects of dredging on stream fish have not been studied here but are likely to be minimal (Harvey, 1986) unless there is direct dredging activity in trout redds (Griffith and Andrews, 1981). Effects on invertebrates would be increased if the operator were to dredge in areas where banks of fine sediment have accumulated or beneath undercut stream banks. Currently, operations are not carried out in those areas, and it is recommended that those precautions continue.

Appendix One:

Species present in Pomahaka R. 1998 (adapted from Bagrie 1998). D = dredged site, sites marked U are controls. were dredged in the preceding season. See Table 4 above for key to codes and explanation.

Group	Species	Score	D			U		
Mayflies	<i>Ameletopsis</i>	10					R	
	<i>Austroclima</i>	7	A	A	A			R
	<i>Coloburiscus</i>	7			R			
	<i>Deleatidium</i>	8	A	A	A	A	A	A
	<i>Nesameletus</i>	9	R					
Stoneflies	<i>Megaleptoperla</i>	9			R			
	<i>Stenoperla</i>	10	R	R		R	C	R
	<i>Zelandobius</i>	5	C	C	C	R	C	C
Dobsonflies	<i>Archicauliodes diversus</i>	7	C	C	R	R	R	R
Dipterans	<i>Aphrophila neozelandica</i>	5	A	A	A	R	C	C
	<i>Austrosimulium australense</i>	3	R	R	C	R	C	R
	Chironominae	3		R	R		R	
	Empididae	3	R		R		R	
	<i>Ephydrella</i>	4						R
	Orthocladinae	3	R		R			R
	<i>Paratimnophila skusei</i>	6	C	R			R	R
	<i>Rhabdomastrix</i> sp.	5	A	C	C	R	A	C
	Tanypodinae	5	C	R				
Coleopterans	<i>Hydora</i>	6	A	A	A	R	C	C
	Scirtidae	8				R	R	R
Caddisflies	<i>Aoteapsyche</i>	4	A	A	A	C	R	A
	<i>Chostachorema</i>	7	R		R			
	<i>Helicopsyche</i>	10	C					
	<i>Hudsonema</i>	5	R	R				
	<i>Hydrobiosis</i>	5	C	R	R	R		R
	<i>Olinga</i>	9	A	A	A	C	R	C
	<i>Polypsectropus</i>	6	R					
	<i>Psilachorema</i>	6	C	C	C	A	A	A
	<i>Pycnocentria</i>	7		R	R			
	<i>Pycnocentrodus</i>	5	A	C	A			
	<i>Tiphobiosis</i>	5	R	C	R			R
Molluscs	<i>Potamopyrgus antipodarum</i>	4	C	C	C	R		R
Oligochaeta	Oligochaete worms	1						
Crustacea	Ostracoda	1	R				R	
	Number of Taxa		26	21	22	14	16	19
	MCI		115	114	112	104	124	116
	Average MCI		114			115		
	OEMCI		339	315	314	239	291	239
	Average OEMCI		323			256		

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