Tadmor River Water Augmentation Scheme - Ecological Aspects Revisited

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Tadmor River Water Augmentation Scheme - Ecological Aspects Revisited

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Prepared for

INTEGRATED CATCHMENT MANAGEMENT for the Motueka River
•ridge tops to the sea•

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EXECUTIVE SUMMARY

This study revisited the sites sampled by Stark (1986) twenty years after that study was conducted to assess whether water quality in the Tadmor River catchment had changed in the intervening years. Concentrations of dissolved reactive phosphorus and nitrate-nitrogen recorded in 2006-2007 were similar to those recorded in 1986. However, concentrations of ammonium-nitrogen were higher in samples collected in 2006-2007 than in 1986. Both nitrate-nitrogen and ammonium-nitrogen were low in the headwater sites and increased with distance travelled downstream, reflecting the cumulative impacts of run-off from agricultural land in the catchment upstream of this sampling location.

In 1986, all four sites sampled (H1, T1, T2, T3) had macroinvertebrate communities indicative of good or excellent water quality. Similar results were obtained in samples collected on 25 September 2006 and 7 January 2007, with the macroinvertebrate communities of most sites indicating good or excellent water quality. However, the lowest site in the Tadmor River (T3), had MCI values indicative of 'good' water quality on both recent sampling occasions, but had a SQMCI value indicative of 'fair' water quality on 7 January 2007. This result is consistent with the highest nitrate-nitrogen and ammonium-nitrogen concentrations being observed at this site on this occasion and is likely to reflect the cumulative effects of agricultural non-point source pollution from the catchment upstream of this sampling location.

Three sites were sampled in the upper Tadmor Catchment to consider if the water augmentation scheme had any discernable effect on macroinvertebrate communities of the Tadmor River. These sites were sampled on two occasions: before the water augmentation scheme was operating for the irrigation season (September 2006), and once the scheme was in operation (January 2007). Differences in community structure were observed between the two sampling occasions, but the differences observed were similar at all three sites sampled, so are unlikely to be a result of the water augmentation scheme. These results provide no evidence to suggest that the water augmentation scheme affects water quality in the upper Tadmor catchment.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

In 1986, the Nelson Catchment Board commissioned the Cawthron Institute to investigate the ecological consequences of the Tadmor Water Augmentation Scheme (henceforth referred to as "the water augmentation scheme"). The water augmentation scheme involves the diversion of water from the upper Hope River into the Tadmor River and was intended to increase the reliability of water supply for water users during summer low flows. To gauge the aquatic values of the Tadmor catchment, a field survey was conducted to describe habitat conditions and sample fish, macroinvertebrates and macroalgae at three sites in the Tadmor River and at one site in the upper Hope River (Stark, 1986).

This study revisits the sites sampled by Stark (1986) twenty years after the initial study was conducted to consider water quality patterns within the Tadmor Catchment and whether water quality has changed relative to 1986 levels. In addition, replicate sampling in the upper Tadmor Catchment was conducted to consider whether the water augmentation scheme has any discernable effect on the macroinvertebrate communities or water chemistry of the Tadmor River.

2. METHODS

2.1. Sampling Sites

This study revisited the sites sampled by Stark 1986, three of which were in the Tadmor River and one of which was in the upper Hope River (Table 1). In addition to these sites, samples were collected from two other sites in the Tadmor River, and one site in Gorge Creek, a tributary of the upper Tadmor River (Table 1).

Table 1. Locations of the sampling sites in the Tadmor and Hope catchments.

	Site code	Distance from mouth (km)	Easting	Northing	Description
Upper Hope River	**H1**	39.9	2481379	5956887	Upstream of weir
Upper Tadmor	**UT1**	35.9	2483780	5959600	Immediately upstream of Gorge Creek confluence
Gorge Creek	**GC1**	35.7	2483790	5959690	Immediately upstream of confluence with Tadmor River
Tadmor T1	**T1**	35.7	2483939	5959766	Beneath bridge downstream of Gorge Ck-Tadmor R. confluence
Tadmor T2	**T2**	28.8	2486840	5963220	Immediately downstream of bridge on Tui Road
Tadmor T2.5	**T2.5**	19.8	2488345	5968130	Immediately downstream of bridge on Picketts Road
Tadmor T3	**T3**	4.7	2493035	5978075	Upstream of bridge on Golden Harvest farm - near swing bridge

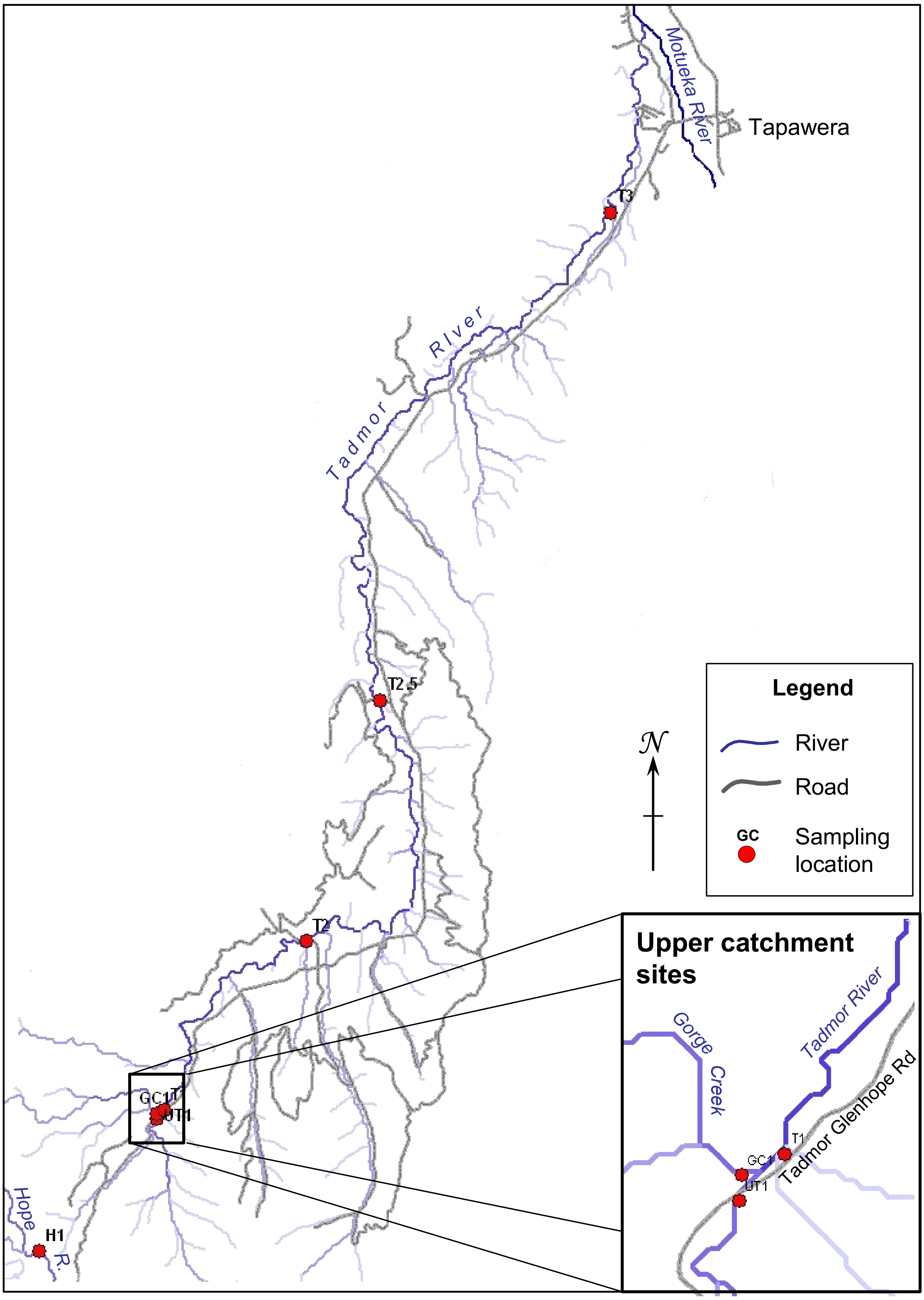

Figure 1. Map of the Tadmor catchment showing the locations sampled in this study. Sampling site abbreviations are outlined in Table 1.

Figure 2. Photographs of the sites sampled in this study. **a)** Upper Hope River (upstream of weir), **b)** Gorge Creek immediately upstream of confluence with Tadmor River, **c)** Upper Tadmor River (immediately upstream of Gorge Creek confluence), **d)** Tadmor River site T1, **e)** Tadmor River site 2 immediately downstream of Tui Road bridge, **f)** Tadmor River site 2.5 immediately downstream of Picketts Road bridge. **Continued overleaf**

Figure 2. cont. Photographs of the sites sampled in this study. **g)** the Tadmor Water augmentation scheme weir on the upper Hope River, and **h)** Tadmor River, site T3 upstream of bridges on Golden Harvest farm

2.2. Field Methods

2.2.1. Macroinvertebrate sampling

A single semi-quantitative kick-net (0.5 mm mesh) sample was collected from sites H1, T1, T2, T2.5 and T3 on each sampling occasion following sampling Protocol C1 (Stark et al. 2001). Each sample was transferred to a white tray for inspection and then into a labelled 1 L plastic pottle and preserved with 70% ethanol.

At the sampling sites in the Upper Tadmor River (UT1), Gorge Creek (GC1), and Tadmor River (T1), five quantitative Surber samples were collected following sampling protocol C3 (Stark et al. 2001), transferred to a white tray for inspection and then into a labelled 1 L plastic pottle and preserved with 70% ethanol.

2.3. Laboratory Methods

2.3.1. *Water analyses*

Water samples collected on 25 September 2006 and 7 January 2007 were analysed on a Lachet flow injection analyser to determine the concentration of dissolved reactive phosphorous (method 4500 G. – APHA, 1998), ammonium-nitrogen (NH_4-N) (method 4500NH_3 H. – APHA,1998), nitrate-nitrogen (NO_3-N) (method 4500NO_3 I. – APHA, 1998), and dissolved organic carbon (method 5310 – APHA, 1998).

2.3.2. *Macroinvertebrate processing*

In the laboratory, each sample of macroinvertebrates was washed through a series of Endecott sieves (4 mm, 1 mm, and 0.5 mm mesh) to assist separation of animals from debris. All macroinvertebrates were identified to the level required for Macroinvertebrate Community Index (MCI) analysis.

The semi-quantitative hand-net samples were processed following protocol P1 (Coded abundance: Stark et al. 2001) and their relative abundances assessed on a 'Rare' (1-4 individuals/sample), 'Common' (5-19), 'Abundant' (20-99), 'Very Abundant' (100-499), 'Very, Very Abundant' (>499) scale. A binocular microscope (35x-160x magnification) was used to aid identification.

The quantitative Surber samples were processed following protocol P3 (Full count: Stark et al. 2001). A binocular microscope (35x-160x magnification) was used to aid identification.

2.4. Data analysis

Physicochemical parameters (specific conductance, DRP, NH_4-N, NO_3-N) were compared between the three occasions (date factor) and the four sites sampled by Stark (1987) (H1, T1, T2, T3; site factor) using a two-factor main effects ANOVA. Because only a single sample was taken from each site on each occasion, it was not possible to assess whether an interaction effect was present.

Multivariate analyses were carried out on Bray-Curtis similarities in Primer version 6.1 (Primer-E, Plymouth PL6 7DX, United Kingdom). Multivariate analyses on semi-quantitative data were conducted by substituting coded abundances (outlined in Section 2.3) with numerical values (rare = 1, common = 2, abundant = 3, very abundant = 4, very, very abundant = 5).

An analysis of similarities (ANOSIM) was used to compare the macroinvertebrate communities between the three sites in the upper Tadmor from sampling conducted in September 2006 and January 2007. This analysis was conducted as a one-way ANOSIM on a date-patch factor, where the two sampling occasions for each site were considered as separate levels of the factor (2 dates x 3 sites = 6 levels). Differences among the three sites on each sampling occasion were interpreted from pair-wise tests produced by ANOSIM. The similarity percentages procedure (SIMPER) also was conducted on these data to determine which taxa contributed the most to any differences apparent between the sites.

3. RESULTS

3.1. Hydrological conditions

Multiple high-flow events (5-6 times baseflow) occurred during the period of this study (spring 2006-summer 2007) (Figure 3). Sampling on 25 and 27 September 2006 was conducted towards the end of a recession following a spate of 2500 l s^{-1} that occurred on 26 August 2006 (Figure 3b). Mean daily flow on both 25 and 27 September was approximately 450 l s^{-1} and mean daily flows for the preceding 14 days ranged from 430-650 l s^{-1}. Flows were consistently high from 1 October 2006-1 January 2007, and regular high-flow events occurred during this period, with the largest on 18 November 2006 in excess of 58,500 l s^{-1} (Figure 3a). Because high flows can affect invertebrate community composition, sampling after the water augmentation scheme was opened was not possible until early January 2007. Sampling on 9 January 2007 occurred at the end of the recession from high flows experienced in November-December 2006 (Figure 3b). The mean daily flow on 9 January was approximately 236 l s^{-1} and mean daily flows for the preceding 14 days ranged from 240-730 l s^{-1}.

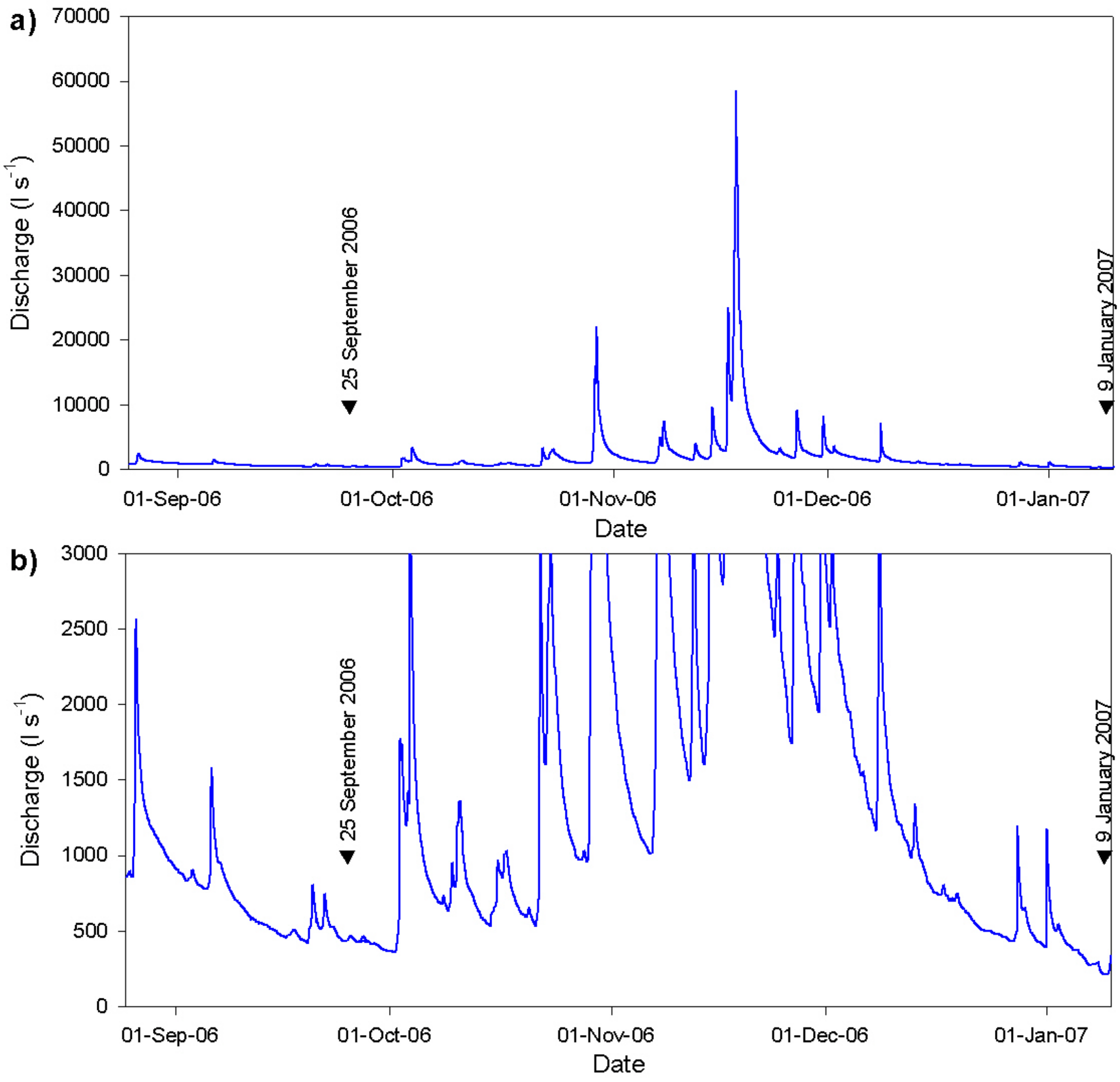

Figure 3. Discharge in Tadmor River from 25 August 2006 to 10 January 2007. Part a) shows the full range of discharge, while part b) shows only the lower part of the hydrograph in detail.

3.2. Physicochemical parameters

Specific conductance was lower in the upper Hope River than in the Tadmor River on all three occasions (Figure 4a). In general, specific conductance was highest at the downstream sites in the Tadmor River, (Figure 4a; $F_{3,6} = 26.3$, $p = 0.0008$). It is impossible to assess the significance of any differences apparent in Figure 4 in the absence of estimates of the temporal variability in these variables.

Concentrations of dissolved reactive phosphorus (DRP) at all sites were similar on the three occasions and showed a general trend of being highest at Site T1 and decreasing downstream in the Tadmor River (Figure 4b; $F_{3,6} = 53.1$, $p = 0.0001$). The single sample in the Upper Tadmor River site on 9 January 2007, yielded much higher levels of DRP relative to most other sites, and may account for elevated levels observed at site T1. However, sampling this site on multiple occasions would be necessary to confirm this.

Concentrations of ammonium-nitrogen were similar across sampling occasions and sites (Figure 4c; Date: $F_{3,6} = 2.7$, $p = 0.14$; Site: $F_{3,6} = 3.4$, $p = 0.10$). Concentrations of NO_3-N were similar on the three sampling occasions ($F_{3,6} = 8.5$, $p = 0.014$) and were highest at sites low (T2 & T3) in the catchment (Figure 4d; $F_{2,6}$=1.4, p=0.32).

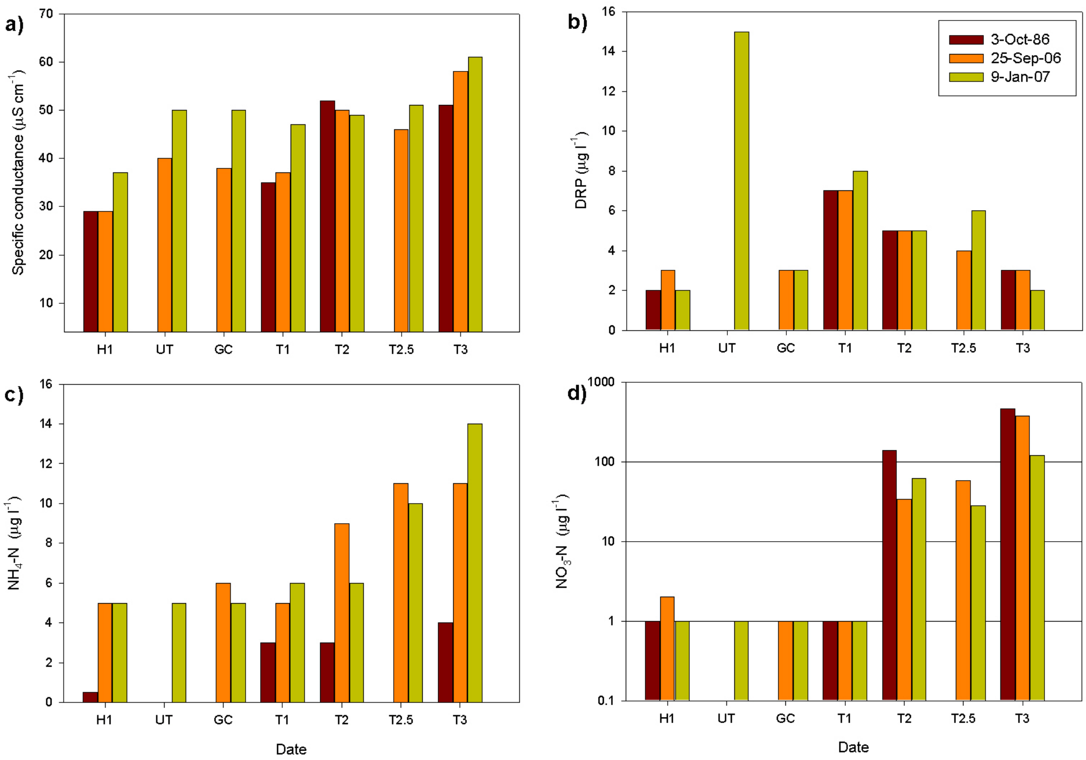

Figure 4. Physicochemical conditions in the upper Hope River (H1) and Tadmor River (see Table 1 for site codes) on the three sampling occasions. a) Specific conductivity, b) dissolved reactive phosphorous (DRP), c) ammonium-nitrogen (NH_4-N), and d) nitrate-nitrogen (NO_3-N; note the logarithmic scale). The detection limit for NO_3-N was 1 µg l^{-1} in samples collected in 1986 and 2 µg l^{-1} in samples collected in 2006 and 2007. The detection limit for NH_4-N was 1 µg l^{-1} and values below these values in parts c) and d) above were below the detection limit.

Table 2. Physicochemical conditions at the study sites in the Tadmor and Hope Rivers on 3 October 1986 (from Stark 1986), 25 and 27 September 2006, and 9 January 2007.

	date	Temp (ºC)	Specific Cond. (uS/cm)	DO (% sat.)	DO (mg/l)	pH	DRP (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	DOC (mg/l)
Upper Hope River H1	3/10/1986	9.5	29	97.0	11.1	6.8	0.002	<0.001	<0.001	
Tadmor T1	3/10/1986	10.0	35	98.0	11.0	6.9	0.007	0.003	<0.001	
Tadmor T2	3/10/1986	11.0	52	96.0	10.6	6.9	0.005	0.003	0.14	
Tadmor T3	3/10/1986	14.5	51	109.0	11.2	6.9	0.003	0.004	0.46	
Upper Hope River	25/9/2006	8.3	29	108.4	12.7		0.003	0.005	0.002	3.2
Upper Tadmor	25/9/2006	9.9	40	110.9	12.5	5.86				
Gorge Creek	25/9/2006	8.6	38	108.5	12.7	5.8	0.003	0.006	<0.002	3.9
Tadmor T1	27/9/2006	8.6	37	107.4	12.5	5.95	0.007	0.005	<0.002	3.8
Tadmor T2	25/9/2006	11.4	50	112.2	12.3		0.005	0.009	0.034	3.3
Tadmor T2.5	25/9/2006	15.1	46	109.9	11.1		0.004	0.011	0.058	2.7
Tadmor T3	25/9/2006	14.2	58	113.7	11.7	6	0.003	0.011	0.38	2
Upper Hope River	9/1/2007	12.5	37	102	10.9	7.52	0.002	0.005	<0.002	2.7
Upper Tadmor	9/1/2007	13.6	50	101.4	10.54	7.65	0.015	0.005	<0.002	3.4
Gorge Creek	9/1/2007	13.12	50	101.3	10.65	7.54	0.003	0.005	<0.002	4.3
Tadmor T1	9/1/2007	13.29	47	102.3	10.71	7.55	0.008	0.006	<0.002	3.8
Tadmor T2	9/1/2007	15.59	49	94	9.36	7.47	0.005	0.006	0.062	4.3
Tadmor T2.5	9/1/2007	17.13	51	102.9	9.92	7.64	0.006	0.01	0.028	2.4
Tadmor T3	9/1/2007	17.96	61	109.6	10.39	7.73	0.002	0.014	0.12	1.9

3.3. Macroinvertebrate communities

3.3.1. Longitudinal patterns

Macroinvertebrate communities at all four sites in the upper Hope and Tadmor Rivers were indicative of excellent or good water quality (%EPT taxa ≥50%, MCI ≥100, SQMCI ≥5.00) on 3 October 1986 (Figure 5). Similarly, on 25 September 2006 and 9 January 2007, macroinvertebrate communities at all sites, except T3 in the lower Tadmor River, were indicative of excellent or good water quality (Figure 5). On both 25 September 2006 and 9 January 2007, Site T3 in the lower Tadmor River had an MCI value of between 100 and 120, which is indicative of 'good' water quality. However, the SQMCI scores of 4.91 on 25 September 2006 and 4.19 on 9 January 2007 suggest that water quality at this site was 'fair' (according to the quality classes of Stark 1998) (Figure 5). It should be kept in mind that these values have been calculated using single kick-net samples on each occasion. Stark (1998) estimated the precision of these indices calculated from different numbers of samples and found that MCI values calculated from single kick-net samples are expected to vary by as much as 10.8, and SQMCI values by as much as 0.83. Thus, whilst the SQMCI value at site T3 on 9 January 2007 was 4.19 (which is representative of 'fair' water quality), the error associated with this estimate means that the water quality at this site could have varied anywhere between 'good' and 'poor' (Figure 5d).

Samples from the five sites are relatively well separated in a 2-dimensional non-metric MDS ordination of the semi-quantitative invertebrate data (Stress = 0.14), with sites in the upper catchments falling in the upper part of the ordination, while sites further downstream are generally found in the lower part of the plot (Figure 6). In addition, samples collected in 1986 generally plot to the right of those collected on 25 September 2006 which, in turn, plot to the right of samples collected on 7 January 2007. The macroinvertebrate communities of sites in the upper right of this plot included the stonefly *Acroperla*, and the caddisfly *Zelolessica*. The first axis of the plot represents a gradient in the abundance of the mayfly *Nesameletus*, with samples plotting to the right having higher densities of *Nesameletus*. The second axis is largely a gradient in the abundance of the caddis flies *Pycnocentrodes* and *Psilochorema* spp. with sites in the lower catchment, with samples plotting towards the bottom of the plot having higher densities of these two taxa.

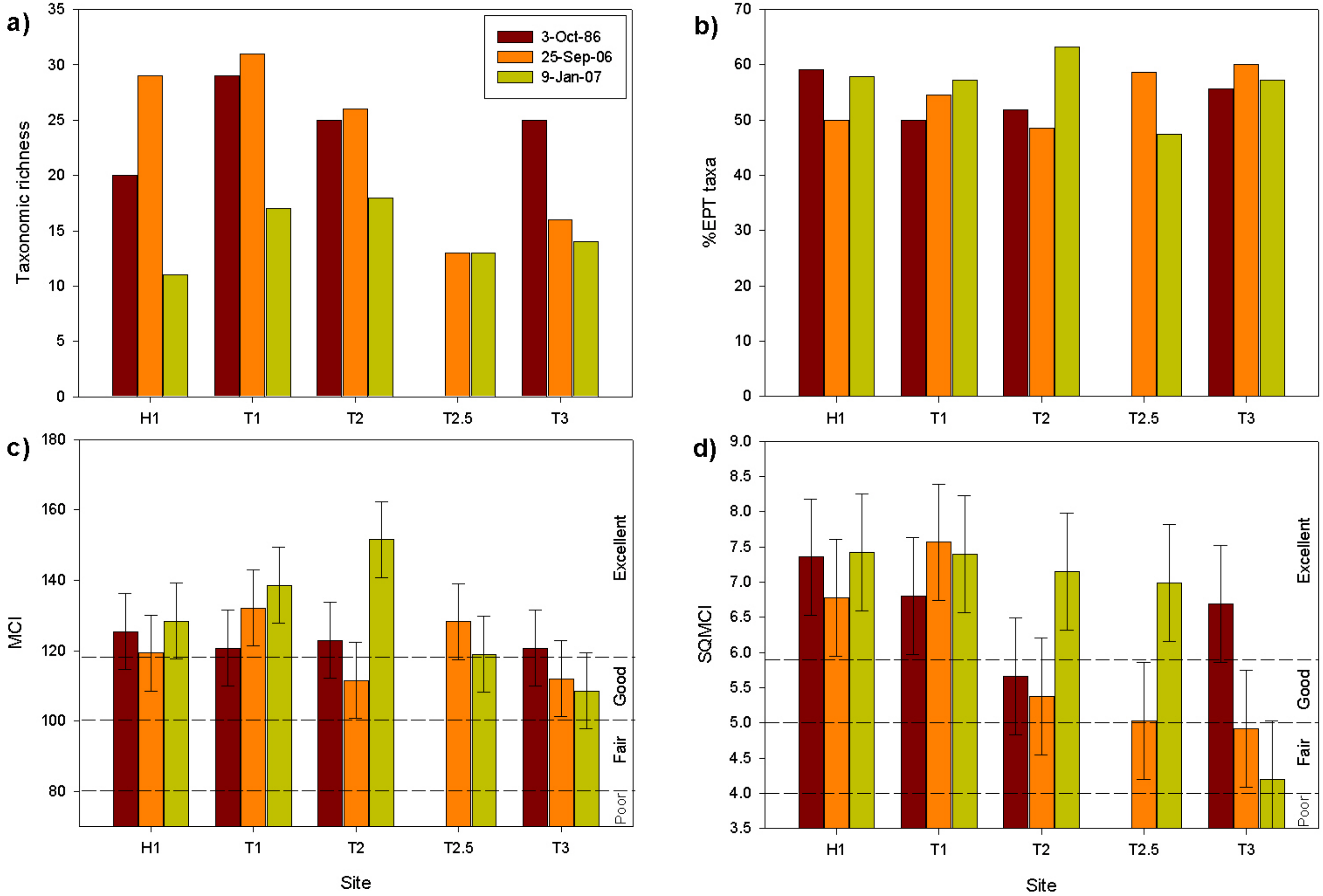

Figure 5. **a)** Taxonomic richness, **b)** % EPT taxa, **c)** macroinvertebrate community index (MCI), **d)** semi-quantitative macroinvertebrate community index (SQMCI) at five sites in the Tadmor River on the three sampling occasions. Parts b) and c) include water quality classifications from Stark (1998). Error bars on parts b) and c) represent the likely error associated with calculating these indices from single kick-net samples (from Stark 1998).

Table 3. Summary of the invertebrate community collected in kick-net samples at sampling sites in the Hope and Tadmor Rivers on the three sampling occasions (3 October 1986, 25 and 27 September 2006, 9 January 2007). Only taxa that were abundant at one or more sites on one or more occasions are shown. R = 'rare' (1-4 individuals per sample), C = 'common' (5-19 individuals per sample), A = 'abundant' (20-99 individuals per sample), - = not collected.

		Hope	**Tadmor**			**Hope**	**Tadmor**				**Hope**	**Tadmor**			
Site	MCI	**H1**	**T1**	**T2**	**T3**	**H1**	**T1**	**T2**	**T2.5**	**T3**	**H1**	**T1**	**T2**	**T2.5**	**T3**
Date	Score	**3/10/86**	**3/10/86**	**3/10/86**	**3/10/86**	**25/9/06**	**27/9/06**	**25/9/06**	**25/9/06**	**27/9/06**	**9/1/07**	**9/1/07**	**9/1/07**	**9/1/07**	**9/1/07**
EPHEMEROPTERA															
Nesameletus sp.	9	A	A	A	A	C	A	A	C	R	R	R	-	-	R
Coloburiscus humeralis	9	A	A	A	A	C	A	C	C	-	A	A	A	R	-
Deleatidium spp.	8	A	-	A	A	C	A	VA	VA	R	C	C	VA	VA	C
Austroclima jollyae	9	-	R	-	-	A	C	-	R	A	C	C	-	-	-
PLECOPTERA															
Zelandobius furcillatus	5	R	-	R	A	R	-	-	R	C	R	-	-	-	-
COLEOPTERA															
Hydraenidae	8	R	C	C	-	R	C	R	A	R	C	R	A	C	R
Elmidae	6	C	R	A	A	C	A	VA	A	R	A	C	VA	A	VA
DIPTERA															
Aphrophila neozelandica	5	C	C	A	R	R	R	C	C	-	R	R	C	C	-
Eriopterini	9	-	R	-	A	R	R	-	R	-	-	-	R	R	-
Maoridiamesa sp.	3	R	C	-	R	-	R	A	A	-	-	-	-	R	C
Orthocladiinae	2	C	C	A	A	C	C	VA	VA	A	R	-	-	C	VA
Austrosimulium	3	R	C	A	-	R	R	C	VA	A	R	C	C	C	C
Tabanidae	3	-	-	R	-	-	-	A	-	-	-	-	-	-	-
TRICHOPTERA															
Hydrobiosis spp.	5	-	C	C	C	-	R	C	R	A	R	C	A	A	A
Pycnocentrodes sp.	5	-	-	R	C	-	-	C	A	A	-	R	C	A	R
Olinga feredayi	9	-	R	C	A	-	C	-	R	-	-	-	A	C	-
Helicopsyche poutini	10	-	-	R	R	-	R	C	A	-	-	-	C	A	-
OLIGOCHAETA	1	C	R	A	C	C	R	R	R	R	R	-	-	R	R
Taxon richness		22	32	27	27	28	33	33	29	15	19	14	19	19	14
%EPT taxa		59%	50%	52%	56%	50%	55%	48%	59%	60%	58%	57%	63%	47%	57%
MCI		125	121	123	121	119	132	112	128	112	128	139	152	119	109
SQMCI		7.35	6.80	5.66	6.69	6.77	7.56	5.38	5.03	4.91	7.42	7.40	7.15	6.99	4.19

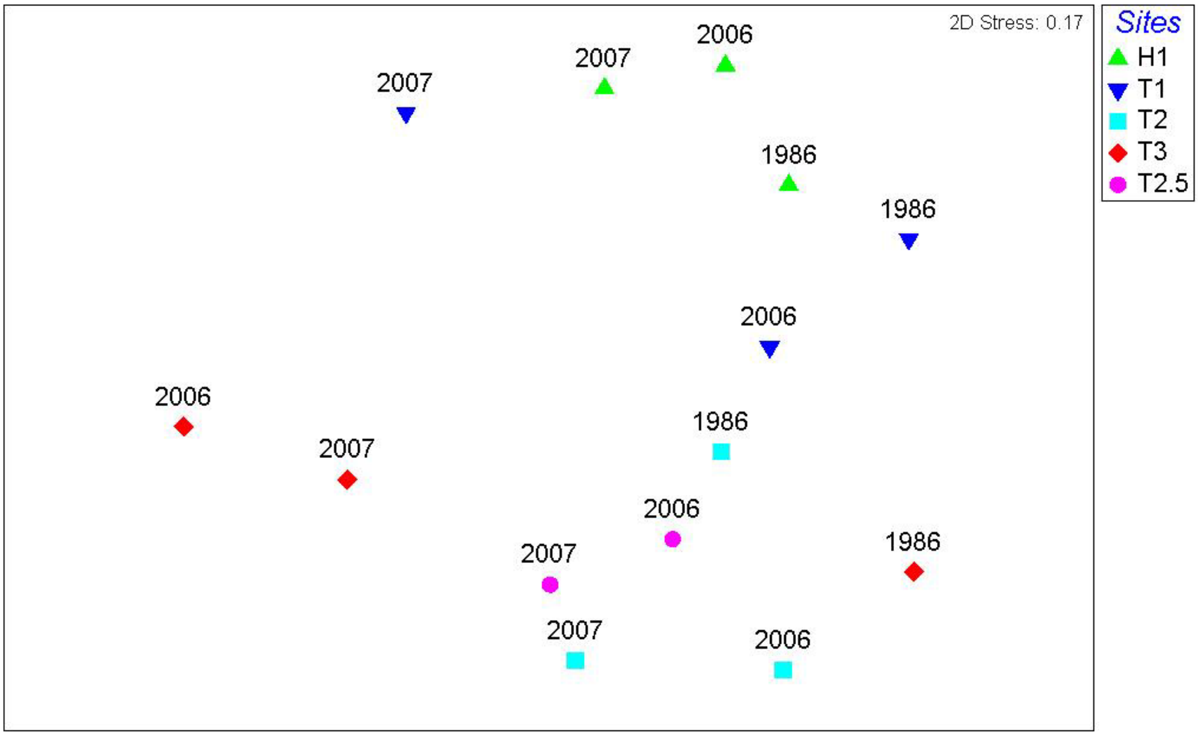

Figure 6. Two-dimensional non-metric multi-dimensional space ordination of the semi-quantitative invertebrate samples collected from the Hope (H1) and Tadmor (T1-T3) Rivers on the three sampling occasions.

3.4. Patterns in the Upper Tadmor Catchment

Three sites were sampled in the upper Tadmor Catchment to consider if the water augmentation scheme had any discernable effect on macroinvertebrate communities of the Tadmor River. Two sites that received the water from the scheme(Upper Tadmor, T1), were compared to a third site, Gorge Creek, which did not, and which acted as a reference site in this comparison.

To consider whether the water augmentation scheme was affecting water quality in the upper Tadmor catchment, two-way ANOVA were conducted. It was expected that there would be no significant difference between the three sites on 29 September 2006 (before the scheme was turned on), and that if the scheme was having an effect on the macroinvertebrate community that the two Tadmor sites (upper Tadmor (UT) and T1) would differ from the control site (Gorge Creek) which does not receive water from the water augmentation scheme. Therefore, a significant site-date interaction term may indicate that the scheme was affecting water quality in the Tadmor River. There is no evidence of a significant site-date interaction term for any of the water quality measures considered, suggesting that the water augmentation scheme was not affecting water quality in the upper Tadmor catchment.

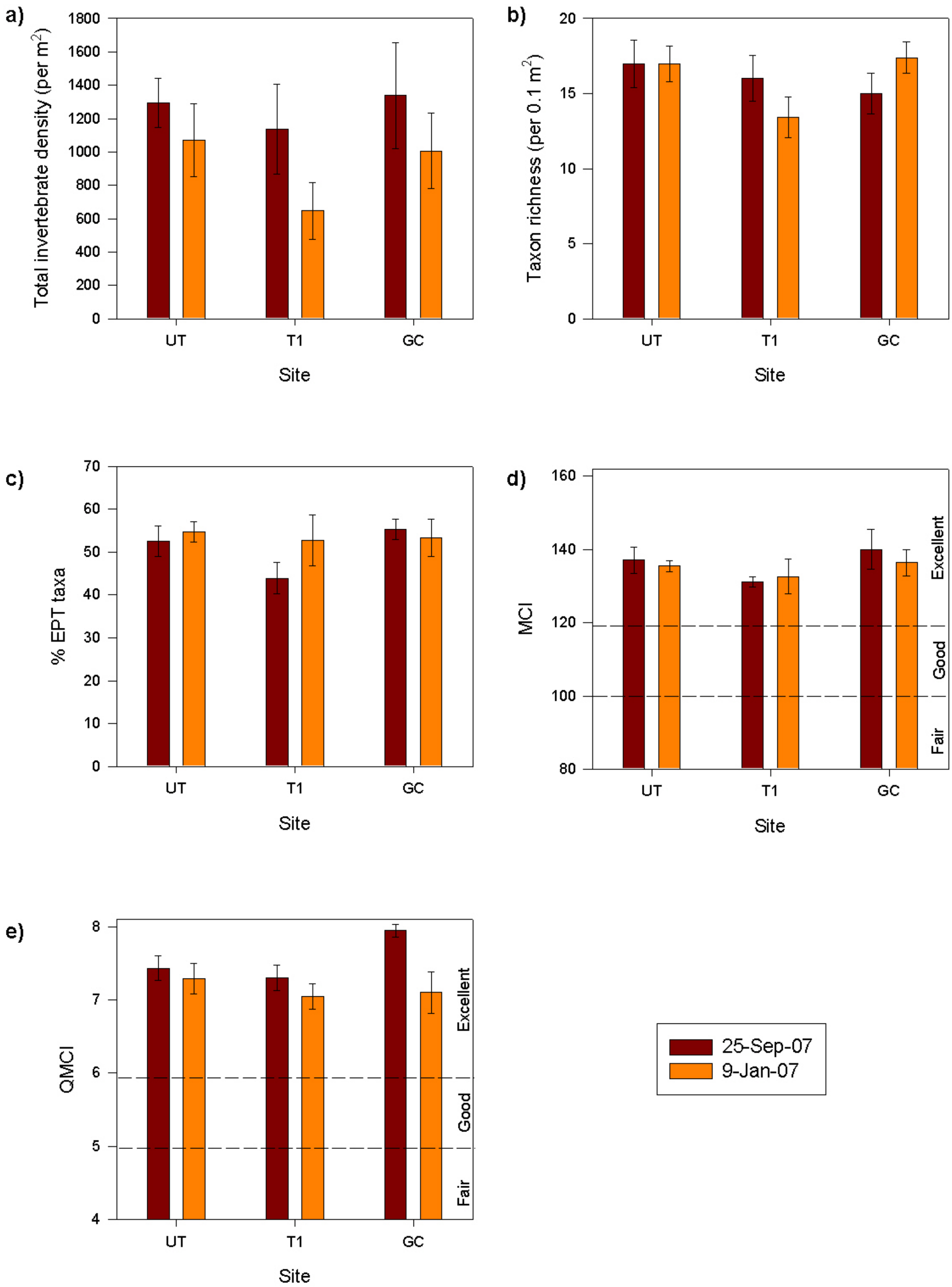

Figure 7. a) Total invertebrate densities, b) Taxonomic richness, c) %EPT taxa, d) macroinvertebrate community index (MCI), and e) quantitative macroinvertebrate community index (QMCI) at three sites in the upper Tadmor catchment on 25 September 2006 and 9 January 2007. Parts d) and e) include water quality classifications from Stark (1998). Error bars represent standard errors.

Table 4. Summary of mean invertebrate densities (and standard errors) collected in replicate Surber samples at sampling sites in Tadmor River and Gorge Creek on 25 September 2006 and 9 January 2007.

		Upper Tadmor				T1				Gorge Ck			
	MCI	9/25/2006		1/9/2007		9/25/2006		1/9/2007		9/25/2006		1/9/2007	
	Score	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
EPHEMEROPTERA													
Nesameletus sp.	9	7.2	2.4	0.2	-	12.0	2.5	0.8	0.3	7.6	1.7	0.2	-
Coloburiscus humeralis	9	15.2	5.0	30.4	10.8	12.4	13.1	12.0	6.3	30.0	15.9	21.8	10.7
Deleatidium sp.	8	49.6	10.1	14.4	1.4	37.6	10.7	13.2	2.5	50.8	9.5	15.0	1.7
COLEOPTERA													
Elmidae	6	19.2	2.7	10.6	5.3	22.6	4.4	13.0	3.3	5.8	2.2	10.0	4.8
DIPTERA													
Aphrophila neozelandica	5	0.8	1.0	1.6	0.9	0.4	0.0	0.2	-	2.6	1.0	2.4	1.4
Orthocladiinae	2	-	-	1.8	0.6	1.4	0.5	1.8	0.8	2.0	0.7	1.4	0.5
Tanytarsini	3	0.2	-	-	-	-	-	-	-	0.0	-	-	-
Stictocladius		0.6	-	0.8	1.0	0.4	0.0	-	-	1.2	2.0	-	-
Orthoclad 'high rise split'		-	-	-	-	-	-	-	-	0.0	-	-	-
Polypedilum sp.	3	0.4	-	-	-	-	-	-	-	0.0	-	-	-
Austrosimulium spp.	3	4.0	1.0	5.6	3.2	1.6	0.4	5.4	8.5	1.0	1.5	7.4	4.8
TRICHOPTERA													
Aoteapsyche sp.	4	1.8	1.0	1.4	0.2	2.8	0.3	0.4	0.0	2.8	0.7	1.0	-
Hydrobiosis sp.	5	0.4	-	0.8	0.3	0.4	-	1.4	0.3	0.2	-	1.4	0.2
Psilochorema spp.	8	0.8	-	0.0	-	0.2	-	0.2	-	0.4	0.0	1.2	0.6
Pycnocentria spp.	7	1.4	2.5	0.0	-	2.4	1.7	-	-	0.8	1.0	-	-
Olinga feredayi	9	3.6	1.3	4.4	1.1	1.6	0.7	1.4	0.5	9.6	5.3	10.4	3.1
CRUSTACEA													
Ostracoda	3	-	-	-	-	-	-	-	-	-	-	-	-
OLIGOCHAETA	1	2.2	0.8	4.4	3.8	0.8	1.0	0.8	0.0	-	-	1.8	-
Total invertebrate abundance (per 1 m^2)		1292.0	146.8	1068.0	218.5	1136.0	269.1	648.0	170.4	1338.0	319.2	1006.0	225.2
Taxon richness		17.0	1.6	17.0	1.2	16.0	1.5	13.4	1.4	15.0	1.4	17.4	1.0
%EPT		52	4	55	2	44	4	53	6	55		53	6
MCI		137	4	135	2	131	1	133	5	140	5	136	4
QMCI		7.44	0.16	7.29	0.21	7.31	0.18	7.04	0.17	7.95	0.09	7.10	0.28

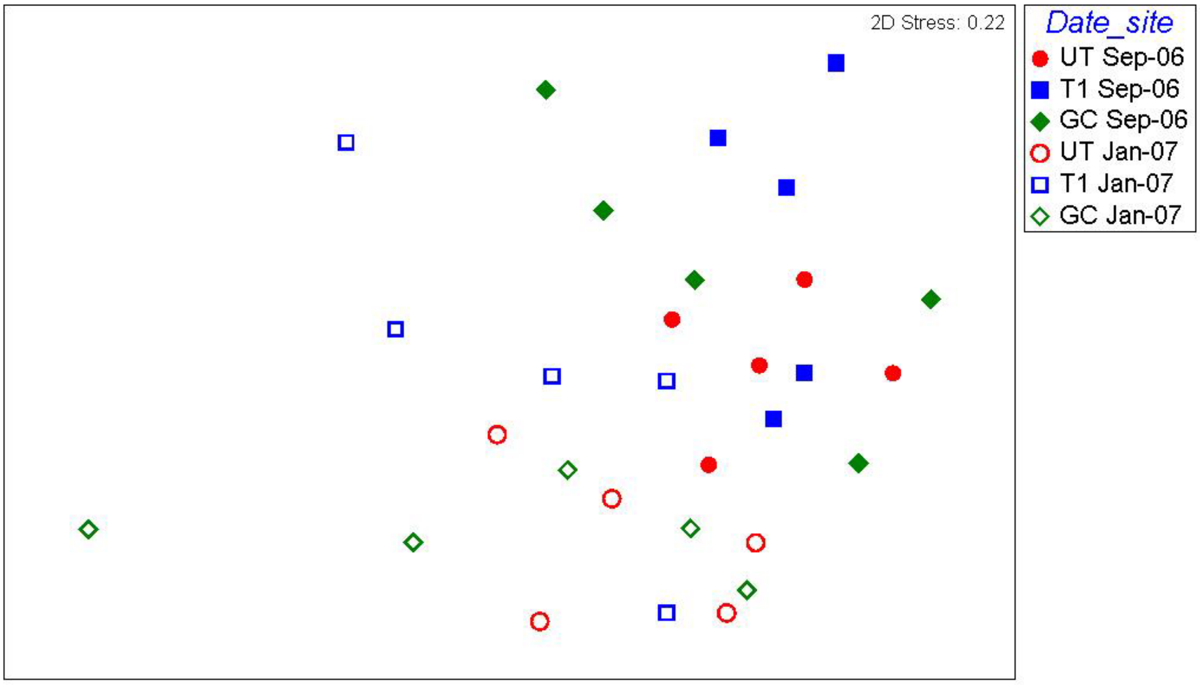

Figure 8. Two dimensional non-metric multi-dimensional space ordination of the replicate quantitative invertebrate samples collected from the Upper Tadmor (UT), Tadmor downstream of the Gorge Creek confluence (T1), and Gorge Creek (GC) on 25 September 2006 and 9 January 2007.

There was some tendency for total invertebrate densities on 25 September 2006 to be higher than those obtained 7 January 2007 at all three sites sampled (Figure 7a; $F_{1,24}$ = 3.4, P=0.08). Also, QMCI values were higher for samples collected on 25 September 2006 than those collected on 7 January 2007 (Figure 7e; $F_{1,24}$ = 7.1, P=0.014). However, taxon richness, %EPT taxa, and MCI values were similar on both sampling occasions at all three sites (Figure 7b-d; all P>0.3). MCI and QMCI values at all sites and on both occasions exceeded 120 and 7.00 respectively, and thus, were indicative of excellent water quality (Figure 7d, e). No statistically significant differences in total invertebrate densities, taxon richness, %EPT taxa, MCI, or QMCI values were evident between the three sites (all P>0.2).

The macroinvertebrate community structure at all three sites differed between the two sampling occasions (Figure 8; ANOSIM: UT: R=0.524, P=0.008, T1: R=0.448, P=0.016, GC: R=0.420, P=0.008) mainly reflecting reduced densities of the mayflies *Deleatidium*, and *Coloburiscus* and increased densities of sandfly larvae (*Austrosimulium* spp.) in January 2007 compared with September 2006.

The macroinvertebrate communities of the upper Tadmor (UT) and T1 site were similar on 25 September 2007 (Figure 8; ANOSIM: R=0.112, P=0.21). However, the communities of both UT and T1 were significantly different to that of Gorge Creek (GC) on this sampling occasion (Figure 8; ANOSIM: UT versus GC: R=0.440, P=0.016, T1 versus GC: R=0.388, P=0.008), reflecting lower densities of the filter-feeding mayfly *Coloburiscus* and the cased caddis *Olinga feredayi* and higher densities of riffle beetles (Elmidae) in these two sites relative to

Gorge Creek. On 7 January 2007, the macroinvertebrate community at the upper Tadmor site was not significantly different to that of Gorge Creek (Figure 8; ANOSIM: R=0.244, P=0.08). However, the community at site T1 was significantly different to that in Gorge Creek (Figure 8; ANOSIM: R=0.624, P=0.008), reflecting higher densities of *Coloburiscus*, *Olinga feredayi*, and *Austrosimulium* in Gorge Creek. There was also weak evidence to suggest that the communities at site T1 and upper Tadmor differed on this sampling occasion (ANOSIM: R=0.232, P=0.056), mainly as a result of higher densities of *Coloburiscus* and oligochaete worms in the upper Tadmor site.

Based on these results, while the community structure at the two sites affected by the water augmentation scheme differed between the two sampling occasions, the community at the control site (Gorge Creek) changed in a similar manner. This suggests that these changes are likely to reflect seasonal changes in community structure rather than an effect of the water augmentation scheme.

4. ACKNOWLEDGEMENTS

Martin Doyle (Tasman District Council) provided the hydrological data presented in Figure 1.

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6. APPENDICES

Appendix 1. Macroinvertebrates collected in kick-net samples at sampling sites in the Hope and Tadmor Rivers on the three sampling occasions (3 October 1986, 25 and 27 September 2006, 9 January 2007).

Site Date	MCI Score	Upper Hope River 3-Oct-86	Tadmor T1 3-Oct-86	Tadmor T2 3-Oct-86	Tadmor T3 3-Oct-86	Upper Hope River 25-Sep-06	Tadmor T1 27-Sep-06	Tadmor T2 25-Sep-06	Tadmor T2.5 25-Sep-06	Tadmor T3 27-Sep-06	Upper Hope River 9-Jan-07	Tadmor T1 9-Jan-07	Tadmor T2 9-Jan-07	Tadmor T2.5 9-Jan-07	Tadmor T3 9-Jan-07
EPHEMEROPTERA (mayflies)															
Ichthybotus hudsoni	8	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Neozephlebia	7	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Nesameletus sp.	9	A	A	A	A	C	A	A	C	R	R	R	-	-	R
Coloburiscus humeralis	9	A	A	A	A	C	A	C	C	-	A	A	A	R	-
Deleatidium sp.	8	A	-	A	A	C	A	VA	VA	R	C	C	VA	VA	C
Austroclima jollyae	9	-	R	-	-	A	C	-	R	A	C	C	-	-	-
Ameletopsis perscitus	10	-	-	-	-	-	-	-	-	-	-	-	R	-	-
PLECOPTERA (stoneflies)															
Austroperla cruentata	9	-	-	-	-	-	R	R	R	-	-	-	R	-	-
Stenoperla prasina	10	R	R	R	R	R	C	R	R	-	-	R	R	-	-
Megaleptoperla spp.	9	R	-	-	-	-	R	-	-	-	R	-	-	-	-
Megaleptoperla grandis	9	-	R	-	-						-	-	-	-	-
Zelandobius furcillatus	5	R	-	R	A	R	-	-	R	C	R	-	-	-	-
Zelandoperla decorata	10	R	R	R	-						-	-	-	-	-
Acroperla trivacuata	5	R	R	-	-	R	-	-	-	-	R	-	-	-	-
MEGALOPTERA (dobsonflies)															
Archichauliodes diversus	7	-	R	R	R	R	C	-	R	-	C	R	C	C	-
COLEOPTERA (beetles)															
Hydraenidae	8	R	C	C	-	R	C	R	A	R	C	R	A	C	R
Hydrophilidae	5	R	R	-	-						-	-	-	-	-
Elmidae	6	C	R	A	A	C	A	VA	A	R	A	C	VA	A	VA
Ptilodactylidae	8	-	R	-	-	-	R	-	-	-	-	-	R	-	-
Scirtidae (=Helodidae)	8	-	-	R	-	R	R	-	-	-	R	-	-	-	-

Appendix 1. continued

Site Date	MCI Score	Upper Hope River 3-Oct-86	Tadmor T1 3-Oct-86	Tadmor T2 3-Oct-86	Tadmor T3 3-Oct-86	Upper Hope River 25-Sep-06	Tadmor T1 27-Sep-06	Tadmor T2 25-Sep-06	Tadmor T2.5 25-Sep-06	Tadmor T3 27-Sep-06	Upper Hope River 9-Jan-07	Tadmor T1 9-Jan-07	Tadmor T2 9-Jan-07	Tadmor T2.5 9-Jan-07	Tadmor T3 9-Jan-07
DIPTERA (true flies)															
Anthomyiidae	3	-	-	-	-	R					-	-	-	-	-
Ceratopogonidae	3	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Paralimnophila skusei	6	-	-	R	-						-	-	-	-	-
Aphrophila neozelandica	5	C	C	A	R	R	R	C	C	-	R	R	C	C	-
Eriopterini	9	-	R	-	A	R	R	-	R	-	-	-	R	R	-
Hexatomini	5	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Molophilus sp.	5	-	-	-	R	-	-	-	-	-	-	-	-	-	-
Tanypodinae	5	-	-	-	R	-	-	-	-	-	-	-	-	-	-
Lobodiamesa	5	-	-	-	-	-	-	R	R	-	-	-	-	-	-
Maoridiamesa sp.	3	R	C	-	R	-	R	A	A	-	-	-	-	R	C
Orthocladiinae	2	C	C	A	A	C	C	VA	VA	A	R	-	-	C	VA
Tanytarsini	3	-	-	-	R	-	R	R	R	R	-	-	-	-	-
Stictocladius	6	-	-	-	-	R	-	R	-	-	-	-	-	-	-
Orthoclad 'high rise split'	2	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Polypedilum sp.	3	R	-	R	C	-	-	R	-	-	-	-	-	-	-
Austrosimulium	3	R	C	A	-	R	R	C	VA	A	R	C	C	C	C
Austrosimulium australense	3	-	R	R	-	-	-	-	-	-	-	-	-	-	-
Empididae	3	-	R	-	-	R	R	R	-	-	-	-	-	-	-
Mischoderus sp.	4	-	R	-	-						-	-	-	-	-
Tabanidae	3	-	-	R	-	-	-	A	-	-	-	-	-	-	-
TRICHOPTERA (caddisflies)															
Aoteapsyche sp.	4	R	R	-	C	C	R	C	R	-	R	-	-	R	R
Oxyethira albiceps	2	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Costachorema spp.	7	-	-	-	-	R	-	-	-	R	-	-	R	R	R
Costachorema xanthopera	7	-	R	C	C	-	-	-	-	-	-	-	-	-	
Costachorema psaroptera	7	R	-	-	-						-	-	-	-	-
Hydrochorema spp.	9	-	-	-	-	R	-	R	-	-	-	-	-	-	-

Appendix 1. continued

Site Date	MCI Score	Upper Hope River 3-Oct-86	Tadmor T1 3-Oct-86	Tadmor T2 3-Oct-86	Tadmor T3 3-Oct-86	Upper Hope River 25-Sep-06	Tadmor T1 27-Sep-06	Tadmor T2 25-Sep-06	Tadmor T2.5 25-Sep-06	Tadmor T3 27-Sep-06	Upper Hope River 9-Jan-07	Tadmor T1 9-Jan-07	Tadmor T2 9-Jan-07	Tadmor T2.5 9-Jan-07	Tadmor T3 9-Jan-07
Hydrobiosis sp.	5	-	-	-	-	-	R	C	R	A	R	C	A	A	A
Hydrobiosis parumbripennis	5	-	C	C	C	-	-	-	-	-	-	-	-	-	-
Hydrobiosis clavigera	5	-	R	R	-	-	-	-	-	-	-	-	-	-	-
Hydrobiosis spatulata	5	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Neurochorema	6	-	-	-	-	-	-	C	R	R	-	-	-	-	-
Psilochorema spp.	8	-	-	-	-	-	R	C	R	-	-	-	R	R	R
Psilochorema nemorale	8	-	-	R	C	-	-	-	-	-	-	-	-	-	-
Psilochorema macroharpax	8	-	-	-	C	-	-	-	-	-	-	-	-	-	-
Hydrobiosidae juveniles	7	-	-	C	R	-	-	-	-	-	-	-	-	-	-
Hydrobiosella stenocerca	9	R	-	-	-	-	R	-	R	-	C	-	-	-	-
Plectrocnemia	8	-	-	-	-	-	-	R	R	-	-	-	R	-	-
Zelolessica cheira	10	C	R	-	-	C	R	-	-	-	R	R	-	-	-
Pycnocentria spp.	7	-	-	-	C	C	R	C	C	R	-	-	-	-	R
Pycnocentria sylvestris	7	R	-	-	-						-	-	-	-	-
Pycnocentrodes sp.	5	-	-	R	C	-	-	C	A	A	-	R	C	A	R
Confluens hamiltoni	5	-	R	-	-	R	-	-	-	-	-	-	-	-	-
Olinga feredayi	9	-	R	C	A	-	C	-	R	-	-	-	A	C	-
Helicopsyche poutini	10	-	-	R	R	-	R	C	A	-	-	-	C	A	-
Hudsonema spp.	6	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Philorheithrus	8	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Triplectides	5	-	-	-	-	-	R	R	-	-	-	-	-	-	-
CRUSTACEA															
Paranephrops	5	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Ostracoda	3	-	-	-	R						-	-	-	-	-
OLIGOCHAETA	1	C	R	A	C	C	R	R	R	R	R	-	-	R	R
MOLLUSCA (snails)											-	-	-	-	-
Potamopyrgus antipodarum	4	-	R	R	-	-	R	C	C	-	-	-	-	C	-
NEMATODA	3	-	R	-	-						-	-	-	-	-
PLATYHELMINTHES	3	-	-	-	-	-	R	R	-	-	-	-	-	-	-
NEMATOMORPHA	3	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Taxon richness		22	32	27	27	28	33	33	29	15	19	14	19	19	14
MCI		125	121	123	121	119	132	112	128	112	128	139	152	119	109
SQMCI		7.35	6.80	5.66	6.69	6.77	7.56	5.38	5.03	4.91	7.42	7.40	7.15	6.99	4.19
%EPT taxa		59%	50%	52%	56%	50%	55%	48%	59%	60%	58%	57%	63%	47%	57%