Wungong Catchment Trial

Aquatic Fauna Biodiversity Assessment, October 2011

January 2013

WATER CORPORATION

Acknowledgement

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CONTENTS

LIST OF FIGURES AND TABLES

Figures

Tables

1. INTRODUCTION

1.1 Background / Objectives

This is the 7th survey in a series of annual surveys commissioned by the Water Corporation to assess the effects of the Wungong Catchment Trial (WCT) on the biodiversity of aquatic fauna (principally aquatic macroinvertebrates) in tributary streams of the Wungong catchment. The surveys commenced in December 2005, when the Water Corporation commissioned Wetland Research & Management (formerly the Aquatic Research Laboratory of The University of Western Australia), to develop a monitoring programme to detect changes in aquatic macroinvertebrate assemblages in response to changes in flow regime or water quality conditions associated with the WCT. Subsequent surveys (2006-2011) were undertaken in spring (September-October) when there was greater availability of surface water.

Under the WCT, streams which used to flow all year, but which now flow seasonally due to reduced rainfall and catchment vegetation characteristics, may once again become perennial, and streams that are currently drying may have more secure flows (*i.e*. flow duration in seasonal streams may increase). Perennial streams tend to support greater biodiversity than seasonal streams.

The aquatic monitoring surveys meet the Water Corporation's Key Performance Indicator (KPI) for monitoring stream biodiversity, where the performance measure is "diversity of aquatic macroinvertebrate species" and the performance target is "no statistical change in diversity from the historic range of variability or from the "current reference condition".

In order to separate short-term stochastic fluctuations from any effects of the Wungong Catchment Trial, Storey and Creagh (2006) recommended that collection of pre-treatment baseline data and post-treatment monitoring data each be continued for a period of years. The original recommendation was that reference and exposed sites be sampled for at least three years prior to commencement of treatments in each sub-catchment (Storey & Creagh 2006, 2007). This has not been possible for all exposed sites owing to commencement of trial thinning in Treatment Area 1 (TA1) in 2006 and commercial harvestings in TA2 in 2007 and 2008 (Table 1).

The current report documents the results of the October 2011 round of sampling for the programme.

2. METHODS

As in previous monitoring years, changes in biodiversity were assessed by comparing macroinvertebrate and fish communities between streams in treated (exposed) and untreated (control/reference) sub-catchments. Quantitative sampling of aquatic macroinvertebrates was conducted in riffle habitat using a Surber sampler (25 x 25 cm metal quadrat with 250 µm mesh) with 6 replicate samples taken at each site. Qualitative sampling for fish and crayfish was conducted using a Smith-Root LR24 backpack electrofisher. In conjunction with the fauna sampling, a range of physical and water quality parameters were measured *in-situ* including dissolved oxygen, water temperature, pH, electrical conductivity, water depth and velocity. Qualitative assessment of riparian vegetation and percent cover of dominant substrate (*e.g.* cobble, pebble, gravel, sand, clay, silt, macrophyte, algae) was made by visual assessment. Full details of methods are provided in previous annual reports (Storey & Creagh 2006, 2007, 2008 & 2009).

The design of the sampling programme is based on a Before-After-Control-Impact (BACI) type design. Univariate (ANOVA) and multivariate (ANOSIM) analysis of quantitative replicate samples is used to determine change in macroinvertebrate community structure. Historic data (1984-1990) collected at reference sites in the Canning and North Dandalup catchments are included in analyses to compare how reference sites change over time relative to their historic condition. ANOVA is performed using SPSS software (Version 19.0 for Windows). ANOSIM is based on similarity matrices (*i.e*. Bray-Curtis similarity matrices for species data or Euclidean distance matrices for physico-chemical data) generated by the computer program PRIMER version 6 (Clarke & Gorley 2006).

The similarity matrices provide a measure of statistical 'distance' and are used to compare:

i. how impact (exposed) sites change over time relative to their baseline condition and relative to reference (control) sites, and
ii. how reference (control) sites change over time relative to their historic (1984-1990) condition.

For example, a Bray-Curtis similarity value of 100% indicates species assemblages are identical, while a value of 0% indicates communities have no taxa in common. ANOSIM is used to test for statistically significant (p <0.05) changes in similarity over time. The expectation is that there will be no change in similarity between the current and future condition of treated sites, if the WCTP effectively offsets the reductions in flow associated with climate change.

2.1 Sampling Sites

Table 1 provides a list of all sites sampled and locations are indicated in Figures 1A-C. Sites sampled in 2011 included:

- Four sites downstream of treatment areas:
  - TA1, TA2 and Vardi Road, which have been sampled annually since 2005;
  - More Seldom Seen Brook, which has been sampled annually since 2008. The choice of locations for monitoring the impact of upstream treatments on this brook was limited. The only suitable site was one which supported minimal gravel riffle habitat, being located in a very shallow, largely swampy reach upstream of the More Seldom Seen gauging station. As such, data collected from this site are not expected to be the same as data collected from other monitoring sites which are dominated by gravel or cobble riffle runs. It is still important however, to compare and track how this site diverges from / converges with other sites over time.
- Four reference sites:
  - Waterfall Gully, 31 Mile Brook and Foster Brook have been sampled annually since 2005;
  - Wilson Brook, which has been sampled annually since 2007;
  - 39 Mile Brook (Jack Rocks), which has been sampled annually since 2007. Sampling at Jack Rocks was not strictly part of the original WCTP monitoring, but was included to provide data on the effects of fine-scale mosaic burns proposed by DEC. While DEC no longer plan to undertake these trials burns, the aquatic fauna sampling has continued in order to provide additional control/reference data for the WCTP.

Table 1. Aquatic fauna sampling sites.

Site Name (& Code)	Catchment	Stream Order	Site Type	Treatment Area 'Exposure'	Treatment Indicative Status	Sampling Years	Sampling Location	UTM (zone 50) WGS84	
Waterfall Gully (WF)	Wungong	1	Reference	Control	Control catchment, no treatment required	2005, 2006, 2007, 2008, 2009, 2010, 2011	Upstream from road culvert 400m above gauging station.	413201 E	6436061 N
Treatment Area 1 (TA1)	Wungong	1	Exposed	WCTP TA1	Treatment Area 1 Total area 2,540ha Available for treatment 1,620ha Treatment already completed 1,070ha	2005, 2006, 2007, 2008, 2009, 2010, 2011	Along Chandler Rd, immediately down-stream of Coronation Rd intersection.	417987 E	6428604 N
Treatment Area 2 (TA2)	Wungong	1	Exposed	WCTP TA2 & 3	Treatment Area 2 Total area (TA2): 2 780ha Available for treatment: 1 780ha Treatment completed: 340 ha Within TA2: Cobiac cub-catchment - Total area 360ha Available for treatment 260ha Treatment completed 260ha	2005, 2006, 2007, 2008, 2009, 2010, 2011	Pumping Station Rd 300 m upstream of the Coronation Rd bridge.	419389 E	6428254 N
Vardi Road (VR)	Wungong	2	Exposed	WCTP TA1, 2 & 3	As for TA1 & TA2	2005, 2006, 2007, 2008, 2009, 2010, 2011	Immediately downstream from gauging station and near 'flying fox'.	416382 E	6431737 N
More Seldom Seen Brook (MSS)	Wungong	1	Exposed	WCTP TA5	Not yet treated	2008, 2009, 2010, 2011	Immediately upstream from gauging station 616022 on More Seldom Seen Brook.	413350 E	6431007 N
31 Mile Brook (31MB)	Canning	1	Reference/ Exposed	Control	No treatment required	2005, 2006, 2007, 2008, 2009, 2010, 2011	Off 31 Mile Road; immediately upstream from gauging station.	420806 E	6434022 N
Jack Rocks 39 Mile Brook (JR)	Serpentine	1	Reference/ Exposed	Control	No treatment required	2007, 2008, 2009, 2010, 2011	Jack Rocks. Off Kennedia Rd (*via* Balmoral Rd), immediately upstream from gauging station.	420689 E	6417649 N
Foster Brook (FB)	Nth Dandalup	1	Reference	Control	No treatment required	2005, 2006, 2007, 2008, 2009, 2010, 2011	Immediately upstream of Sharp Rd culvert, above Nth Dandalup reservoir.	410324 E	6403239 N
Wilson Brook (WB)	Nth Dandalup	1	Reference	Control	No treatment required	2007, 2008, 2009, 2010, 2011	Off North Road, above Nth Dandalup reservoir. First sampled in 2007 as replacement for 31MB which will be impacted by CSIRO thinning trials.	410084 E	6399053 N

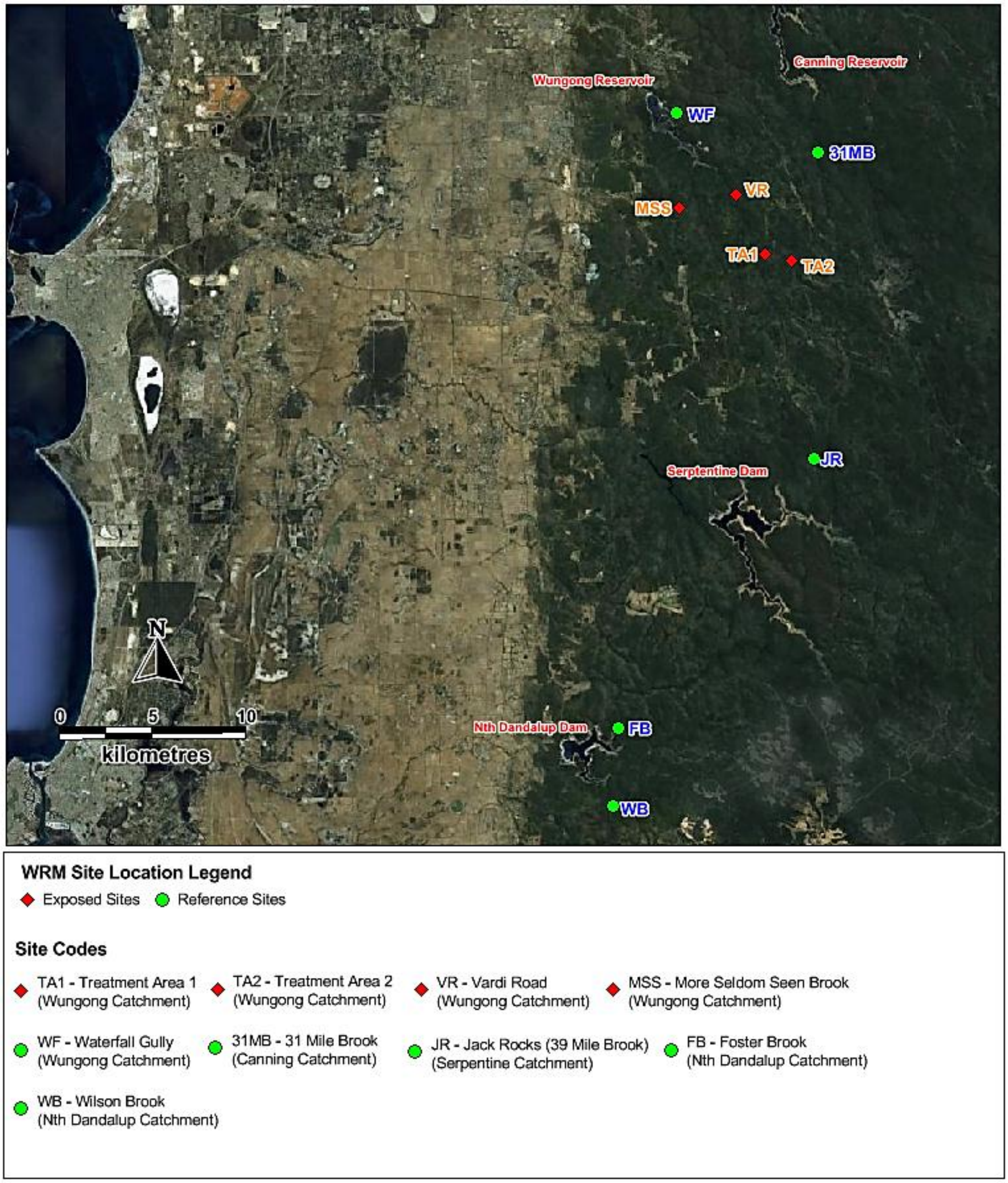

Figure 1A. Overview of location of aquatic fauna survey sites within the Canning Catchment, North Dandalup Catchment, Serpentine Catchment, and Wungong catchment.

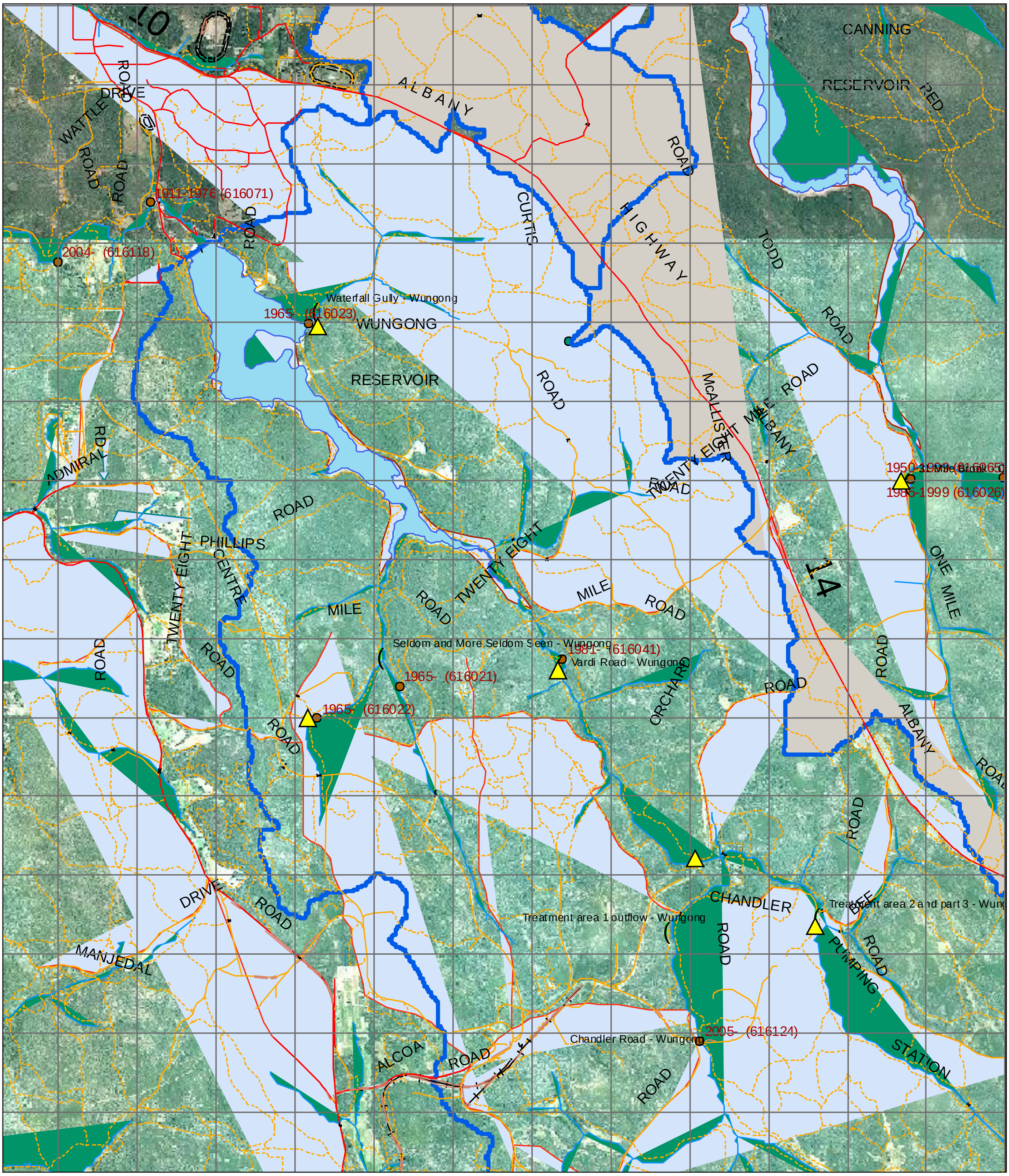

Figure 1B. Location of aquatic fauna survey sites (△) within the WCT area and on 31 Mile Brook in the Upper Canning catchment.

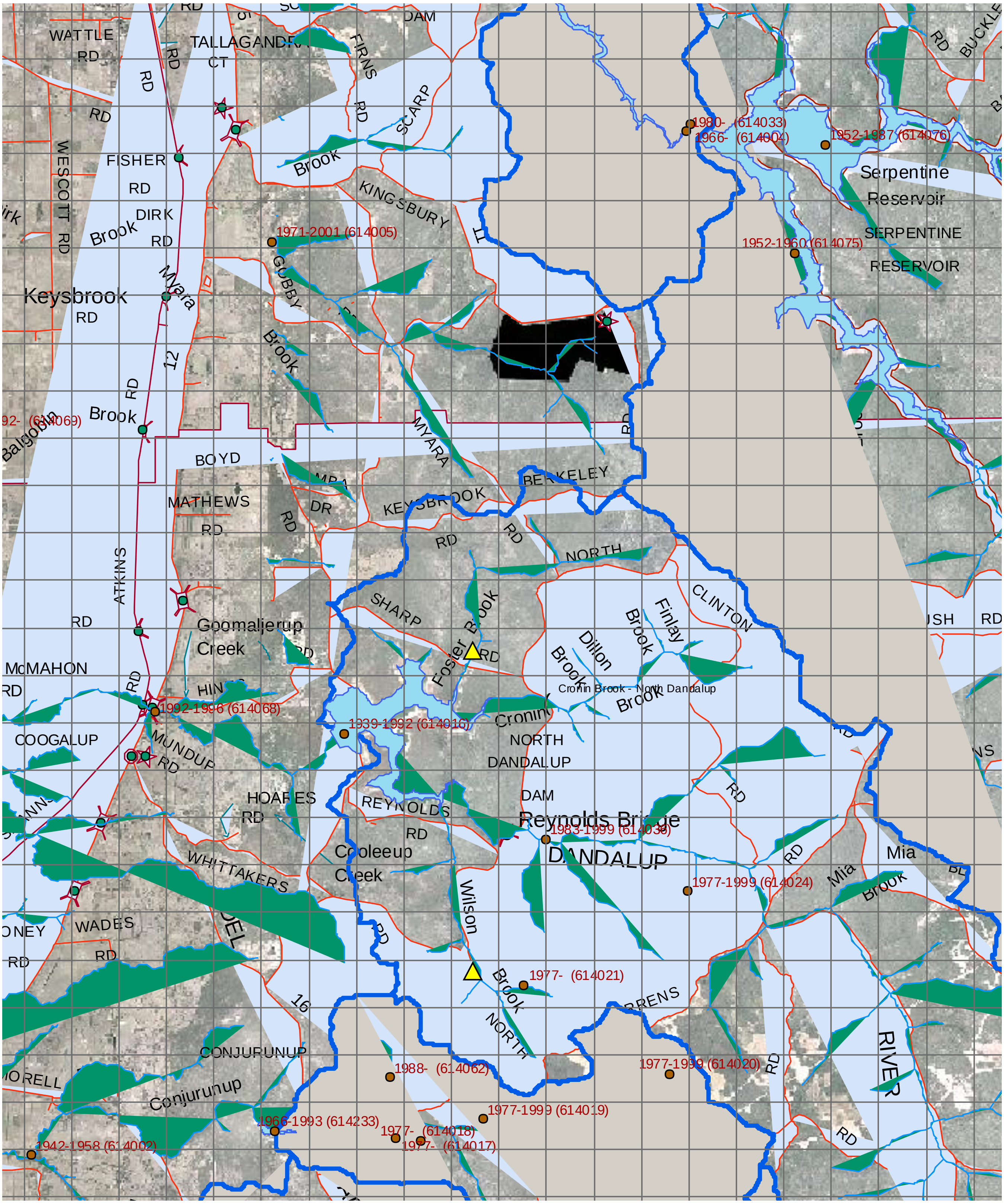

Figure 1C. Location of WCT reference (control) sites (△) on Foster Brook and Wilson Brook in the upper North Dandalup catchment.

3. RESULTS

Photographs of each sampling site are presented in Appendix 1 and all raw data collected during the 2011 survey are provided in Appendices 2 to 4. Major results and trends from the current and previous years' sampling are summarised below.

3.1 Physico-chemistry

Since monitoring commenced in 2005, there have been no obvious changes in riparian vegetation (Appendix 2) and no significant changes in water chemistry that can be attributed to the WCT (Table 2 & Appendix 3). While significant temporal differences were found for some water quality parameters these were considered to predominantly reflect natural annual variations in rainfall and streamflow, *i.e.* dissolved oxygen, temperature, electrical conductivity (Table 2). Examples of changes in water chemistry at individual sites are plotted in Figures 2A-B.

Significant spatial and temporal differences in water velocity were also recorded at individual exposed and control sites (Table 2). The most consistent trend amongst sites was a decline in water velocity in 2009, with flow remaining low in 2010 and 2011 sampling periods. At most sites, this was accompanied by a decline in dissolved oxygen (DO) levels and an increase in water temperature (Figure 2A-B). In general, *in situ* spot measurements suggested that at both exposed and control sites, the water quality in 2011 was comparable to that in 2010 (Figure 2A-B).

Table 2. Summary results from one-way ANOVA testing for statistical differences in water quality variables between years 2005 - 2011. Where appropriate, data were log-transformed prior to analyses. Significance level $p<0.05$.

Exposed Sites					Control Sites				
Site	**Variable**	**df**	**F**	***p***	**Site**	**Variable**	**df**	**F**	***p***
Vardi Road	Water velocity	6	9.741	<0.0001	**Waterfall Gully**	Water velocity	6	27.619	<0.0001
	Dissolved oxygen	6	74.385	<0.0001		Dissolved oxygen	6	21.568	<0.0001
	Temperature	6	1.7162	0.1463		Temperature	6	440.562	<0.0001
	ECond	6	5.295	0.0005		ECond	6	288.670	<0.0001
	pH	6	153.482	<0.0001		pH	6	106.648	<0.0001
TA1	Water velocity	6	23.488	<0.0001	**31 Mile Brook**	Water velocity	6	64.1753	<0.0001
	Dissolved oxygen	6	49.058	<0.0001		Dissolved oxygen	6	34.835	<0.0001
	Temperature	6	305.674	<0.0001		Temperature	6	129.882	<0.0001
	ECond	6	221.475	<0.0001		ECond	6	1507.823	<0.0001
	pH	6	70.367	<0.0001		pH	6	19.166	<0.0001
TA2	Water velocity	6	22.818	<0.0001	**Foster Brook**	Water velocity	6	14.040	<0.0001
	Dissolved oxygen	6	66.225	<0.0001		Dissolved oxygen	6	10.866	<0.0001
	Temperature	6	926.445	<0.0001		Temperature	6	31.497	<0.0001
	ECond	6	166.945	<0.0001		ECond	6	30.229	<0.0001
	pH	6	39.515	<0.0001		pH	6	1156.978	<0.0001
Jack Rocks	Water velocity	4	121.906	<0.0001	**Wilson Brook**	Water velocity	4	26.098	<0.0001
	Dissolved oxygen	4	17.488	<0.0001		Dissolved oxygen	4	26.535	<0.0001
	Temperature	4	14.826	<0.0001		Temperature	4	306.322	<0.0001
	ECond	4	391.546	<0.0001		ECond	4	30417.70	<0.0001
	pH	4	46.755	<0.0001		pH	4	10.041	<0.0001

Although changes in water quality variables were observed at individual sites, most values remained within the range recommended by ANZECC/ARMCANZ (2000) for the protection of aquatic fauna (Appendix 2). Salinity levels have typically remained low (<500 µS cm^{-1}), DO levels moderate to high (70 - 116% saturation) and pH largely within the range of 6 to 8. The exceptions were daytime pH and DO levels at More Seldom Seen Brook in 2011. The pH at More Seldom Seen Brook in 2011 was acidic (5.3) relative to the ANZECC/ARMCANZ (2000) lower guideline limit of pH 6.5, while daytime DO concentration was ~50%, which was low relative to the ANZECC/ARMCANZ (2000) guideline of 90%. Though the DO was relatively low, it was not considered low enough to adversely impact aquatic fauna[1]. The low pH and DO were considered due to higher quantities of organic detritus at this site, which comprised a shallow, narrow ill-defined slow-flowing channel in dense, swampy riparian vegetation with extensive deposits of organic silts.

Analysis of similarity (ANOSIM) based on Euclidean distance was used to investigate multivariate patterns in physico-chemistry amongst sites. In all years, there were significant differences between exposed sites and control sites (Table 3). However, these differences existed before treatment commenced, and for most exposed sites, the degree to which they differ from control sites has not shown a consistent trend over the monitoring period. In 2011, the greatest difference in water quality between sites was between Jack Rocks and More Seldom Seen Brook (Table 3).

Table 3. Summary results from one-way ANOSIM (Analysis of Similarity) on 2005-2011 physico-chemical data, comparing exposed sites with control sites. Where R-statistic >0.75 = groups well separated, R-statistic >0.5 = groups overlapping but clearly different, and R-statistic >0.25 = groups barely separable. For all pairwise comparisons, significance level p <0.05; ns = not significant.

Exposed Site	Year	R-statistic for Pairwise Test with Control Site			
		Waterfall Gully	Foster Bk	31 Mile Bk	Wilson Bk
Vardi Rd	2005	0.517	0.926	0.867	--
	2006	0.991	0.581	0.948	--
	2007	0.441	0.876	0.752	1.000
	2008	0.469	0.594	0.487	0.665
	2009	0.635	0.457	ns	0.437
	2010	0.633	0.643	0.472	0.793
	2011	0.993	0.893	0.646	0.941
TA1	2005	0.598	0.554	0.809	--
	2006	0.865	ns	0.781	--
	2007	ns	0.600	0.778	0.998
	2008	ns	ns	ns	0.659
	2009	ns	ns	ns	ns
	2010	0.719	0.969	0.409	0.941
	2011	0.967	0.730	0.657	0.776
TA2	2005	0.639	0.863	0.524	--
	2006	1.000	0.961	0.996	--
	2007	0.856	1.000	0.952	1.000
	2008	0.861	0.896	0.681	0.956
	2009	0.926	0.456	0.607	0.604
	2010	0.561	0.659	0.596	0.693
	2011	0.972	0.800	0.676	0.943
More Seldom Seen Bk	2008	0.774	ns	0.728	0.846
	2009	0.646	0.559	0.612	ns
	2010	--	--	--	--
	2011	1.000	0.837	1.000	0.996
Jack Rocks	2007	ns	0.635	0.722	0.833
	2008	0.691	ns	0.620	0.565
	2009	0.772	0.772	0.656	ns
	2010	0.776	0.987	0.773	0.869
	2011	1.000	0.971	0.928	0.998

[1] DO concentrations less than ~20% typically represent environmental conditions of 'stress' to resident aquatic fauna, particularly fish with high metabolic demand for oxygen.

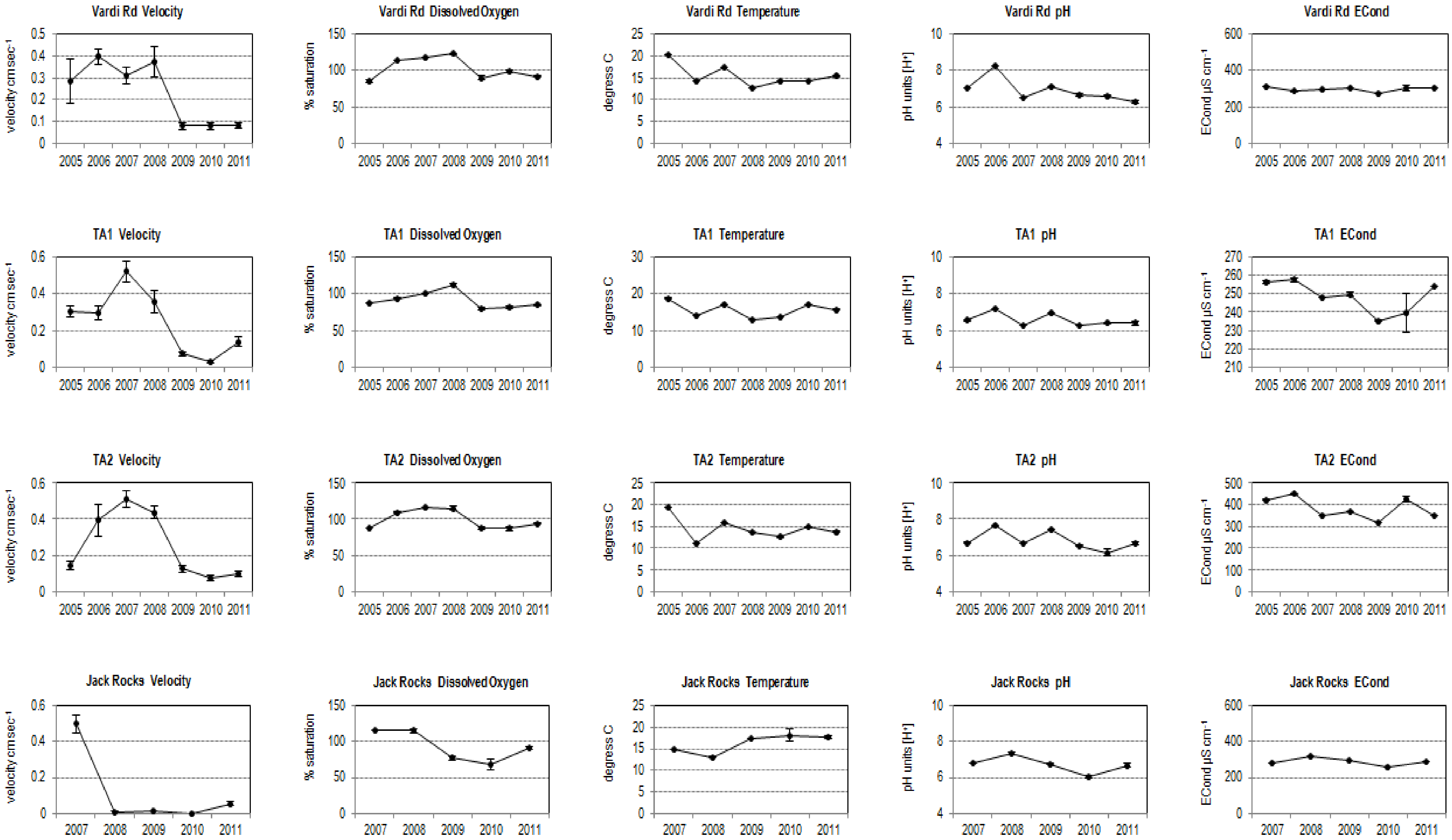

Figure 2A. Annual variability in selected physico-chemical parameters (means ± SE) at exposed sites Vardi Road, TA1 and TA2, and at Jack Rocks.

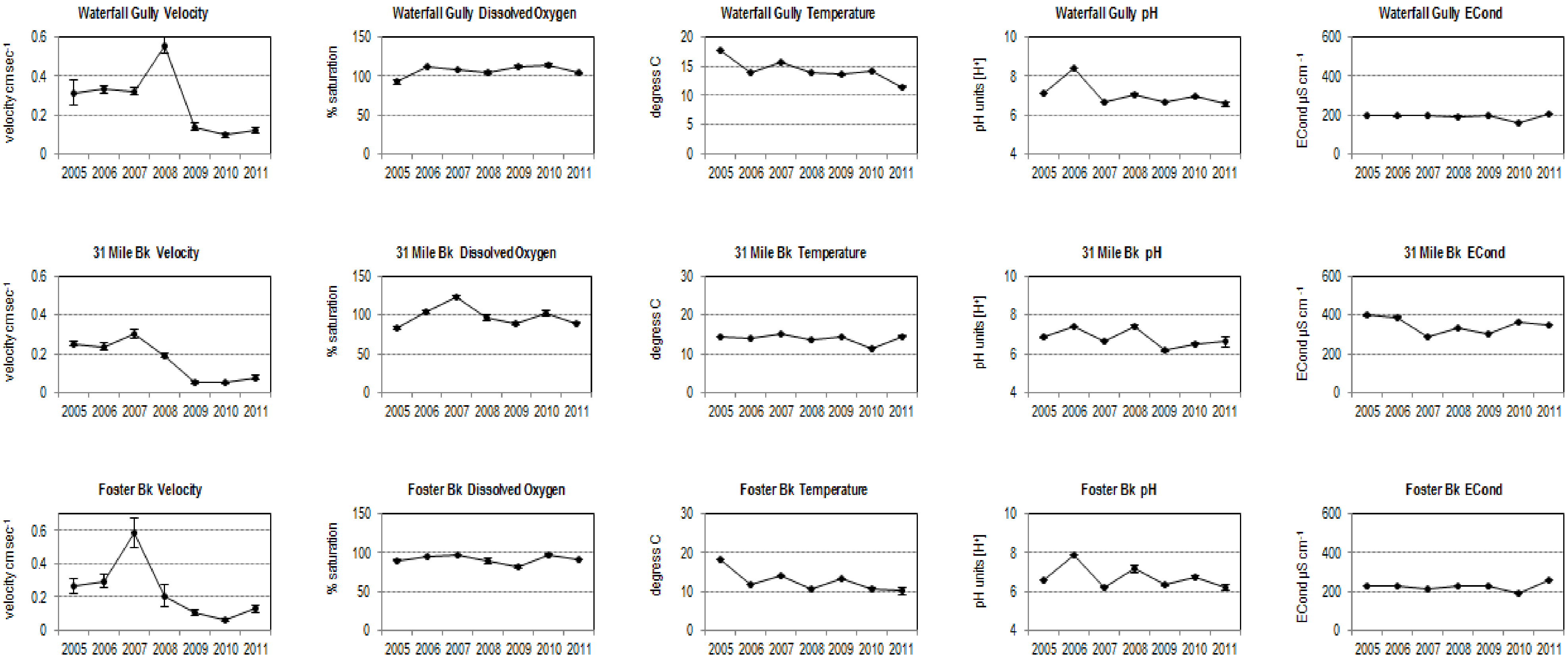

Figure 2B. Annual variability in selected physico-chemical parameters (means ± SE) at control (reference) sites Waterfall Gully, 31 Mile Brook and Foster Brook.

3.2 Macroinvertebrates

A total of 9,656 individuals representing at least 101 taxa were collected from the 9 sites sampled in spring 2011. This was considerably more than the 7, 518 individuals from 95 taxa collected in 2010 and the 4,956 individuals from 86 taxa in 2009 (with taxonomy standardised between years). Based on estimated abundance per m^{-2}, this equated to a total 154,496 individuals present in 2011, compared to 116,624 individuals in 2010 and 79,296 present in 2009. In 2011 (as in all previous years), fauna were dominated by insects (81%), in particular the Chironomidae (non-biting midges), which constituted a large proportion (32%) of the total fauna richness. A systematic list of all macroinvertebrate taxa collected in 2011 is provided in Appendix 4.

In 2011, macroinvertebrate species richness and abundance at most control and exposed sites was comparable to, or higher than, that recorded in 2008, 2009 and 2010 (Figure 3A-B). At Vardi Road there appeared to be continued recovery following the large declines in species richness (~40%) and abundance (~80%[2]) recorded between 2006 and 2009. Exposed sites TA1 and TA2 and the control site on Foster Brook however, showed a marked decline in species richness in 2011 in comparison to 2010. This trend was not apparent in abundance data. Decline in species richness was greatest at TA2 where 38% fewer species were recorded in 2011 than in 2010.

Rainfall during winter and spring of 2010 was low in comparison to previous years and lower stream flow was also recorded (Figure 4). The decline in species richness observed at TA1, TA2 and Foster Brook in 2011 may represent a lagged response to low stream flow in 2010. That this was not recorded at other sites possibly reflects a longer flow period at these sites. Though flow data were not available for all sites, visual observation suggested longer flow duration at Vardi Road, Waterfall Gully and Wilson Brook, as well as persistence of higher water velocities into late spring/early summer. The relatively large, deeper channel pools at Jack Rocks may also provide summer refuge for many species at this site.

In contrast to total species richness, the number of south-west endemics recorded across control and exposed sites in 2011, was generally lower than in previous years. The exception was at Vardi Road, where an increase in the number of south-west endemics was recorded; from only 3 species in 2010 to 8 in 2011, though still less than the maximum 15 species recorded in 2006 (Figures 3A-B). Many south west endemic species, including species from orders generally considered more sensitive to disturbance (*i.e.* EPT taxa), are known to be adapted to seasonal flow regimes. However, the reduced flows in 2010/11 (Figure 4) may have prevented some species from completing their life cycles, resulting in poor recruitment and subsequent lower diversity of endemics recorded during the current study.

Since 2005, monitoring has revealed statistically significant variation in macroinvertebrate species richness and abundance data at sites, both within and between control and exposed groups (Table 4). Similar results were found for whole community structure, based on multivariate analysis (ANOSIM on Bray-Curtis pairwise similarities) of species assemblage data (Tables 5 & 6). In 2011, there were significant differences in macroinvertebrate assemblages between exposed and control sites. As noted in previous reports, these differences existed before the WCT commenced, and for most exposed sites, the degree to which they differ from control sites has not shown a consistent increasing or decreasing trend over the monitoring period.

[2] Abundance per m^2 calculated from the total number of individuals collected in a 25cm x 25 cm quadrat (area = 0.0625 m^2), multiplied by the number of replicate quadrats sampled per site, *i.e*. 6.

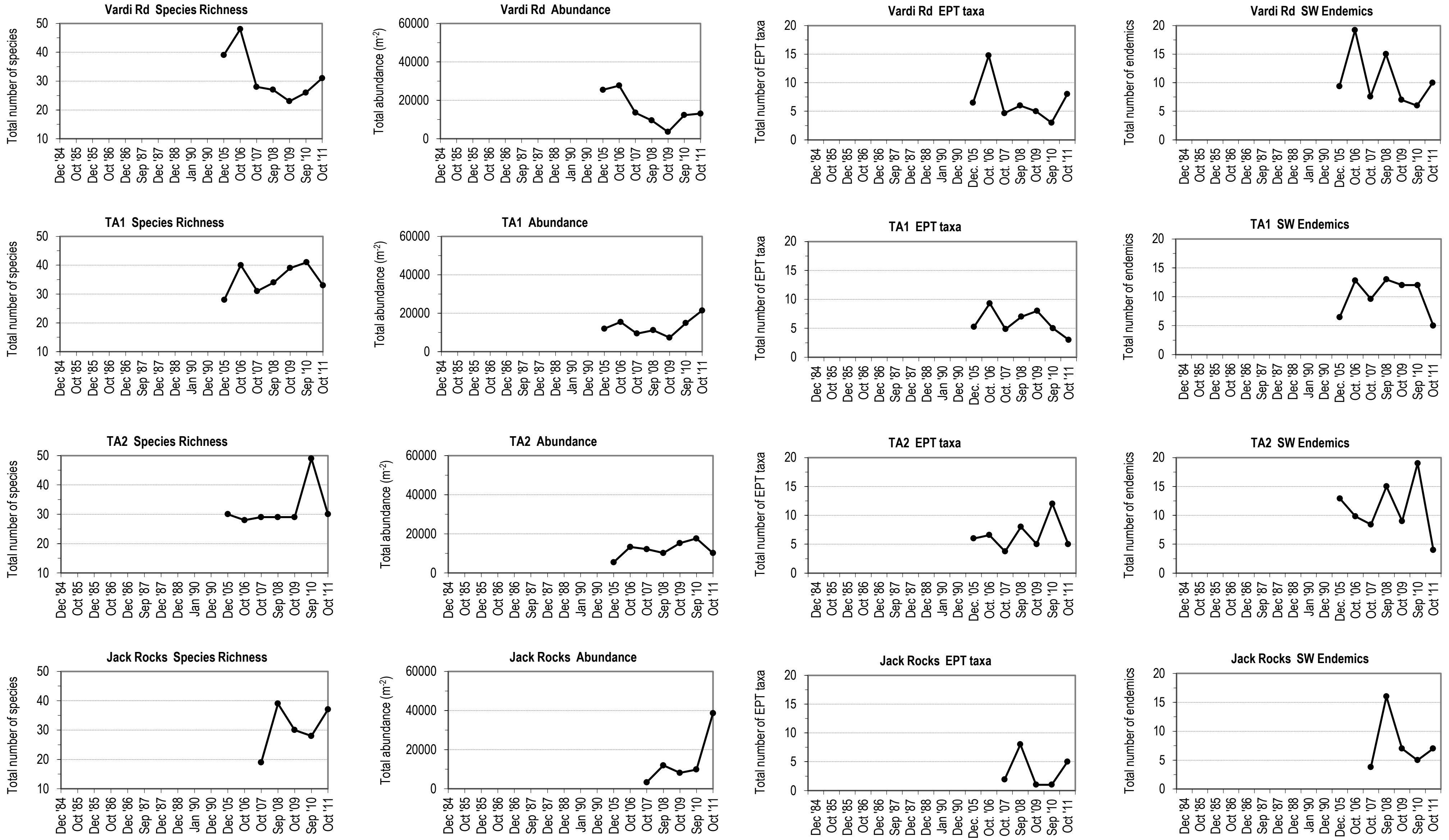

Figure 3A. Annual variability in macroinvertebrate species metrics (total richness, total abundance, total number of EPT taxa and total number of south-west endemics) at WCT sites and Jack Rocks. <u>Note</u>: taxonomy has been standardised across years and sampling dates for historic data (1984 -1990) included on x-axes for comparison with reference sites in Figure 3B.

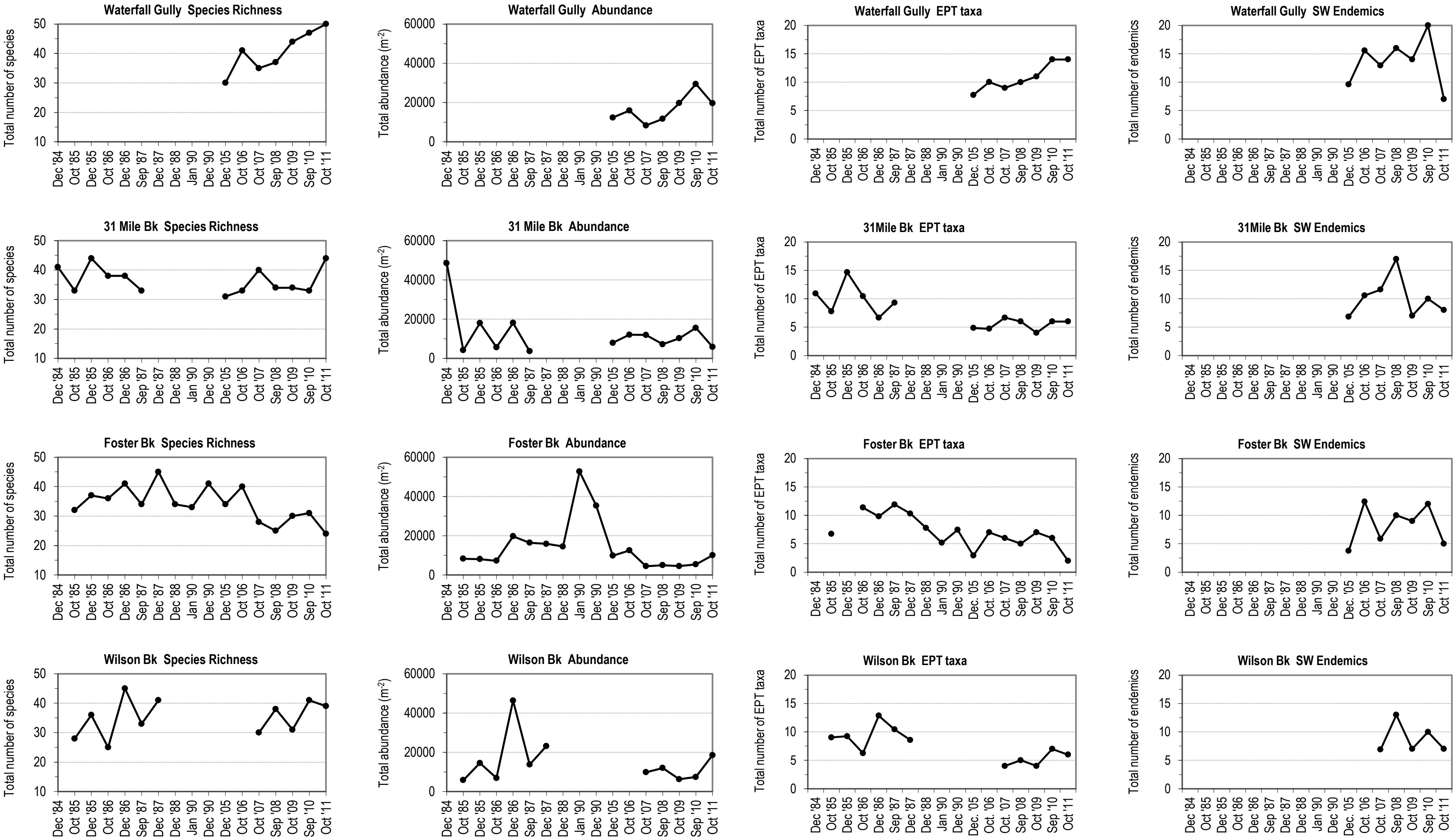

Figure 3B. Annual variability in macroinvertebrate species metrics (total richness, total abundance, total number of EPT taxa and total number of south-west endemics) at control (reference) sites. Historic (1984-90) data for reference sites are included for comparison with recent data (2005-11). Note: taxonomy has been standardised across years.

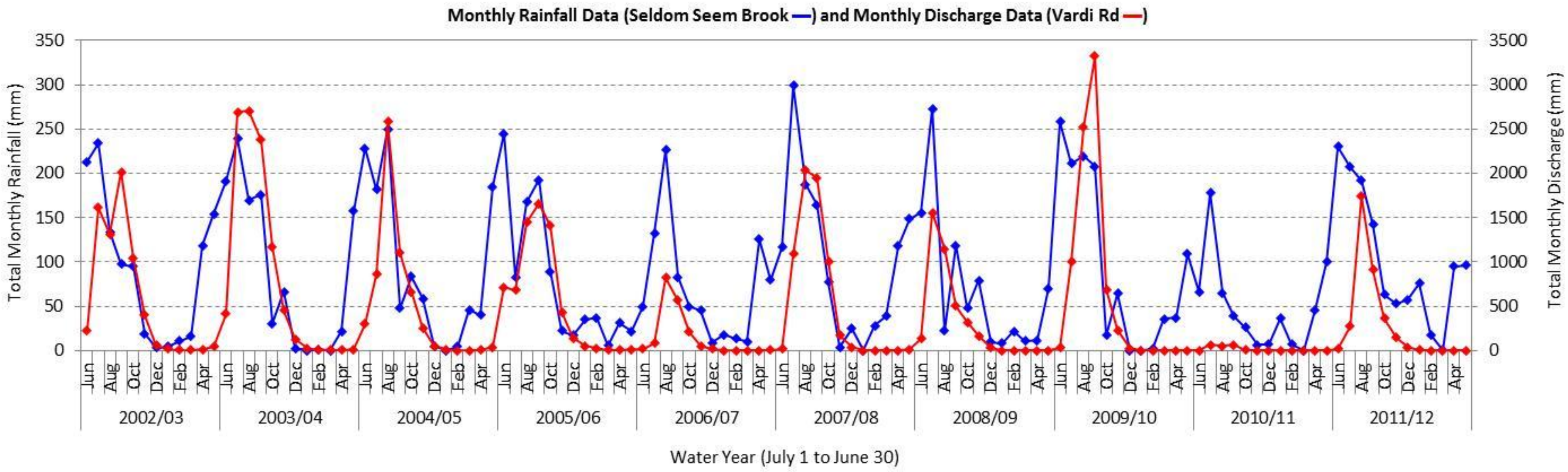

Figure 4. Rainfall (Stn 509269 - Seldom Seen Brook - Gardens) and runoff (Stn 616041 - Vardi Road) in the Wungong catchment.

Table 4. Summary of results from one-way ANOVA on change in macroinvertebrate species richness (number of species) and log (x+1) transformed abundance (m^{-2}) at individual sites over time (2005 - 2011). Significance level *p* value ≤ 0.05; ns = not significant. Where significant differences are indicated, refer to Figures 3A-B to determine which years differ.

Exposed Sites					Control Sites				
Site	**Variable**	**df**	**F**	***p***	**Site**	**Variable**	**df**	**F**	***p***
Vardi Road	Richness	6	12.708	0.000	**Waterfall Gully**	Richness	6	5.429	0.001
	Abundance	6	5.314	0.001		Abundance	6	5.147	0.001
TA1	Richness	6	2.370	0.050	**31 Mile Brook**	Richness	6	2.000	ns
	Abundance	6	1.938	ns		Abundance	6	2.214	ns
TA2	Richness	6	1.941	ns	**Foster Brook**	Richness	6	2.794	0.025
	Abundance	6	3.679	0.006		Abundance	6	3.011	0.018
Jack Rocks	Richness	6	7.070	0.001	**Wilson Brook**	Richness	6	3.098	0.034
	Abundance	6	5.365	0.003		Abundance	6	3.104	0.033

Table 5. Summary results from one-way ANOSIM on log (x+1) transformed macroinvertebrate species abundance data (m^{-2}) for 2005-2011, comparing exposed sites with control sites. Significance level *p* <0.05; ns = not significant. Refer Table 3 for explanation of the R-statistic.

Exposed Site	**Year**	**R-statistic for Pairwise Test with Control Site**			
		Waterfall Gully	**Foster Bk**	**31 Mile Bk**	**Wilson Bk**
Vardi Road	2005	0.669	0.63	0.657	--
	2006	0.996	0.993	1	--
	2007	0.861	0.991	0.641	0.957
	2008	0.767	0.457	0.641	ns
	2009	0.777	0.489	0.602	ns
	2010	1	0.622	0.978	0.63
	2011	0.972	0.643	0.922	1
TA1	2005	0.84	0.565	0.507	--
	2006	0.978	0.563	0.869	--
	2007	0.93	0.915	0.652	0.919
	2008	0.815	0.615	0.726	0.457
	2009	0.856	0.688	0.701	0.491
	2010	1	ns	0.919	0.917
	2011	0.985	0.6	0.881	0.996
TA2	2005	0.948	ns	0.48	--
	2006	0.994	0.843	0.722	--
	2007	0.917	0.819	0.77	0.935
	2008	0.785	0.58	0.67	0.424
	2009	0.743	0.592	0.666	0.457
	2010	0.83	0.511	0.515	0.9
	2011	0.919	0.289	0.657	0.919
More Seldom Seen Brook	2008	0.57	0.635	0.474	0.724
	2009	0.6	0.592	0.484	0.785
	2010	--	--	--	--
	2011	0.994	0.946	0.787	0.985
Jack Rocks	2007	1	0.963	0.998	0.93
	2008	0.948	0.833	0.893	0.706
	2009	0.956	0.801	0.899	0.753
	2010	0.95	0.824	0.956	0.835
	2011	0.865	0.748	0.646	0.707

Change in pairwise percentage similarity was used to provide a time series analysis of change in spring faunal assemblages at treated sites relative to reference sites and relative to their baseline condition (*i.e.* the first spring sampled) (Figure 5). Similar to the changes in species richness and abundance data noted above, there have been shifts in whole community structure, *i.e*. shifts in species assemblages. Amongst exposed sites in 2011, Vardi Road and TA1 showed little change from the 2010 condition and to date, these sites have shown only a slight (<10%) net shift away from the spring 2006 baseline condition (Figure 5). At TA2, however, there was a 25% decline in similarity from the 2010 condition and an 18% decline from the 2006 baseline condition (Figure 5). Taxa contributing to the shift away from baseline condition included gripopterygid stoneflies, the leptophlebiid mayfly *Nyungara bunni*, hydropsychid caddisflies and black-fly larva (Simulidae), none of which were collected from TA2 in 2011.

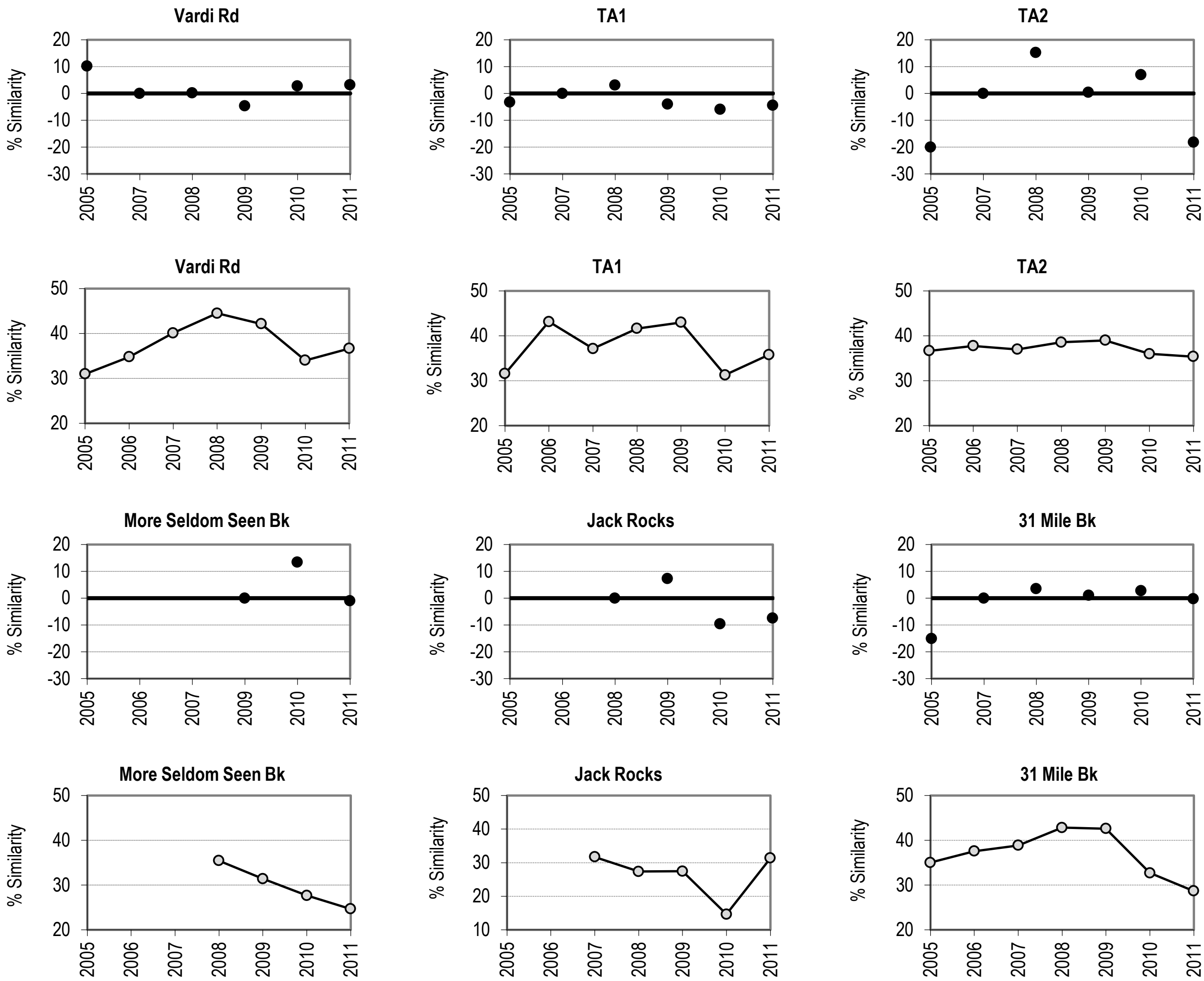

Figure 5. Change in similarity of macroinvertebrate species assemblages at individual sites (Vardi Road, TA1, TA2, More Seldom Seen Bk, Jack Rocks & 31 Mile Bk) relative to their baseline condition (● top rows) and their similarity to reference sites (○ bottom rows). Baseline condition is indicated as the solid dark line and is based on condition at the time of the first spring sampling; *i.e*. spring 2006 for Vardi Rd, TA1, TA2 and 31 Mile Bk; spring 2007 for Jack Rocks; spring 2008 for More Seldom Seen Bk. All data are percent similarity values determined from pairwise Bray-Curtis distance matrices based on species abundance. As Bray-Cutis similarity increases, similarity between species assemblages increases, *i.e*. the exposed site is becoming more similar to the control sites over time.

In general, species assemblages at TA2 have shown relatively higher temporal variation (up to 20%) than other exposed sites, but this variation has more consistently reflected the average temporal variation recorded across control sites. In contrast to TA2, Vardi Road and TA1 have shown less temporal variation in species assemblage composition, but the year-to-year fluctuations have not always mirrored those at control sites.

The other WCT site sampled, More Seldom Seen Brook, has shown an almost linear decline in similarity to reference sites over time, with species assemblage composition in 2011 only 24% similar to control sites (Figure 5A). This site is atypical of other exposed sites sampled. The channel is a small, shallow drainage line that flows through swampy, dense riparian vegetation. Flow is highly seasonal. Water depths during spring sampling occasions have typically been <30cm and in 2010, the channel was largely dry. The generally low species richness and abundance at this site and continuing shift in assemblage composition away from baseline condition were considered a function of an increasingly shortened flow regime and increased frequency of drying.

In 2011, as in previous monitoring years, faunal assemblages showed significant spatial variation amongst reference sites, as evidenced by ANOSIM tests (see example in Table 6). Since 2006, there has been a gradual shift in species composition at 31 Mile, Foster and Wilson brooks away from the historic (1985 - 1987) condition. The greatest net shift has been at Foster Brook, where similarity to the 1985 condition has declined by 30% (Figure 6).

In general, the temporal changes within reference sites were associated with an increased abundance of species more common to seasonal and/or slow flowing waters (ostracods, water mites, and paramelitid amphipods), and decreased abundance of taxa more typically associated with higher water velocities and fast-flowing reaches (simulids, baetid mayflies, stoneflies and several midge species).

Table 6. Summary results from one-way ANOSIM on log (x+1) transformed macro-invertebrate species abundance data (m^{-2}), comparing recent data (2005 -2011) for 31 Mile Brook with (A) recent data from other reference sites and (B) with historic (1985-87) baseline data. Significance level p <0.05.

Site	Year	R-statistic for Pairwise Test: Waterfall Gully	Foster Bk	Wilson Bk
(A) 31 Mile Bk	2005	0.687	0.554	--
	2006	0.993	0.891	--
	2007	0.826	0.980	0.874
	2008	0.891	0.683	0.656
	2009	0.821	0.660	0.633
	2010	0.974	0.626	0.915
	2011	0.952	0.922	0.835
		31 MB 1985	31MB 1986	31MB 1987
(B) 31 Mile Bk	2005	0.891	0.881	0.913
	2006	0.706	0.598	0.589
	2007	0.830	0.754	0.841
	2008	0.772	0.602	0.563
	2009	0.856	0.716	0.672
	2010	0.889	0.652	0.594
	2011	0.791	0.815	0.583

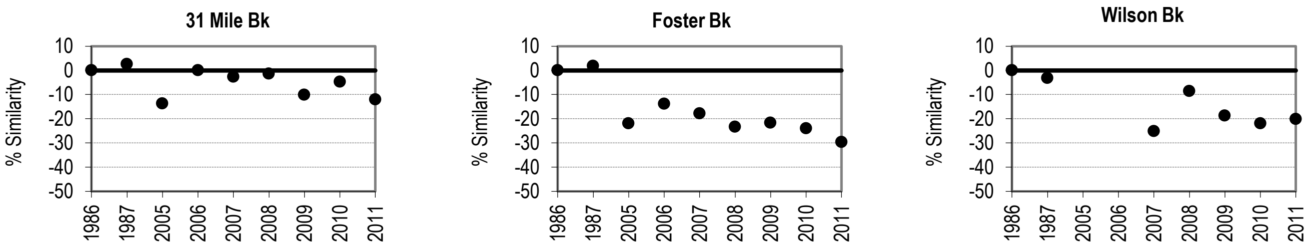

Figure 6. Change in similarity of macroinvertebrate species assemblages at reference sites 31 Mile Brook, Foster Brook and Wilson Brook, relative to their historic condition. Baseline condition is indicated as the solid dark line and is based on spring data collected in 1985. All data are percent similarity values determined from pairwise Bray-Curtis distance matrices based on species abundance.

Also of note were changes in abundance of paramelitid amphipods. These are obligate groundwater species that require permanent water. Between 2005 and 2010 there was a trend toward declining abundance of these amphipods at TA1 and Vardi Road, though absolute numbers recorded at Vardi Road were low (<15 individuals) in all years. At TA1, there has been a more or less consistent decline form 158 individuals in 2005 to 6 in 2011. Figure 7 illustrates interannual variation for sites where absolute abundances of >20 have been recorded. Conversely, there was a considerable increase in numbers at More Seldom Seen Brook from 61 in 2010 to 425 in 2011. Fluctuations in abundance of paramelitids may reflect changes in frequency and/or duration of connectivity between ground and surface waters, or possibly movement and concentration of animals as saturated zones contract in around the main channel.

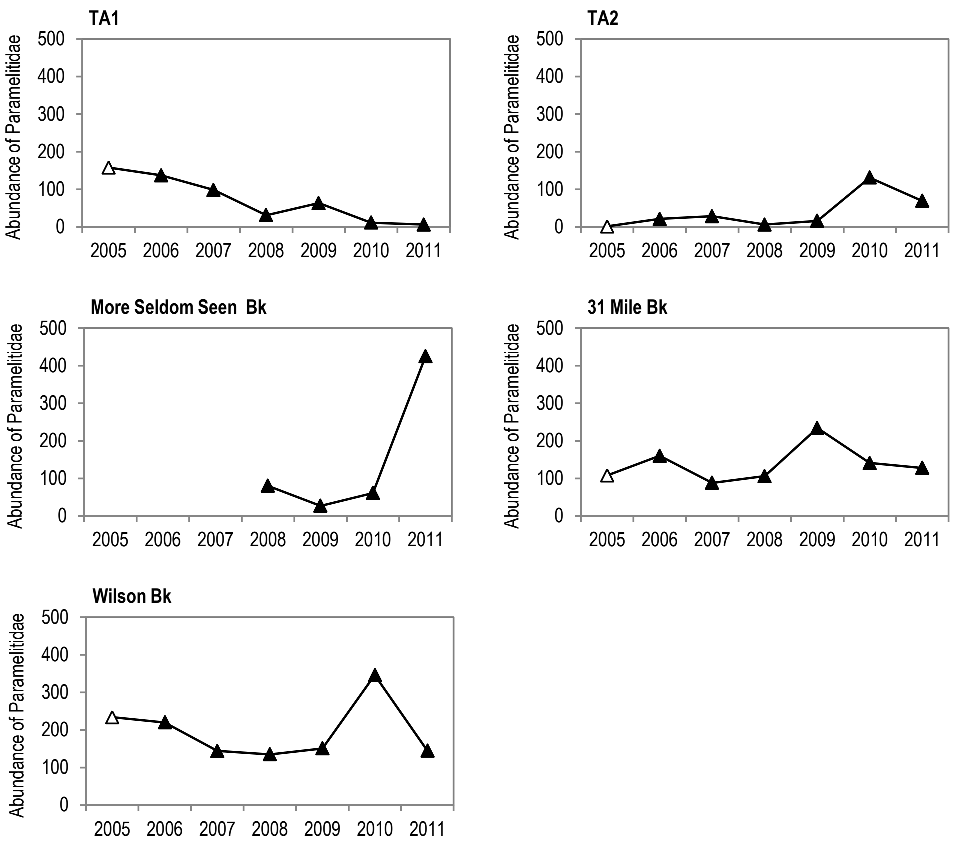

Figure 7. Change in absolute abundance of paramelitid amphipods (total number of individuals collected per site) at TA1, TA2, More Seldom Seen Brook, 31 Mile Brook and Wilson Brook.

3.3 Fish and Crayfish

Only two of the four species of freshwater fish previously recorded were caught in 2011. They were the native western minnow and the introduced trout. Two freshwater crayfish species (the native gilgie and introduced yabby) were again recorded in 2011. Data are tabulated as relative abundance categories in Table 7.

The low species richness and abundance of fish and crayfish recorded at both control and exposed sites in 2011 was unexpected. It was considered to be predominantly an artefact of sampling method rather than solely a response to any changes in streamflow. As in previous years, fishing effort could not be standardised between sites due to the physical nature of stream habitats, *i.e.* large number of snags and/or dense fringing vegetation at many sites, and as such there will be inherent variation. It is probable that if re-sampled next spring, a greater richness and abundance of fish and crayfish would be recorded.

Table 7. Fish and crayfish recorded. Codes: † introduced species ★ present; ★★common, ★★★abundant.

Site	Season/Year	Fish			Crayfish		
		Western minnow	Western pygmy perch	Nightfish	Trout†	Gilgie	Yabby†
TA1	Summer 2005					★★	
	Spring 2006					★★	
	Spring 2007		★★	★★		★★★	
	Spring 2008			★		★★	
	Spring 2009		★★	★★		★★★	
	Spring 2010	★	★	★		★★★	
	Spring 2011					★	
TA2	Summer 2005					★★★	
	Spring 2006			★		★★	
	Spring 2007	★★	★★	★		★★★	
	Spring 2008	★★	★★			★★★	
	Spring 2009	★★	★★			★★★	
	Spring 2010		★	★		★★★	
	Spring 2011				★	★	
Vardi Road	Summer 2005						
	Spring 2006		★★	★★		★★★	
	Spring /2007		★★		★	★★★	
	Spring 2008		★★	★★		★★★	
	Spring 2009		★★	★★	★	★★★	
	Spring 2010		★	★★		★★★	
	Spring 2011				★	★	
More Seldom Seen Bk	Spring 2008					★★	
	Spring 2009					★★	
	Spring 2010					★★	
	Spring 2011						
Waterfall Gully	Summer 2007						
	Spring 2006	★				★★★	
	Spring 2007					★★★	
	Spring 2008					★★★	
	Spring 2009	★★				★★★	
	Spring 2010	★★				★★★	
	Spring 2011					★	
31 Mile Bk	Summer 2005	★				★★	
	Spring 2006	★★★				★★	
	Spring 2007	★★★				★★	
	Spring 2008	★★★				★★	
	Spring 2009	★★★		★		★★	
	Spring 2010	★★★				★	
	Spring 2011	★				★	
Foster Bk	Summer 2005				★★		
	Spring 2006				★★	★★	
	Spring 2007	★★			★	★★★	
	Spring 2008	★			★★	★★	
	Spring 2009	★★	★		★★	★★	
	Spring 2010	★★			★★	★★	
	Spring 2011	★					
Wilson Bk	Spring 2007	★★				★★★	
	Spring 2008	★★	★★	★★		★★★	
	Spring 2009	★★	★★	★★		★★★	
	Spring 2010	★★	★★	★		★★★	
	Spring 2011					★	
Jack Rocks	Spring 2007	★★★				★★	★★

Site	Season/Year	Fish			Crayfish		
		Western minnow	Western pygmy perch	Nightfish	Trout†	Gilgie	Yabby†
	Spring 2008	★★★				★★	★★
	Spring 2009	★★★				★★	★★
	Spring 2010	★				★	★★★
	Spring 2011						★

4. DISCUSSION

Based on collective data from monitoring surveys conducted annually between 2005 and 2011, there was no evidence that the WCT has reduced the diversity of aquatic macroinvertebrate species. There was however, evidence that macroinvertebrate species assemblages were responding to variations in annual rainfall and streamflow patterns, but that this did not appear to be offset by the WCT.

In 2011, macroinvertebrate species richness and abundance at most exposed and control sites continued to show varying degrees of recovery following significant declines in 2007. This included Vardi Road, where particularly large declines in species richness (~40%) and abundance (~80%[3]) had been recorded between 2006 and 2009. The declines in 2007 were attributed to lower annual rainfall and streamflow in 2006. Similarly low rainfall/low streamflow occurred in 2010 and it was expected that this would also be followed by a decreases in species richness and abundance in 2011. However, this was not the case. One possible explanation may be that relatively higher streamflow between June and September 2009 maintained lotic habitats for a longer period into spring-summer.

Although most sites in 2011 supported species richness and abundance either greater than or comparable to 2010, declines in species richness were recorded at a three sites; exposed sites TA1 and TA2, and the control site Foster Brook (North Dandalup). Decline was greatest at TA2 where 38% fewer species were recorded in 2011 than in 2010. At TA2, there was also a 25% decline in similarity between species assemblages present in 2010 and those in 2011 and an 18% decline from the baseline spring 2006 condition. In contrast, exposed sites at Vardi Road and TA1 have shown only a slight (<10%) net shift in species assemblages away from the baseline condition in spring 2006, despite large decreases in species richness and abundance in 2007.

The decline in species richness observed at TA2 in 2011 (and to a lesser degree TA1 and Foster Brook), may represent a lagged response to low stream flow and/or late onset of flows in 2010. That this was not recorded at other sites possibly reflects a longer stream flow period at these other sites. Though flow data were not available for all sites, visual observation suggests longer flow duration at Vardi Road and Waterfall Gully (Wungong catchment) and Wilson Brook (North Dandalup), as well as persistence of higher water velocities into late spring/early summer. The relatively large, deeper channel pools at Jack Rocks (Serpentine) may also provide summer refuge for many species at this site.

Taxa contributing to the shift in species assemblages away from baseline condition at TA2 included gripopterygid stoneflies (Plecoptera), the leptophlebiid mayfly (Ephemeroptera) *Nyungara bunni*, hydropsychid caddisflies (Trichoptera) and black-fly larva (Simulidae), none of which were collected from TA2 in 2011. In general, fewer EPT taxa (Ephemeroptera, Plecoptera, Trichoptera) were recorded across exposed and control sites in 2011. EPT taxa include species considered more sensitive to disturbance as well as many south-west endemics.

[3] Abundance per m^2 calculated from the total number of individuals collected in a 25cm x 25 cm quadrat (area = 0.0625 m^2), multiplied by the number of replicate quadrats sampled per site, *i.e*. 6.

The decline in stoneflies and *Nyungara bunni* at TA2 was counter to results from past years which indicated a general increase in stoneflies and leptophlebiid mayflies associated with reduced rainfall and streamflow. However, the decline in hydropsychid caddisflies was consistent with past findings of decreased abundance of taxa more typically associated with higher water velocities and fast-flowing reaches, *i.e.* simulids, caddis-flies, baetid mayflies and several midge species.

As noted by Davies and Storey (2012), faunal response to a drying climate is unlikely to be linear whilst drought refugia, such as permanent pools, persist along the same or adjacent creeks in these catchments. In the initial phases, dominance patterns may change little year to year for common macroinvertebrate species in perennial streams. Temporal and spatial unevenness (‘noise’) will predominantly be driven by the more sensitive (and typically less common) species, at least in the early stages when stream drying is infrequent. This may explain the inconsistencies observed between years and amongst sites.

There is likely to be a minimum flow duration, below which fauna cannot complete their life-cycles. Even fauna that are pre-adapted to seasonal flow may not survive if the duration of flow falls below a critical minimum duration. To date, there has been little research on critical flow duration thresholds in south-west streams and rivers below which species adapted to seasonal (as opposed to episodic) flow regimes would be lost.

Also of note in 2011 were changes in the abundance of paramelitid amphipods. These are obligate groundwater species that require permanent water. Between 2005 and 2010 there was a trend toward declining abundance of these amphipods at TA1 and Vardi Road, though absolute numbers recorded at Vardi Road were low (<15 individuals) in all years. At TA1, there has been a more or less consistent decline form 158 individuals in 2005 to 6 in 2011. Conversely, there was a considerable increase in numbers at More Seldom Seen Brook from 61 in 2010 to 425 in 2011. Fluctuations in abundance of paramelitids may reflect changes in frequency and/or duration of connectivity between ground and surface waters, or possibly movement and concentration of animals as saturated zones contract in around the main channel. As these amphipods are vagrants in surface waters, targeted sampling of groundwater bores would be required to confirm any long-term population trends of these species in groundwaters.

REFERENCES

ANZECC/ARMCANZ (2000). Australian and New Zealand Water Quality Guidelines. Australian & New Zealand Environment & Conservation Council and Agriculture & Resource Management Council of Australia & New Zealand. http://www.deh.gov.au/water/quality/nwqms/index.html#quality.

Boulton A.J. (2003). Parallels and contrasts in the effects of drought on stream macroinvertebrate assemblages. *Freshwater Biology* **48**(7): 1173-1185.

Clarke K.R. & Gorley R.N. (2006). Primer v6: User Manual/Tutorial, Primer E: Plymouth. Plymouth Marine Laboratory, Plymouth, UK.

Davies S. & Storey A. (2010). Wungong Catchment Trial Project: Aquatic Fauna Biodiversity Assessment October 2009. Unpublished report to the Water Corporation prepared by the Aquatic Research Laboratory, the University of Western Australia. June 2010. ISBN/ISSN 1 74043 640 7.

Davies S. & Storey A.W. (2012) Temporal Persistence in Northern Jarrah Forest Aquatic Macroinvertebrate Communities - Preliminary Investigation of Response to Declining Rainfall. Unpublished report to the Water Corporation prepared by the Aquatic Research laboratory, The university of Western Australia. July 2012. ISBN/ISSN 1 74043 796 9.

Storey A. & Creagh S. (2006). Wungong Catchment Environment and Water Management Project: Aquatic Fauna Biodiversity Assessment December 2005. Unpublished report by the Aquatic Research Laboratory, the University of Western Australia to the Water Corporation. June 2006. ISBN/ISSN 1 74043 636 9.

Storey A. & Creagh S. (2007). Wungong Catchment Environment and Water Management Project: Aquatic Fauna Biodiversity Assessment October 2006. Unpublished report to the Water Corporation prepared by the Aquatic Research Laboratory, the University of Western Australia. June 2007. ISBN/ISSN 1 74043 637 7.

Storey A. & Creagh S. (2008). Wungong Catchment Trial Project: Aquatic Fauna Biodiversity Assessment October 2007. Unpublished report to the Water Corporation prepared by the Aquatic Research Laboratory, the University of Western Australia. July 2008. ISBN/ISSN 1 74043 638 5.

Storey A. & Creagh S. (2009). Wungong Catchment Trial Project: Aquatic Fauna Biodiversity Assessment September 2008. Unpublished report to the Water Corporation prepared by the Aquatic Research Laboratory, the University of Western Australia. June 2009. ISBN/ISSN 1 74043 639 3.

APPENDICES

Appendix 1. Photographs of sampling sites taken in October 2011


Vardi Road weir


View downstream from Vardi Road weir


Site TA1 - view upstream


Waterfall Gully – view upstream from road bridge


Site TA2 - view upstream


Site TA2 - view downstream

Jack Rocks on 39 Mile Brook, in the Serpentine catchment - view upstream

Jack Rocks on 39 Mile Brook - view downstream

31 Mile Brook in the Canning catchment– view upstream from weir

Foster Brook in the North Dandalup catchment – immediately downstream of sampling site

Sampling site on Wilson Brook in the North Dandalup

Appendix 2. Foreshore condition rating

Foreshore condition and stream environmental ratings based on visual, qualitative methods of Pen & Scott (1995) and WRC (1999). Refer to Storey and Creagh (2006) for descriptions of ratings. NA = not assessed.

Site	Baseline Foreshore Condition in 2005	Baseline Stream Environmental Rating in 2005	Condition/Rating 2006 - 20011	
			2006	2007 - 2011
Waterfall Gully	A1-2 (near 'pristine')	Good	A1-2 / Good	A1-2 / Good
Vardi Road	A1-2 (near 'pristine')	Excellent	A1-2 / Excellent	A1-2 / Excellent
TA1	A3 (soil exposed due to recent burn)	Good	A3 / Good	A3 / Good
TA2	B1-2 (local weed infestation)	Good	B1-2 / Good	B1-2 / Good
More Seldom Seen	NA	NA	NA	A1-2 / Excellent
31 Mile Brook	A1-2 (near 'pristine')	Excellent	A1-2 / Excellent	A1-2 / Excellent
Foster Brook	A3 (soil exposed due to recent burn)	Moderate (severe burn)	A3 / Moderate (some regrowth)	A2 / Good (strong regrowth)
Wilson Brook	NA	NA	NA	A1-2 / Excellent
Jack Rocks	NA	NA	NA	A1-2 / Excellent

Appendix 3. Physico-chemical data recorded at each site in October 2011 in conjunction with aquatic fauna sampling.

Site	Date	Start Time	Rep#	Ave. Velocity m/s	DO %	DO mg/L	Temp deg C	pH	Econd. uS/cm
Foster Bk	19/10/11	8:00 AM	1	0.046	90.9	11.40	11.00	6.94	258
Foster Bk	19/10/11		2	0.155	91.5	10.42	10.40	6.28	258
Foster Bk	19/10/11		3	0.188	90.3	11.43	5.90	5.84	258
Foster Bk	19/10/11		4	0.135	89.1	10.05	11.00	5.92	258
Foster Bk	19/10/11		5	0.119	93.4	10.33	10.80	5.95	258
Foster Bk	19/10/11		6	0.123	91.5	7.50	11.30	6.37	258
31 Mile Bk	21/10/11	12:15 PM	1	0.077	89.4	7.08	14.90	7.86	346
31 Mile Bk	21/10/11		2	0.040	88.0	7.10	14.20	6.31	346
31 Mile Bk	21/10/11		3	0.067	92.5	7.53	13.80	6.18	346
31 Mile Bk	21/10/11		4	0.111	91.5	7.42	14.40	6.49	346
31 Mile Bk	21/10/11		5	0.065	87.9	8.89	15.20	6.15	346
31 Mile Bk	21/10/11		6	0.101	88.6	8.80	15.00	6.77	346
Waterfall Gully	20/10/11	7:15 AM	1	0.158	101.8	10.98	11.80	6.31	203
Waterfall Gully	20/10/11		2	0.134	102.9	11.09	11.70	6.46	203
Waterfall Gully	20/10/11		3	0.113	105.1	11.28	11.5	6.54	203
Waterfall Gully	20/10/11		4	0.095	104.7	8.94	11.70	6.46	203
Waterfall Gully	20/10/11		5	0.074	102.9	8.81	11.20	6.30	203
Waterfall Gully	20/10/11		6	0.152	108.4	9.38	11.10	7.17	203
Wilson Bk	19/10/11	10:45 AM	1	0.057	90.5	9.88	11.90	7.45	284
Wilson Bk	19/10/11		2	0.131	89.6	9.44	12.80	7.05	284
Wilson Bk	19/10/11		3	0.111	89.1	9.62	12.20	6.65	284
Wilson Bk	19/10/11		4	0.085	90.4	9.62	12.40	7.00	284
Wilson Bk	19/10/11		5	0.149	92.1	9.88	12.20	5.81	284
Wilson Bk	19/10/11		6	0.064	92.5	7.74	12.70	6.91	284
TA1	20/10/11	1:15 PM	1	0.064	79.6	8.58	14.60	6.16	254
TA1	20/10/11		2	0.205	87.2	6.82	15.50	6.32	254
TA1	20/10/11		3	0.117	88.0	6.88	15.50	6.40	254
TA1	20/10/11		4	0.216	86.8	6.79	16.20	6.70	254
TA1	20/10/11		5	0.175	86.8	6.80	16.10	6.65	254
TA1	20/10/11		6	0.059	79.3	6.01	16.40	6.18	254
TA2	20/10/11	10:50 AM	1	0.056	93.7	9.58	13.00	6.96	349.0
TA2	20/10/11		2	0.147	97.4	10.07	13.70	6.56	349.0
TA2	20/10/11		3	0.138	92.4	9.56	13.80	6.34	349.0
TA2	20/10/11		4	0.076	95.2	9.85	14.00	6.44	349.0
TA2	20/10/11		5	0.088	92.4	9.41	13.80	6.82	349.0
TA2	20/10/11		6	0.090	90.9	9.33	14.10	6.69	349.0
Vardi Rd	20/10/11	3:35 PM	1	0.058	89.1	8.77	16.60	6.64	300
Vardi Rd	20/10/11		2	0.131	92.4	9.42	14.90	6.41	300
Vardi Rd	20/10/11		3	0.085	92.9	9.33	14.90	6.20	300
Vardi Rd	20/10/11		4	0.042	89.8	9.03	15.00	6.01	300
Vardi Rd	20/10/11		5	0.069	92.1	9.23	15.40	6.21	300
Vardi Rd	20/10/11		6	0.103	93.5	9.44		6.09	300
Jack Rocks	19/10/11	4:00 PM	1	0.033	84.1	6.08	19.30	7.05	287
Jack Rocks	19/10/11		2	0.057	97.7	7.25	18.10	6.91	287
Jack Rocks	19/10/11		3	0.039	89.5	6.72	18.30	6.40	287
Jack Rocks	19/10/11		4	0.037	91.6	6.56	17.40	6.69	287
Jack Rocks	19/10/11		5	0.094	91.7	7.07	17.00	6.44	287
Jack Rocks	19/10/11		6	0.069	89.9	6.48	16.30	6.48	287
More Seldom Seen Bk	21/10/11	9:45 AM	1	0.018	68.0	6.90	14.60	5.36	281
More Seldom Seen Bk	21/10/11		2	0.022	52.5	5.57	13.40	5.13	281
More Seldom Seen Bk	21/10/11		3	0.017	50.9	5.21	13.30	5.70	281
More Seldom Seen Bk	21/10/11		4	0.032	44.5	4.77	13.40	5.33	281
More Seldom Seen Bk	21/10/11		5	0.026	42.9	4.41	13.60	5.45	281
More Seldom Seen Bk	21/10/11		6	0.017	44.5	4.68	13.10	5.06	281

Appendix 4. Combined raw abundance data for macroinvertebrate taxa for each site sampled in October 2011.

Phylum/Class/Order	Family/Species	*TA1*	TA2	Vardi Rd	More Seldom Seen Brook	Waterfall Gully	31 Mile Brook	Foster Brook	Wilson Brook	Jack Rocks
NEMATODA	Nematoda sp.	15	4	1	1	3	20	7	0	135
PLATYHELMINTHES	Turbellaria sp.	1	1	0	0	0	1	0	0	1
CNIDARIA	Hydra sp.	0	0	0	0	0	1	0	0	0
ANNELIDA	Oligochaeta spp.	246	130	321	4	356	48	141	432	433
GASTROPODA	Gastropoda sp.	0	0	0	0	0	3	0	0	0
	Glacidorbidae	0	0	0	0	0	0	1	0	0
CRUSTACEA										
AMPHIPODA	Amphipoda sp.	6	69	11	425	145	105	1	9	40
	Perthiidae									
	Perthia acutitelson	0	0	0	3	0	0	0	0	0
	Paramelitidae									
	Totgammarus eximius	0	0	0	0	0	23	0	0	0
DECAPODA	**Parastacidae sp.**	0	0	0	0	0	1	0	0	0
CLADOCERA	Cladocera sp.	5	0	0	0	0	1	10	0	8
COPEPODA	Copepoda sp.	3	0	1	0	0	0	0	0	3
	Cyclopoida sp.	6	0	3	1	0	1	0	1	0
	Harpacticoida sp.	5	0	0	0	0	0	0	0	0
ISOPODA	Isopoda sp.	0	0	0	0	0	1	0	1	0
OSTRACODA	Ostracoda spp.	31	1	28	0	1	37	2	45	143
ARACHNIDA	Hydracarina spp.	14	20	31	3	4	4	5	4	14
	Oribatida spp.	0	1	0	19	0	6	0	0	0
COLLEMBOLA	Entomobryoidea spp.	0	1	0	1	0	1	0	0	1
	Poduroidea spp.	1	3	0	4	1	1	2	1	3
	Symphypleona spp.	0	0	1	1	1	4	0	0	0
INSECTA										
EPHEMEROPTERA	**Baetidae**									
	Baetidae spp.	0	4	0	1	26	1	0	0	1
	Offadens soror	0	0	0	0	13	0	0	0	0
	Offadens sp.	0	0	0	0	2	0	0	0	0
	Leptophlebiidae									
	Leptophlebiidae spp.	15	12	8	2	30	17	0	65	76
	Nousia sp. AV16	26	30	1	0	16	1	0	3	40
	Nyungara bunni	0	0	2	0	0	0	0	6	0
	Bibulmena kadjina	0	0	0	0	0	1	0	0	0
PLECOPTERA	**Gripopterygidae**									
	Gripopterygidae spp. (imm)	0	0	1	0	0	0	0	0	0
	Leptoperla australica	0	0	0	0	0	2	0	0	5
	Newmanoperla exigua	9	0	1	0	0	24	8	91	2
	Riekoperla occidentalis	0	0	0	0	0	0	0	65	0
MEGALOPTERA	**Corydalidae**									
	Apochauliodes cervulus	0	0	0	1	0	1	2	1	0
ODONATA	Anisoptera spp. (imm.)	0	0	0	0	7	0	0	0	2
	Gomphidae									
	Armagomphus armiger	0	0	0	0	2	0	0	0	0
	Synthemistidae									
	Austrosyntemis cyanitincta	0	0	0	0	3	0	0	0	0
	Telephlebiidae									
	Austroaeschna anacantha	0	0	0	0	1	0	0	0	0
	Curculionidae									
COLEOPTERA	**Curculionidae**	0	0	0	1	0	2	0	0	0

Phylum/Class/Order	Family/Species	*TA1*	TA2	Vardi Rd	More Seldom Seen Brook	Waterfall Gully	31 Mile Brook	Foster Brook	Wilson Brook	Jack Rocks
	Dytiscidae									
	Platynectes sp. (L)	12	0	1	0	0	0	0	0	2
	Sternopriscus sp. (L)	0	1	1	0	0	1	0	0	2
	Hydraenidae									
	Limnebius sp.	0	0	0	1	0	0	0	0	0
	Ptilodactylidae	2	0	0	4	0	0	2	0	0
	Scirtidae	1	0	0	0	1	0	0	4	0
DIPTERA	**Athericidae**	0	0	0	2	0	0	0	0	0
	Cecidomyiidae	0	3	0	6	0	4	3	7	0
	Ceratopogonidae									
	Ceratopogonidae sp. (P)	0	0	0	0	0	0	0	1	0
	Ceratopogoninae spp.	6	0	12	2	65	2	0	18	1
	Dasyheleinae sp.	0	0	0	0	0	0	0	0	2
	Forcipomyiinae sp.	0	0	1	1	0	0	0	0	11
	Leptoconopinae sp.	0	0	0	0	0	0	1	0	0
	Chironomidae									
	Chironomidae spp. (P)	13	16	5	12	2	0	11	7	23
	Chironomidae(V30)	0	0	0	0	9	1	0	0	0
	Chironomidae (VCD8)	0	0	2	0	0	0	0	0	0
	Aphroteniinae									
	Aphroteniella filicornis (V23)	0	0	0	0	30	0	0	1	0
	Tanypodinae									
	Alotanypus dalyupensis (VSC11)	0	0	0	0	0	1	0	1	0
	Australopelopia prionaptera (V10)	0	0	0	0	42	0	0	0	0
	Paramerina levidensis (V1)	61	18	10	41	0	5	32	24	89
	?*Zavrelimyia* (V20)	0	2	0	6	1	3	0	16	0
	Orthocladiinae									
	Unknown genus (V15)	0	2	0	0	0	0	0	4	0
	Unknown genus (V31)	4	7	1	368	8	6	10	7	1
	Unknown genus (V43)	0	0	0	0	0	0	0	2	0
	Unknown Genus (V59)	0	0	0	11	0	0	0	3	9
	Botryocladius bibulmun (V11)	0	1	0	0	81	0	0	2	0
	Botryocladius freemani (V77)	0	0	0	0	1	0	1	0	0
	Coryoneura sp. (V49)	1	1	0	0	0	2	0	0	0
	Cricotopus amuliventris (V2)	481	125	194	2	3	7	106	6	1067
	nr *Gymnometriocnemus* sp. 1 (V44)	0	0	0	10	0	3	0	2	9
	nr *Gymnometriocnemus* sp. 2 (V45)	0	0	0	0	0	0	0	0	1
	nr *Stictocladius* (?*Lopescladius*) (V35)	0	0	0	0	0	0	0	105	1
	Parakiefferiella sp. (nr *variegatus* VSC9)	0	1	0	0	0	1	0	13	0
	Paralimnophyes sp. (V42)	21	3	0	16	0	3	0	3	4
	Strictocladius ?*uniserialis* (V8)	0	0	2	0	89	0	0	0	0
	Thienemanniella sp. (V19)	220	164	101	19	30	3	223	32	91
	Chironominae									
	Unknown genus (?*Paratendipes*) (V12)	0	0	0	0	1	0	0	0	0
	Cladotanytarsus sp. (VSC12)	0	0	0	0	3	0	0	0	0
	Cryptochironomus griseidorsum (V25)	0	0	1	12	2	0	2	0	1
	Dicrotendipes sp. (V47)	0	0	2	0	0	0	0	0	0
	Harrisius sp. (nr *montanus*) (V27)	0	0	0	1	0	0	0	1	0
	Paracladopelma sp. (VCD10)	0	0	0	0	0	0	0	0	5
	Polypedilum sp. (V3)	2	0	0	28	3	4	24	48	0
	Polypedilum watsoni (V33)	0	0	1	0	18	0	0	0	0
	Rheotanytarsus sp. (V18)	0	0	7	0	28	0	0	0	0

Phylum/Class/Order	Family/Species	*TA1*	TA2	Vardi Rd	More Seldom Seen Brook	Waterfall Gully	31 Mile Brook	Foster Brook	Wilson Brook	Jack Rocks
	Riethia sp. ?*stictoptera* (V5)	3	0	0	0	3	1	0	0	0
	Riethia sp. ?*zeylandica* (V4)	0	0	0	0	20	0	0	0	0
	Stempellina sp. (V7)	0	0	0	0	1	1	0	0	0
	Tanytarsus fuscithorax (V6)	98	5	50	1	52	8	7	2	82
	Culicidae									
	Aedes sp.	0	0	0	6	0	0	0	0	0
	Culex sp.	1	0	0	2	0	0	0	0	0
	Dolichopodidae	1	0	0	0	0	0	0	0	1
	Empididae	0	0	0	0	5	0	0	4	2
	Psychodidae	0	0	0	0	2	0	0	0	0
	Sciaridae	0	0	0	1	0	0	0	1	0
	Simuliidae									
	Simuliidae spp.	22	5	0	7	72	3	22	111	99
	Simuliidae spp. (P)	0	0	0	46	0	0	0	1	0
	Tabanidae	1	0	0	0	0	0	0	0	0
	Tanyderidae	0	0	0	0	0	1	0	2	0
	Tipulidae	6	1	0	0	22	1	0	8	4
TRICHOPTERA	Trichoptera spp. (imm.)	0	1	1	0	0	0	0	0	0
	Ecnomidae									
	Ecnomina sp.	0	0	0	0	5	0	0	0	0
	Hydrobiosidae									
	Hydrobiosidae sp. (imm.)	0	0	0	0	1	0	0	0	0
	Taschorema sp.	0	0	0	0	2	0	0	0	0
	Hydropsychidae									
	Hydropsychidae sp.	0	0	2	0	1	0	0	0	0
	Hydroptilidae									
	Hydroptilidae sp. (imm.)	0	0	0	0	1	0	0	0	0
	Acritoptila/*Hellyethira* sp.	0	2	0	0	0	0	0	0	0
	Leptoceridae									
	Leptoceridae spp.	0	0	13	0	0	0	0	0	0
	Triplectides australicus	0	0	0	0	3	0	0	0	0
	Philopotamidae									
	Philopotamidae spp. (imm.)	0	0	0	0	1	0	0	0	0
	Hydrobiosella michaelseni	0	0	0	1	0	0	3	1	0
	Hydrobiosella sp. AV16	0	0	0	0	1	0	0	0	0
	Polycentropodidae									
	Polycentropodidae sp. (dam.)	0	0	0	0	1	0	0	0	0