# Wungong Catchment Trial

## Aquatic Fauna Biodiversity Assessment, September 2010

August 2011

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## Recommended Reference Format

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## Disclaimer

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# 1.Introduction

## 1.1 Background and Objectives

This is the sixth in a series of annual surveys commissioned by the Water Corporation to assess the effects of the Wungong Catchment Trial Project (WCTP) on the biodiversity of aquatic fauna (principally aquatic macroinvertebrates) in tributary streams of the Wungong catchment. The monitoring program has been designed to detect changes in aquatic macroinvertebrate assemblages in response to changes in flow regime or water quality conditions associated with the WCTP. 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 annual aquatic fauna 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".

The aquatic fauna monitoring surveys commenced in 2005, when the Water Corporation commissioned the Aquatic Research Laboratory (ARL) of The University of Western Australia, to develop a monitoring programme for aquatic fauna. In order to separate short-term stochastic fluctuations from any effects of the Wungong Catchment Trial, ARL (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 (ARL 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 September 2010 round of sampling for the program against all data collected since 2005.

# 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 six replicate samples taken at each site. Qualitative sampling for fish is conducted using a back-pack electrofisher over a standardised 40 m at each site. Fish and crayfish were surveyed using standardised CPUE electrofishing (Smith-Root backpack electrofisher). *In-situ* measurement of a range of physical and water quality parameters was made in conjunction with the fauna sampling together with qualitative visual assessment of changes in riparian vegetation. Full details of methods are provided in previous annual reports (ARL 2006, 2007, 2008 & 2009).

The design of the sampling program 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 control (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 17.0 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 control (reference) sites, and

ii). how control (reference) sites change over time relative to their historic condition.

For example, a Bray-Curtis similarity value of 100% indicates species assemblages in macroinvertebrate communities are identical, while a value of 0% indicates communities have no taxa in common.  ANOSIM is used to test for statistically significant changes ($p$ <0.05) 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 and 1B. Sites sampled in 2010 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, and 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.  Flow in the More Seldom Seen Brook is also highly seasonal and in 2010, there was not enough surface water to enable collection of all six replicate macroinvertebrate samples for statistical comparison (only two replicates were taken in 2010).

- 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 | 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<br>Total area 2,540ha<br>Available for treatment 1,620ha<br>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<br>Total area (TA2): 2 780ha<br>Available for treatment: 1 780ha<br>Treatment completed: 340 ha<br><br>Within TA2:<br>Cobiac cub-catchment -<br>Total area 360ha<br>Availble for treatment 260ha<br>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 |

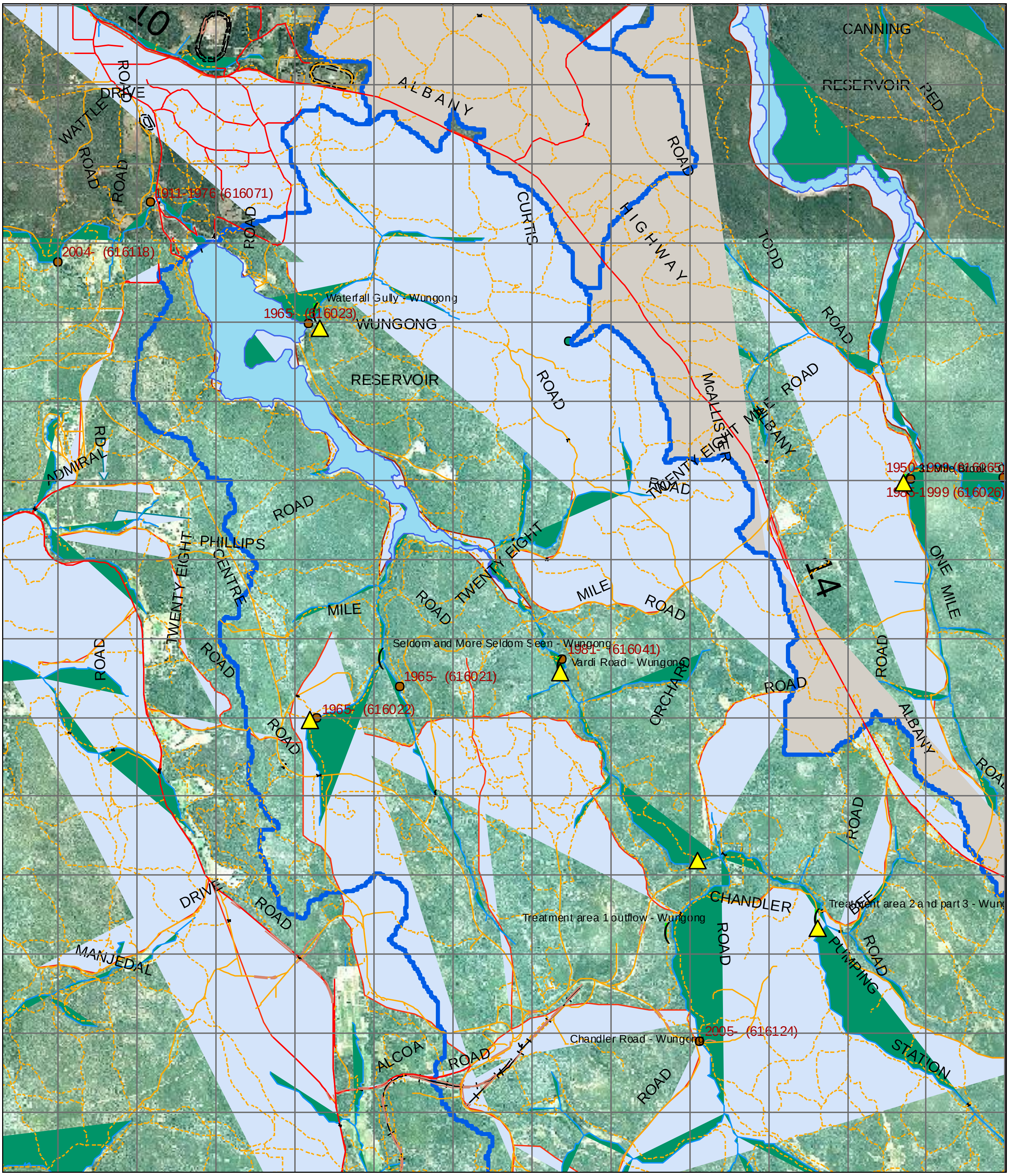



**Figure 1A Location of aquatic fauna survey sites (△) Wungong catchment and on 31 Mile Brook in the Upper Canning catchment**

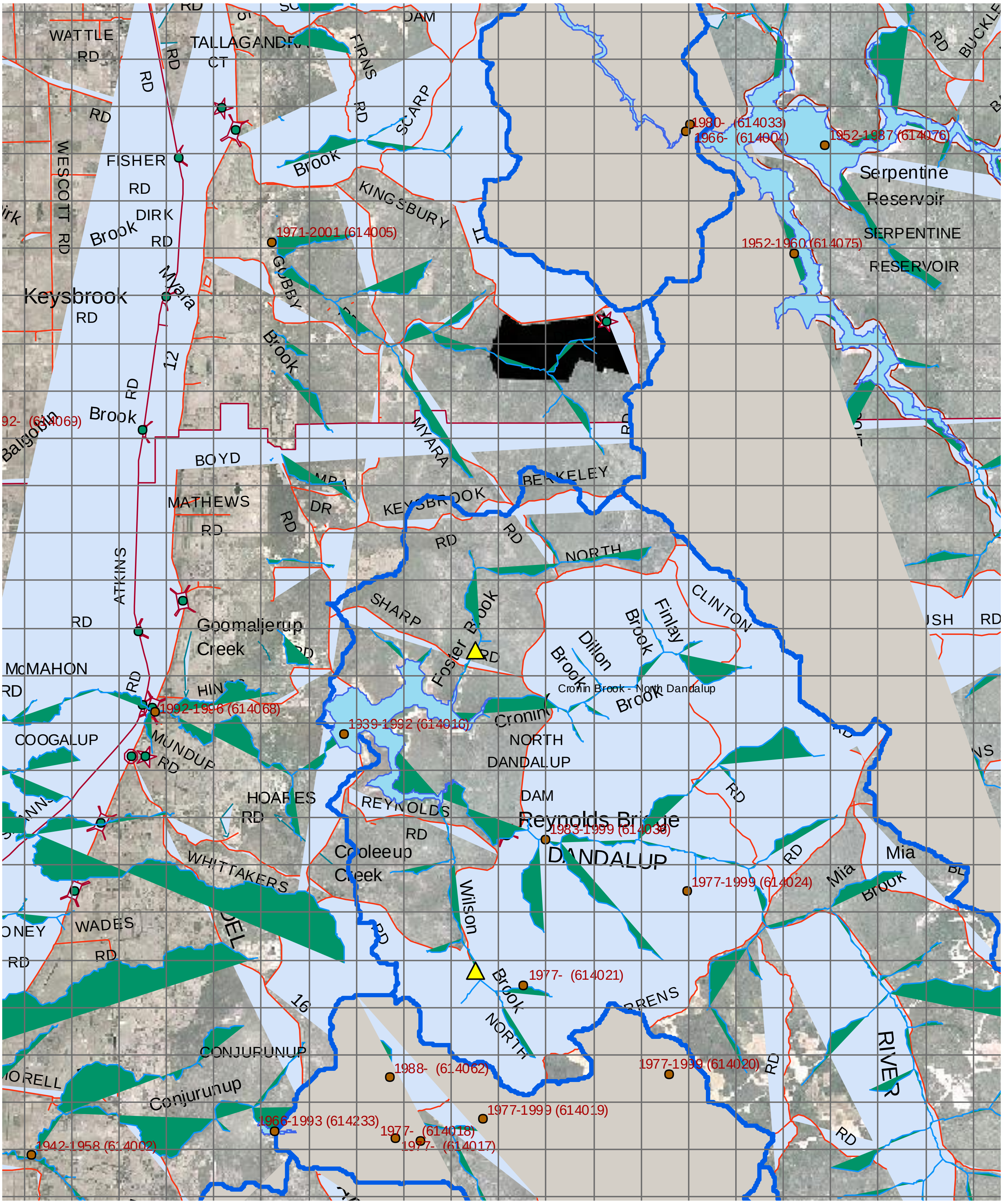



**Figure 1B Location of aquatic fauna reference sites (△) on Foster Brook and Wilson Brook in the upper North Dandalup catchment**

# 3. Results

Photographs of each sampling site are presented in Appendix 1 and all raw data collected during the 2010 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 obvious differences in water chemistry between the treated (exposed) group and control (reference) group. For some water quality parameters (*e.g.* water velocity, temperature, DO), the differences between 2005 and all later monitoring years are due to the fact that monitoring was undertaken in summer (December) in 2005, rather than spring (September-October) in subsequent years due to a delays for project start date. Differences therefore largely reflect seasonal differences.

Significant spatial and temporal differences in water velocity were however, recorded at individual sites (refer Table 2). Examples of changes in water chemistry at individual sites are provided in Figure 2. Water velocity is dependent on the influence of rainfall prior to and during surveys and natural variation between sites and between years was not unexpected. The most consistent trend was the strong decline in water velocity in 2009 and 2010. This was observed at all sites, both exposed and controls. There was an accompanying decline in dissolved oxygen levels and an increase in water temperature at most sites (Figure 2). The pH of waters also appeared to be in decline, though this trend was not as strong, nor as consistent, across sites. Salinity levels too were highly dependent on rainfall events, most notably at shallow-water sites where low values in 2010 were a direct result of rainfall during sampling days.

Although changes in water quality variables were observed at individual sites, all values remained within the range recommended by ANZECC/ ARMCANZ (2000) for the protection of aquatic fauna. In general, salinity levels have remained low (<500 µS $cm^{-1}$), dissolved oxygen levels moderate to high (68 - 116% saturation) and pH largely within the range of 6 to 8.

**Table 2 Summary of results from one-way ANOVA o*n change in physico-chemistry at individual sites over time (2005–2010). Only statistically significant results are shown (Bonferroni adjusted p value = 0.002)***

| Treated Sites | | | | | Control Sites | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Variable** | **df** | **F** | ***p*** | **Site** | **Variable** | **df** | **F** | ***p*** |
| **Vardi Road** | Water velocity | 5 | 8.133 | <0.0001 | **Waterfall Gully** | Water velocity | 5 | 24.614 | <0.0001 |
| | Dissolved oxygen | 5 | 116.8685 | <0.0001 | | Dissolved oxygen | 5 | 23.821 | <0.0001 |
| | Temperature | 5 | 6265.584 | <0.0001 | | Temperature | 5 | 351.529 | <0.0001 |
| | ECond | 5 | 5.351 | <0.0001 | | ECond | 5 | 265.748 | <0.0001 |
| | pH | 5 | 284.500 | <0.0001 | | pH | 5 | 490.190 | <0.0001 |
| **TA1** | Water velocity | 5 | 25.399 | <0.0001 | **31 Mile Brook** | Water velocity | 5 | 63.768 | <0.0001 |
| | Dissolved oxygen | 5 | 79.738 | <0.0001 | | Dissolved oxygen | 5 | 38.934 | <0.0001 |
| | Temperature | 5 | 1040.449 | <0.0001 | | Temperature | 5 | 254.295 | <0.0001 |
| | ECond | 5 | 223.939 | <0.0001 | | ECond | 5 | 1550.662 | <0.0001 |
| | pH | 5 | 235.861 | <0.0001 | | pH | 5 | 195.190 | <0.0001 |
| **TA2** | Water velocity | 5 | 20.742 | <0.0001 | **Foster Brook** | Water velocity | 5 | 13.918 | <0.0001 |
| | Dissolved oxygen | 5 | 71.204 | <0.0001 | | Dissolved oxygen | 5 | 9.579 | <0.0001 |
| | Temperature | 5 | 2178.116 | <0.0001 | | Temperature | 5 | 1033.310 | <0.0001 |
| | ECond | 5 | 171.703 | <0.0001 | | ECond | 5 | 595.092 | <0.0001 |
| | pH | 5 | 50.072 | <0.0001 | | pH | 5 | 43.587 | <0.0001 |
| **Jack Rocks** | Water velocity | 5 | 136.818 | <0.0001 | **Wilson Brook** | Water velocity | 3 | 24.614 | <0.0001 |
| | Dissolved oxygen | 5 | 37.897 | <0.0001 | | Dissolved oxygen | 3 | 23.821 | <0.0001 |
| | Temperature | 5 | 14.878 | <0.0001 | | Temperature | 3 | 351.529 | <0.0001 |
| | ECond | 5 | 417.626 | <0.0001 | | ECond | 3 | 265.748 | <0.0001 |
| | pH | 5 | 95.300 | <0.0001 | | pH | 3 | 490.190 | <0.0001 |

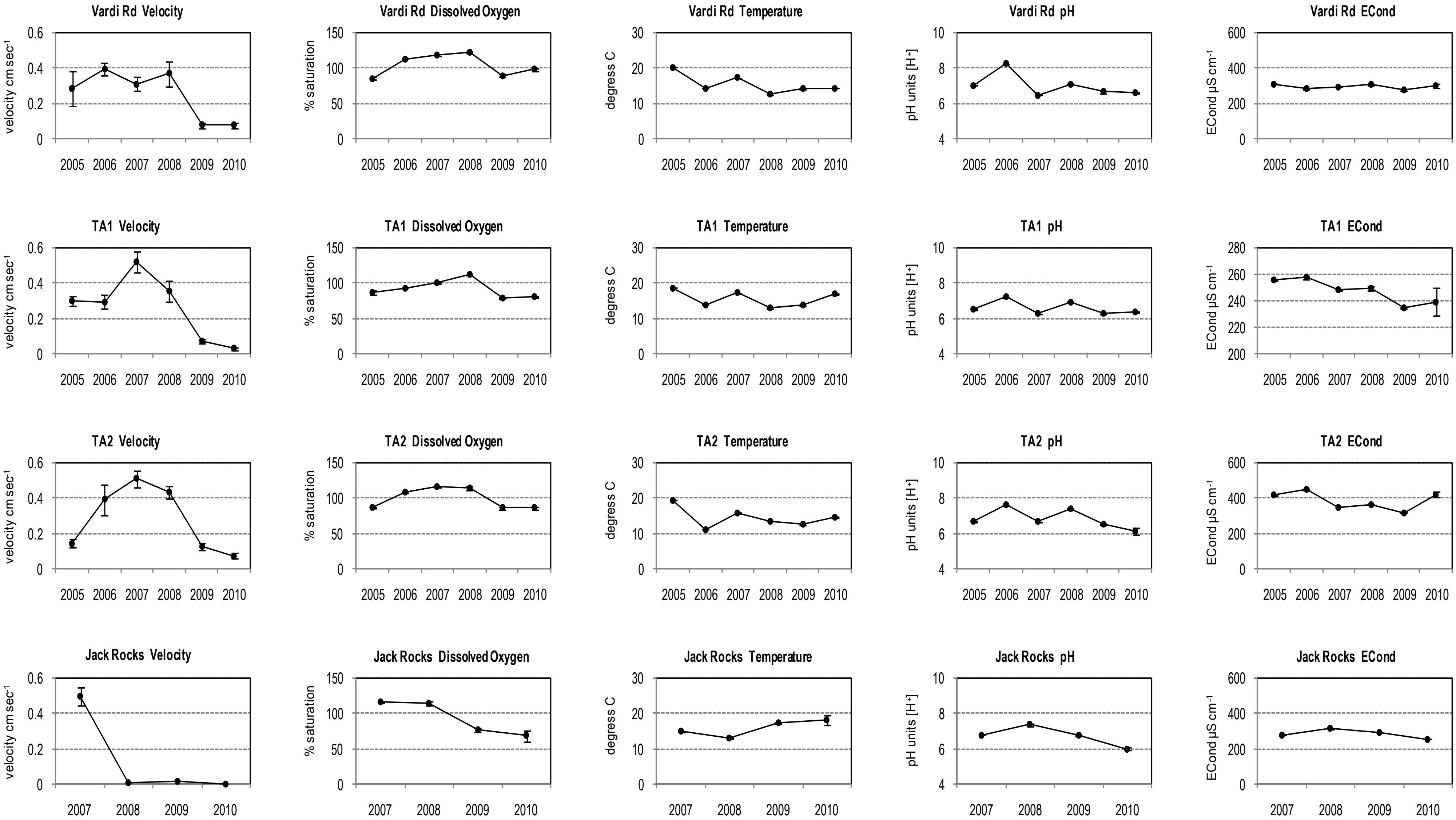



**Figure 2A Annual variability in selected physico-chemical parameters (means ± SE) at treated (exposed) sites Vardi Road, TA1 and TA2, and at Jack Rocks**

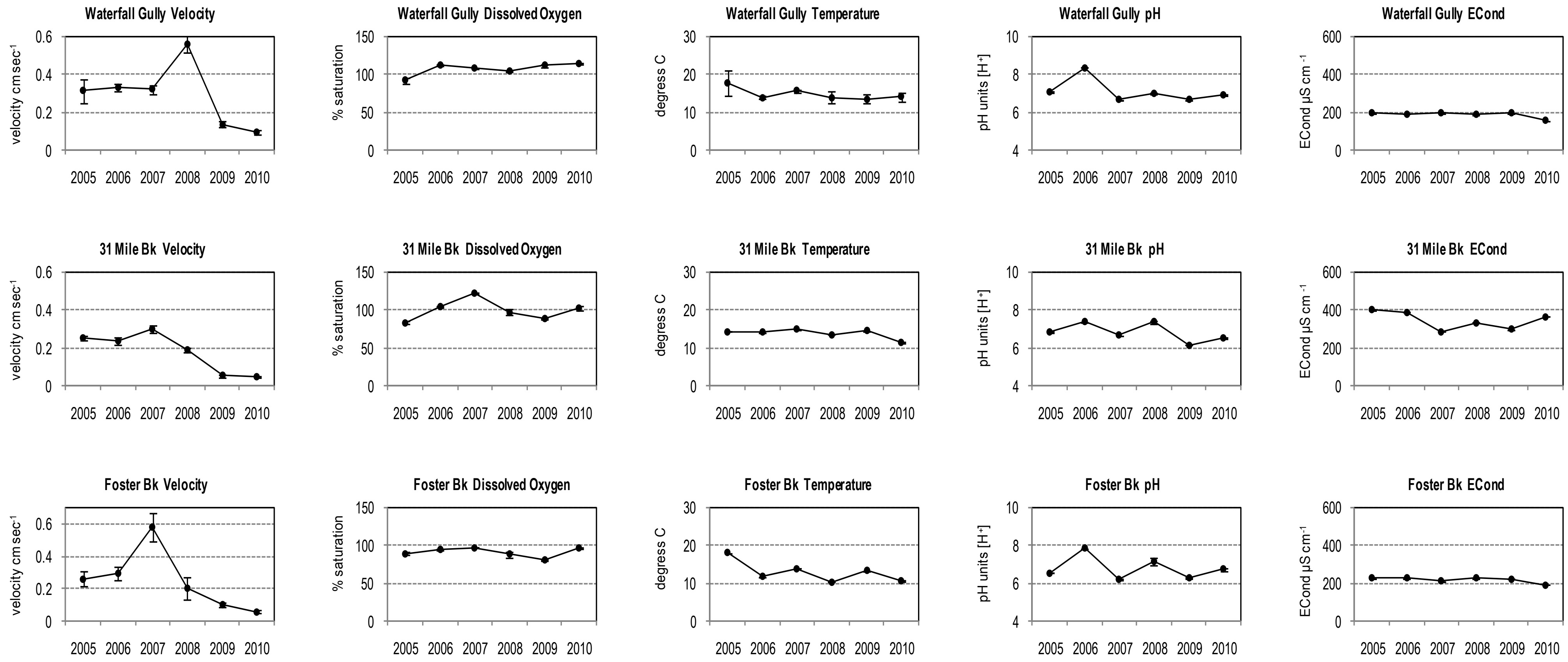



**Figure 2B Annual variability in selected physico-chemical parameters (means ± SE) at control (reference) sites Waterfall Gully, 31 Mile Brook and Foster Brook**

Analysis of Similarity (ANOSIM) based on Euclidean distance was used to investigate multivariate patterns in physico-chemistry. In all years, there were significant differences between treated sites and reference sites (Table 3). However, these differences existed before treatment commenced, and for most treated sites, the degree to which they differ from reference sites has not shown a consistent trend over the monitoring period.

Change in similarity was plotted (Figure 3) to provide a time series of change in physico-chemistry at exposed sites relative to reference sites and relative to the baseline condition at each site (*i.e*. condition during initial spring sampling). More Seldom Seen Brook and Jack Rocks were the only sites to show a strong trend toward decreasing similarity with reference sites. Contributing most to the decreased similarity were declining DO levels, increasing water temperature and increasing proportion of clay and silt substrate at both More Seldom Seen Brook and Jack Rocks. Obvious reductions in flow and water level were also observed at these sites during spring sampling between 2008 and 2010. Reduced flows in spring will lead to increased water temperatures and reduced flushing, which in turn will lead to higher silt levels and increased biological oxygen demand BOD.

**Table 3 Summary results from one-way ANOSIM (Analysis of Similarity)**
*Summary results from one-way ANOSIM (Analysis of Similarity) on 2005-2010 physico-chemical data, comparing treated 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 Reference 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 |
| 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 |
| 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 |
| More Seldom Seen Bk | 2008 | 0.774 | ns | 0.728 | 0.846 |
| | 2009 | 0.646 | 0.559 | 0.612 | ns |
| | 2010 | -- | -- | -- | -- |
| 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 |

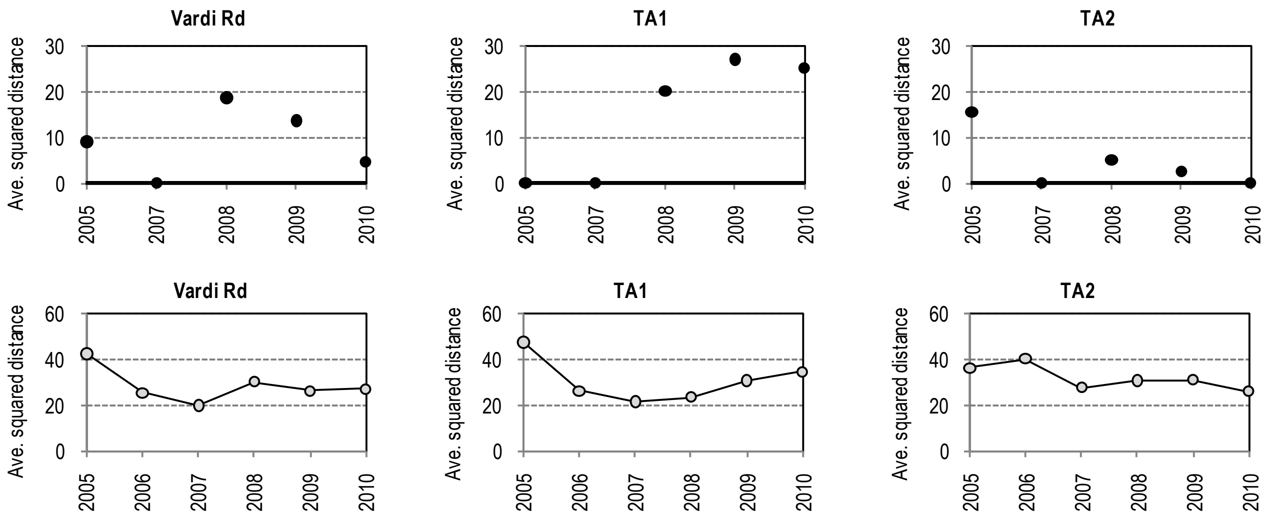



**Figure 3A Change in similarity of physico-chemistry at individual sites *(Vardi Road, TA1 & TA2) in treated areas, relative to their baseline condition (top) and their similarity to reference sites (bottom).***
*Baseline condition is equivalent to an average squared Euclidean distance of zero, and is based on the spring 2006 condition. All data are average squared distances determined from pairwise Euclidean distance matrices. As Euclidean distance increases, similarity decreases, i.e. the treated site is becoming less similar to the reference sites over time.*

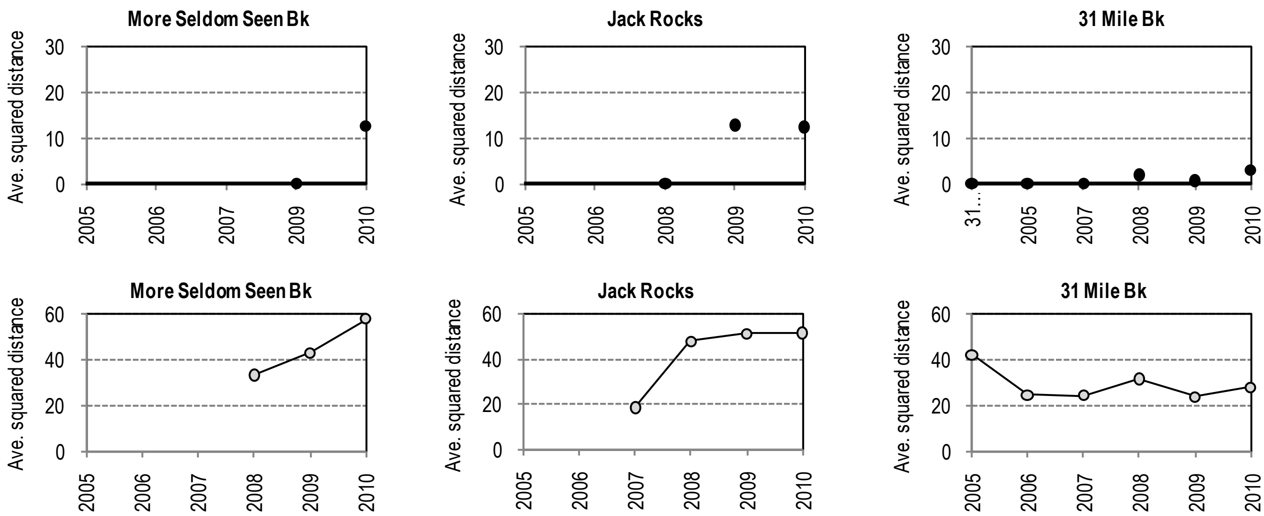



**Figure 3B As for Figure 3A, but showing WCTP site More Seldom Seen Brook and control sites Jack Rocks and 31 Mile Brook.**
*Baseline condition is equivalent to an average squared Euclidean distance of zero, and is based on spring 2008 condition for More Seldom Seen Brook, spring 2007 for Jack Rocks and spring 2006 for 31 Mile Brook (i.e. year of initial spring sampling). 31 Mile Brook has been included to illustrate the extent of variation at individual control sites relative to all other reference sites.*

## 3.2 Macroinvertebrates

A total of 7,518 individuals representing at least 95 taxa were collected from the 9 sites sampled in spring 2010. This was considerably more than the 4,956 individual from 86 taxa collected from the same sites in spring 2009 (with taxonomy standardised between years). Based on estimated abundance per $m^{-2}$, this equated to a total 116,624 individuals present in 2010 and 79,296 present in 2009. In 2010, as in all previous years, insects (88%) and in particular the Chironomidae (non-biting midges; 28%) constituted a large proportion of the total fauna richness. A systematic list of all macroinvertebrate taxa collected is provided in Appendix 4.

During 2008, 2009 and 2010 macroinvertebrate species abundance and richness showed varying degrees of recovery following significant declines in 2007 (Figure 4A-B), which were considered to be a lag response to low annual rainfall in 2006 (Figure 5). At most sites in 2010, there was a notable increase in total species richness and abundance above 2009 levels. This was despite low rainfall in winter and spring of 2010 and associated low streamflow (Figure 5). Monitoring in 2011 should reveal if there is a species response to this low rainfall, or if it requires more than one year of low winter flow and/or late onset of flows to elicit a detectable change in the fauna, such as occurred in 2006-07.

Trends in the total number of EPT taxa and the total number of south-west endemic species followed the same general trends evident for the total number of species at each site (Figure 4A-B). The most notable exceptions were More Seldom Seen Brook and Jack Rocks where most species metrics have continued to decline, and at Vardi Road, where numbers of EPT taxa and south-west endemics do not appear to have recovered despite an increase in species richness abundance between 2009 and 2010. It is likely that the continued late onset of flows at Vardi Road in 2007, and the relatively short flow duration prevented some EPT Taxa completing their life cycles, resulting in their loss from this site.

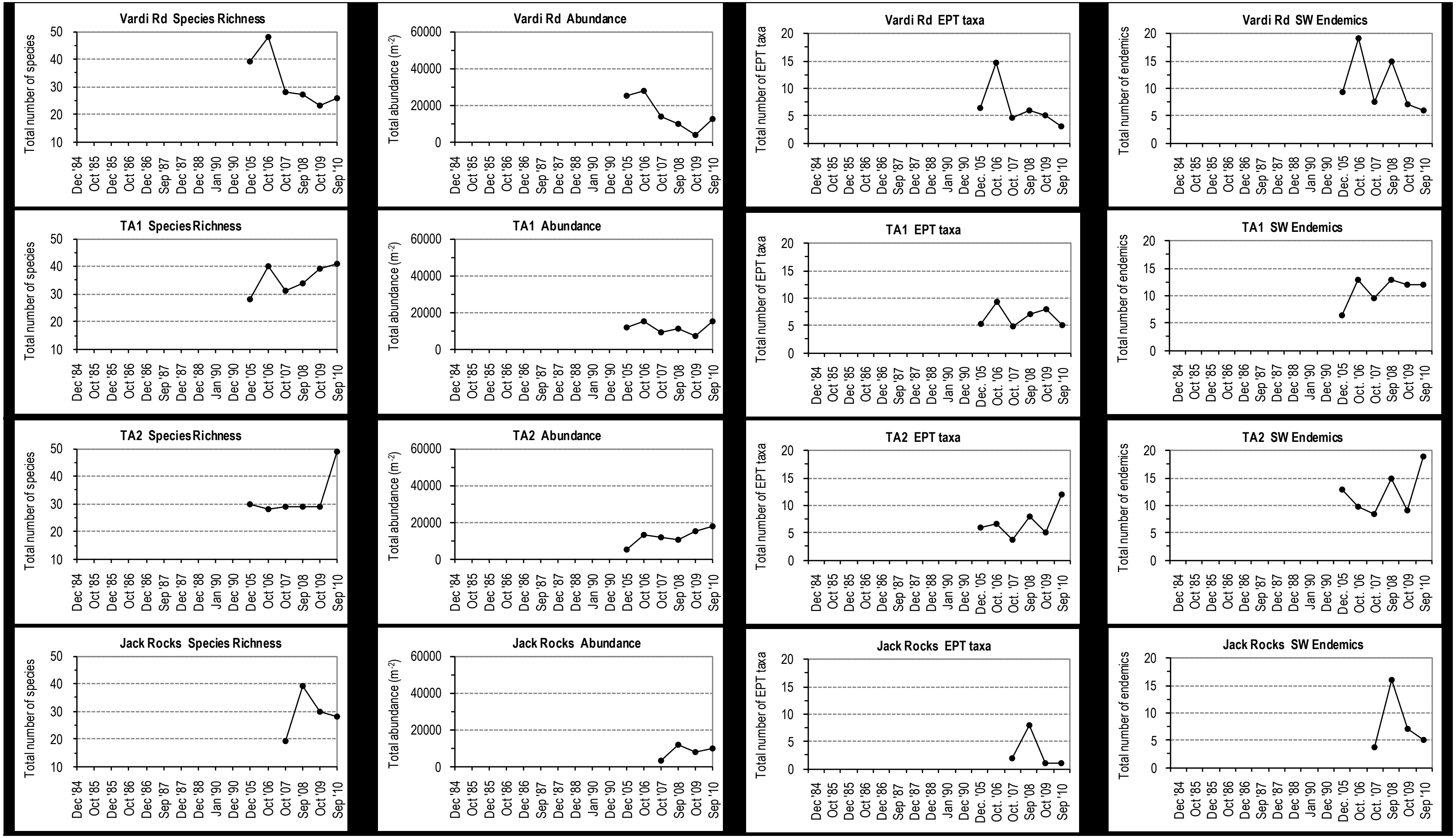



**Figure 4A Annual variability in macroinvertebrate species metrics**

*Total richness, total abundance, total number of EPT taxa and total number of south-west endemics at treated 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.*

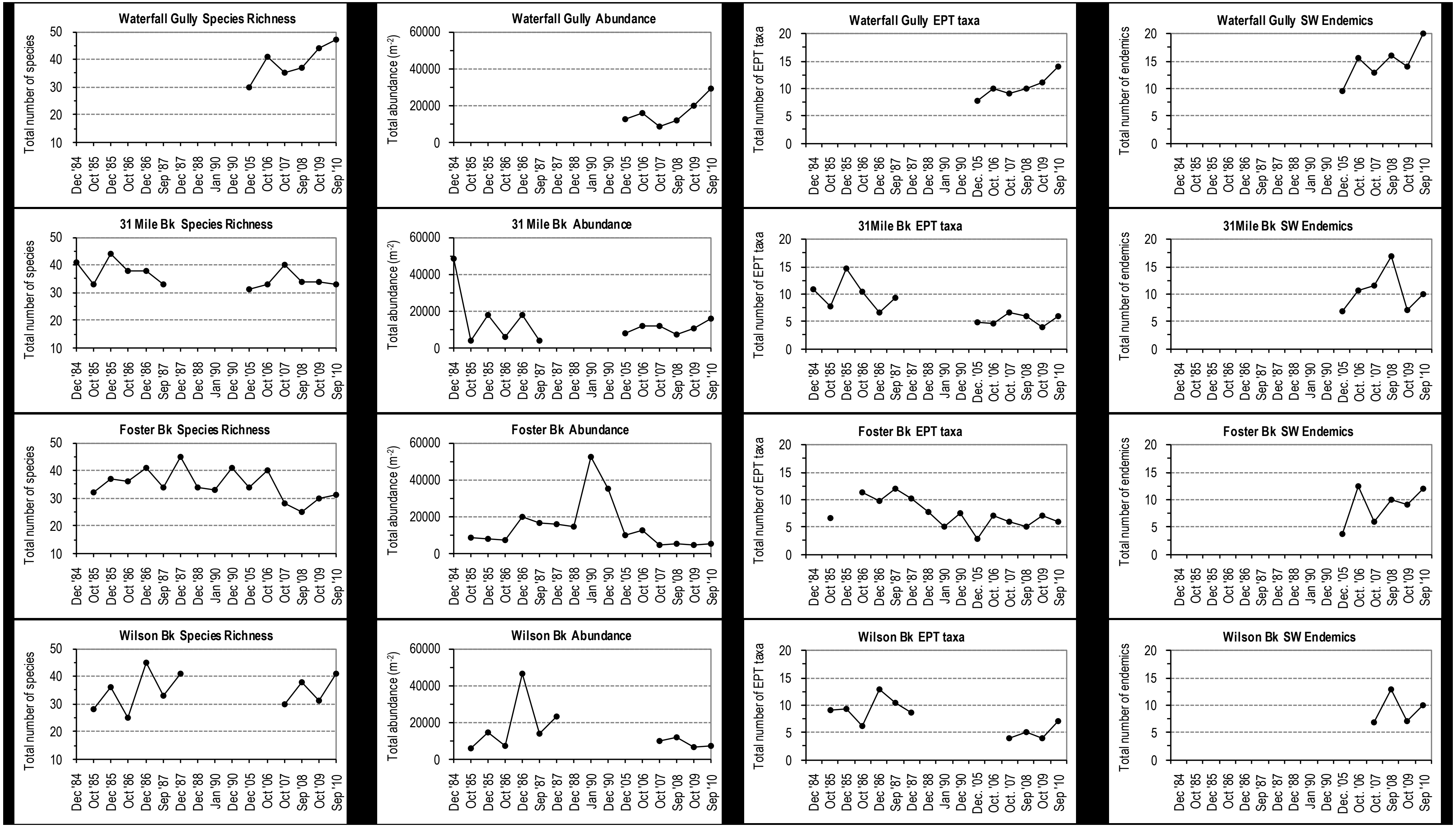
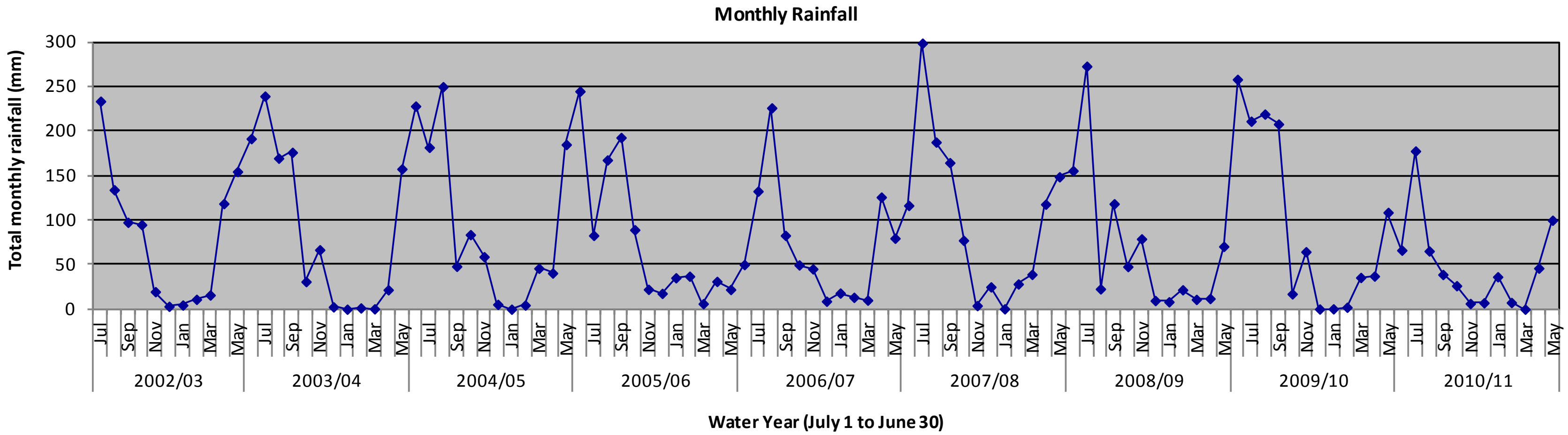



**Figure 4B Annual variability in macroinvertebrate species metrics**

*Total richness, total abundance, total number of EPT taxa and total number of south-west endemics) at control/reference sites. Historic (1984-1990) data for reference sites are included for comparison with recent data (2005-10). Note: taxonomy has been standardised across years.*



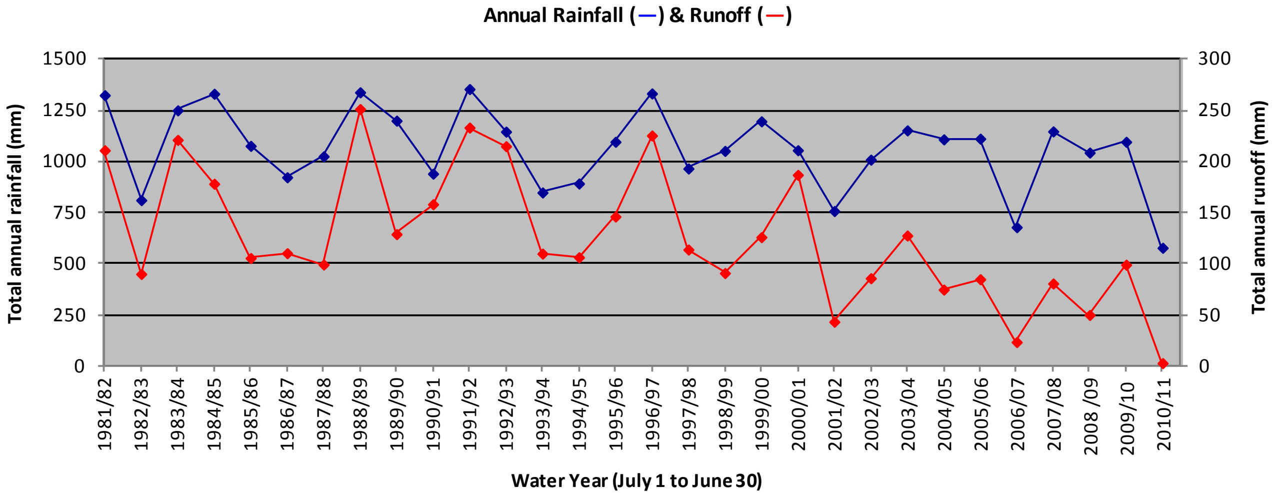




**Figure 5 Rainfall (Stn 509269 - Seldom Seen Brook - Gardens) and runoff (Stn 616041 - Vardi Road) in the Wungong catchment**

Monitoring since 2005 has revealed significant variation in species richness, abundance, number of EPT taxa and number of endemics amongst years (Table 4) and sites, both within and between control and treated groups. Similar results were found for species assemblage data when ANOSIM (based on Bray-Curtis similarity) was used to investigate multivariate patterns in community structure (Table 5). In all years, there were significant differences between faunal assemblages at treated sites and those at reference sites. As noted in previous reports, these differences existed before treatment commenced, and for most treated sites, the degree to which they differ from reference sites has not shown a consistent increasing or decreasing trend over the monitoring period.

**Table 4 Summary of results from one-way ANOVA on change in macroinvertebrate species richness *(number of species), log (x+1) transformed abundance ($m^{-2}$), number of EPT taxa and number of south-west endemics at individual sites over time (2005 - 2010). Significance level for p value ≤ 0.05; ns = not significant. Where significant differences are indicated, refer to Figure 4 to determine year differences.***

| Treated Sites | | | | | Control Sites | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Variable** | **df** | **F** | ***p*** | **Site** | **Variable** | **df** | **F** | ***p*** |
| **Vardi Road** | Richness | 5 | 13.580 | <0.0001 | **Waterfall Gully** | Richness | 5 | 4.686 | 0.003 |
| | Abundance | 5 | 11.017 | <0.0001 | | Abundance | 5 | 10.611 | <0.0001 |
| | EPT taxa | 5 | 13.662 | <0.0001 | | EPT taxa | 5 | 2.359 | 0.004 |
| | SW endemics | 5 | 12.362 | <0.0001 | | SW endemics | 5 | 3.774 | 0.003 |
| **TA1** | Richness | 5 | 2.289 | ns | **31 Mile Brook** | Richness | 5 | 2.602 | 0.045 |
| | Abundance | 5 | 1.378 | ns | | Abundance | 5 | 1.661 | ns |
| | EPT taxa | 5 | 1.926 | 0.070 | | EPT taxa | 5 | 2.662 | 0.032 |
| | SW endemics | 5 | 2.282 | nsn | | SW endemics | 5 | 3.591 | 0.023 |
| **TA2** | Richness | 5 | 3.704 | 0.010 | **Foster Brook** | Richness | 5 | 2.547 | 0.049 |
| | Abundance | 5 | 1.597 | nsn | | Abundance | 5 | 4.613 | 0.003 |
| | EPT taxa | 5 | 1.892 | 0.024 | | EPT taxa | 5 | 3.321 | 0.055 |
| | SW endemics | 5 | 1.656 | 0.022 | | SW endemics | 5 | 3.487 | ns |
| **Jack Rocks** | Richness | 5 | 5.734 | 0.005 | **Wilson Brook** | Richness | 3 | 2.185 | ns |
| | Abundance | 5 | 2.150 | ns | | Abundance | 3 | 0.952 | ns |
| | EPT taxa | 5 | 6.321 | 0.003 | | EPT taxa | 3 | 1.362 | 0.044 |
| | SW endemics | 5 | 9.653 | 0.003 | | SW endemics | 3 | 2.642 | ns |

**Table 5 Summary results from one-way ANOSIM on log *(x+1) transformed macroinvertebrate species abundance data ($m^{-2}$) for 2005-2010, comparing treated 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 Reference Site | | | |
|---|---|---|---|---|---|
| | | Waterfall Gully | Foster Bk | 31 Mile Bk | Wilson Bk |
| **Vardi Road** | 2005 | 0.669 | 0.630 | 0.657 | -- |
| | 2006 | 0.996 | 0.993 | 1.000 | -- |
| | 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 | 1.000 | 0.622 | 0.978 | 0.630 |
| TA1 | 2005 | 0.840 | 0.565 | 0.507 | -- |
| | 2006 | 0.978 | 0.563 | 0.869 | -- |
| | 2007 | 0.930 | 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 | 1.000 | ns | 0.919 | 0.917 |
| TA2 | 2005 | 0.948 | ns | 0.480 | -- |
| | 2006 | 0.994 | 0.843 | 0.722 | -- |
| | 2007 | 0.917 | 0.819 | 0.770 | 0.935 |
| | 2008 | 0.785 | 0.580 | 0.670 | 0.424 |
| | 2009 | 0.743 | 0.592 | 0.666 | 0.457 |
| | 2010 | 0.830 | 0.511 | 0.515 | 0.900 |

| Exposed Site | Year | R-statistic for Pairwise Test with Reference Site | | | |
|---|---|---|---|---|---|
| | | Waterfall Gully | Foster Bk | 31 Mile Bk | Wilson Bk |
| More Seldom Seen Bk | 2008 | 0.570 | 0.635 | 0.474 | 0.724 |
| | 2009 | 0.600 | 0.592 | 0.484 | 0.785 |
| | 2010 | -- | -- | -- | -- |
| Jack Rocks | 2007 | 1.000 | 0.963 | 0.998 | 0.930 |
| | 2008 | 0.948 | 0.833 | 0.893 | 0.706 |
| | 2009 | 0.956 | 0.801 | 0.899 | 0.753 |
| | 2010 | 0.950 | 0.824 | 0.956 | 0.835 |

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*. in the first spring sampled (Figure 6). In accord with the changes in species richness and abundance noted above, there have been shifts in the type of species present at sites, *i.e.* shifts in species assemblages. Of most note were the changes at Vardi Road, TA2 and the reference site on 31 Mile Brook.

At Vardi Road, there has been only a slight shift in species assemblages away from the baseline condition. This occurred in spring 2009 and 2010 however, the direction of change was not consistent over these years. Relative to the baseline condition in spring 2006, species assemblages were slightly less (-5%) similar in 2009, but slightly more (3%) similar in 2010. Between 2006 and 2009, there was also an increase in similarity (~10%) between species assemblages at Vardi Road and those at reference sites. These small changes do not signify a major ecological response, but rather change in a few taxa that are more sensitive to environmental disturbance. Primarily, a reduction in abundance and number of "high-flow" taxa, such as simulids (black flies) and baetid mayflies, and an apparent increase in plecopterans (stoneflies) and leptophlebiid mayflies. The latter may be a response to changes in stream temperature regime as much as changes in flow regime.

Temperature (as well as flow) is known to play a critical role in hatching, larval development and adult emergence (Bunn 1988, Sutcliff *et al*. 2002). These changes were most obvious between 2007 and 2009 and are likely the result of particularly low rainfall in 2006. Some recovery of these species was apparent by 2010.

In contrast, TA2 (downstream of Cobiac sub-catchment) recorded smaller annual fluctuations in species richness and abundance than other exposed sites. Species assemblages at TA2 also showed little inter-annual variation in their similarity to reference sites, with virtually no change since 2006 (Figure 6). Like Vardi Road, taxa contributing most to fluctuations at TA1 and TA2 included griptopterygid stoneflies, the mayfly *Nyungara bunni*, paramelitid amphipods and simulids. However, there have been relatively large shifts in species assemblages at TA2, relative to the baseline spring 2006 condition at this site (Figure 6). The relatively large change from baseline condition compared to the small change relative to reference sites indicates annual variation in species assemblages at TA2 more closely mirrors that at reference sites.

Faunal assemblages amongst reference sites have shown significant spatial variation in most years as evidenced by ANOSIM tests (see example in Table 5). However, species assemblages at 31 Mile Brook (Figure 5) and Foster Brook showed a small increase in similarity (~5%) between 2006 and 2009. This was also attributed to antecedent rainfall and the loss (likely temporary) of taxa more sensitive to change in annual flow regime. Since 2006, there has also been a shift (~10%) away from the historic condition at these sites and at Wilson Brook, based on data collected between 1985 and 1987 (Figure 7). In general, these changes were associated with an increased abundance of species more common to seasonal and/or slow flowing waters (ostracods, acarines & the chironomid *Cricotopus annuliventris*), increased abundance of stoneflies and the leptophlebiid *Nyungara bunni*, and decreased abundance of taxa more typically associated with higher water velocities and fast-flowing reaches (caddis-flies, baetid mayflies, several midge species & the dragonfly *Austrosynthemis cyanitincta*).

**Table 6 Summary results from one-way ANOSIM o*n log (x+1) transformed macro-invertebrate species abundance data ($m^{-2}$), comparing recent data (2005 -2010) 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 |
| | | 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 |

Other macroinvertebrate fauna of note included stygal paramelitid amphipods. These are obligate groundwater species that require permanent water. Between 2005 and 2009 there was a trend toward declining abundance of these amphipods at TA1, Vardi Road and Waterfall Gully. In 2010, this continued at TA1 and Vardi Road, but there was a considerable increase at Waterfall Gully and TA2. Change in their abundance may reflect frequency and/or duration of connectivity between ground and surface waters. Where there is strong connectivity between ground and surface waters it is assumed they will frequent surface waters in search of food, particularly during wetter months.

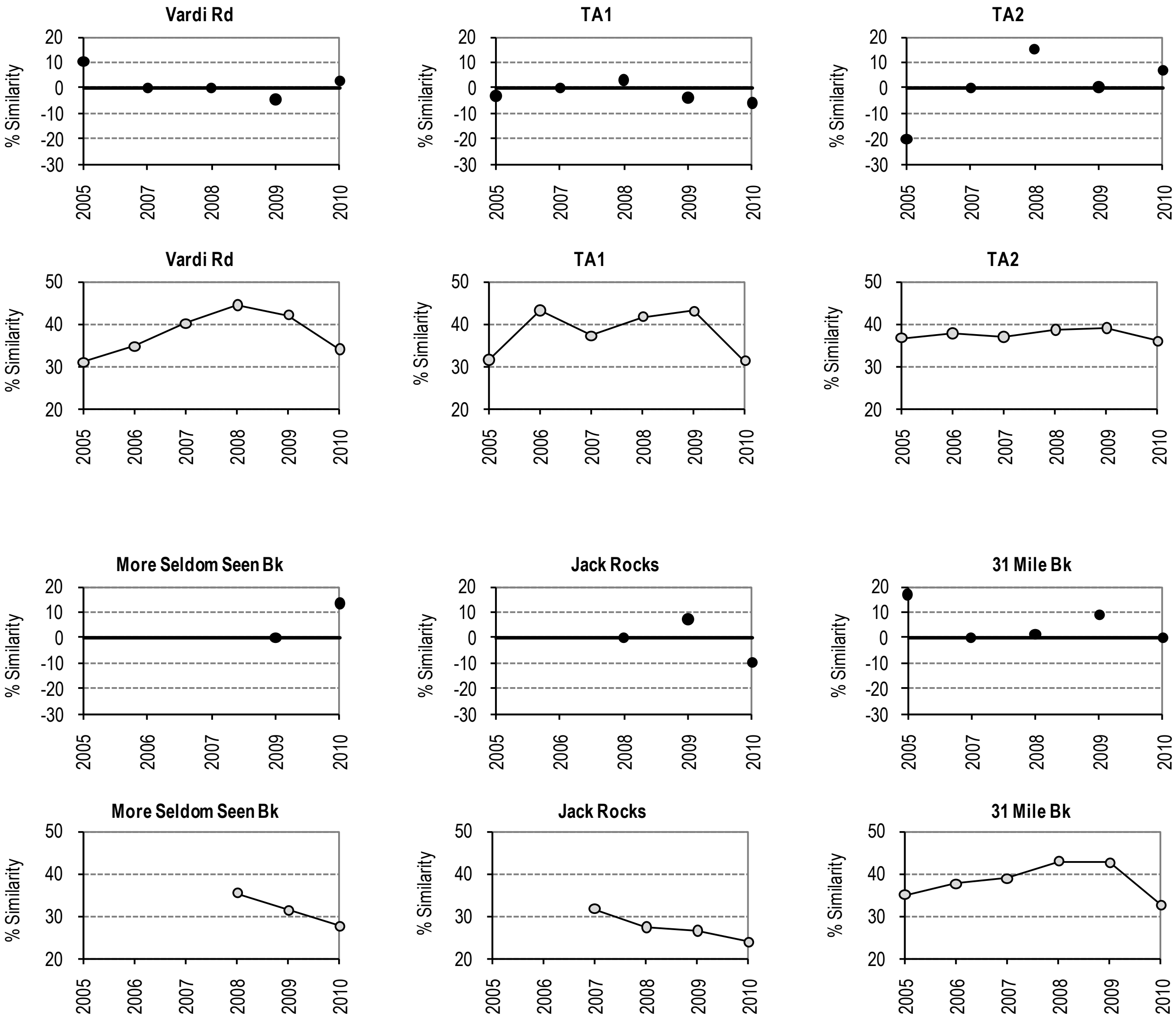



**Figure 6 Change in similarity of macroinvertebrate species assemblages at individual sites**
*Vardi Road, TA1, TA2, More Seldom Seen Bk, Jack Rocks & 31 Mile Bk — relative to their baseline condition (top rows) and their similarity to reference sites (bottom rows). Baseline condition is indicated as 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 treated site is becoming more similar to the reference sites over time.*

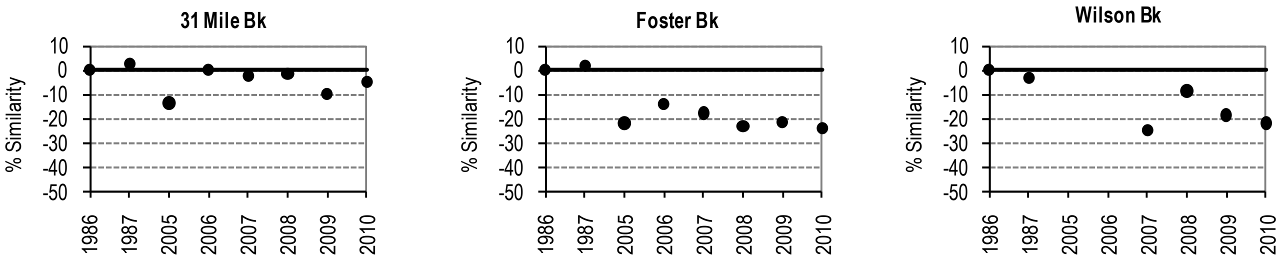



**Figure 7  Change in similarity of macroinvertebrate species assemblages at reference sites**
*31 Mile Brook, Foster Brook and Wilson Brook — relative to their historic condition.  Baseline condition is indicated as the solid dark line and is based on spring data collected in 1985.  All data are per cent similarity values determined from pairwise Bray-Curtis distance matrices based on species abundance.*

## 3.3 Fish and Crayfish

Four freshwater fishes (three native and one introduced), and two freshwater crayfish species (one native and one introduced) were again recorded from the study sites in 2010.  Fishing effort is not standardised due to the physical nature of stream habitats, *i.e.* large number of snags and densely fringing vegetation.  Data are therefore tabulated as relative abundance categories (Table 7).  To date the most obvious changes in distribution or abundance of native fish and crayfish, have been the lower numbers in 2009 and 2010 (associated with low water levels).

**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 | ★ | ★ | ★ | | ★★★ | |
| TA2 | Summer 2005 | | | | | ★★★ | |
| | Spring 2006 | | | ★ | | ★★ | |
| | Spring 2007 | ★★ | ★★ | ★ | | ★★★ | |
| | Spring 2008 | ★★ | ★★ | | | ★★★ | |
| | Spring 2009 | ★★ | ★★ | | | ★★★ | |
| | Spring 2010 | | ★ | ★ | | ★★★ | |
| Vardi Road | Summer 2005 | | | | | | |
| | Spring 2006 | | ★★ | ★★ | | ★★★ | |
| | Spring /2007 | | ★★ | | ★ | ★★★ | |
| | Spring 2008 | | ★★ | ★★ | | ★★★ | |
| | Spring 2009 | | ★★ | ★★ | ★ | ★★★ | |
| | Spring 2010 | | ★ | ★★ | | ★★★ | |
| More Seldom Seen Bk | Spring 2008 | | | | | ★★ | |
| | Spring 2009 | | | | | ★★ | |
| | Spring 2010 | | | | | ★★ | |
| Waterfall Gully | Summer 2007 | | | | | | |
| | Spring 2006 | ★ | | | | ★★★ | |
| | Spring 2007 | | | | | ★★★ | |
| | Spring 2008 | | | | | ★★★ | |
| | Spring 2009 | ★★ | | | | ★★★ | |
| | Spring 2010 | ★★ | | | | ★★★ | |
| 31 Mile Bk | Summer 2005 | ★ | | | | ★★ | |
| | Spring 2006 | ★★★ | | | | ★★ | |
| | Spring 2007 | ★★★ | | | | ★★ | |
| | Spring 2008 | ★★★ | | | | ★★ | |
| | Spring 2009 | ★★★ | | ★ | | ★★ | |
| | Spring 2010 | ★★★ | | | | ★ | |
| Foster Bk | Summer 2005 | | | | ★★ | | |
| | Spring 2006 | | | | ★★ | ★★ | |
| | Spring 2007 | ★★ | | | ★ | ★★★ | |
| | Spring 2008 | ★ | | | ★★ | ★★ | |
| | Spring 2009 | ★★ | ★ | | ★★ | ★★ | |
| | Spring 2010 | ★★ | | | ★★ | ★★ | |
| Wilson Bk | Spring 2007 | ★★ | | | | ★★★ | |
| | Spring 2008 | ★★ | ★★ | ★★ | | ★★★ | |
| | Spring 2009 | ★★ | ★★ | ★★ | | ★★★ | |
| | Spring 2010 | ★★ | ★★ | ★ | | ★★★ | |
| Jack Rocks | Spring 2007 | ★★★ | | | | ★★ | ★★ |
| | Spring 2008 | ★★★ | | | | ★★ | ★★ |
| | Spring 2009 | ★★★ | | | | ★★ | ★★ |
| | Spring 2010 | ★ | | | | ★ | ★★★ |

# 4. Discussion

To date, monitoring has shown no adverse effects of the Wungong Catchment Trial Project (WCTP) on aquatic fauna biodiversity, however, assemblages at the previously perennial Vardi Road appear to be showing effects of a drying climate, in particular, the low annual rainfall in 2006. While this appeared to have at least a temporary affect on fauna in a number of creeks, species richness at Vardi Road has not recovered. The authors have also observed a general decline in aquatic macroinvertebrate species diversity in several other northern jarrah forest streams (*i.e.* in the upper Dandalup and Serpentine catchments) between 2006 and 2009. Fauna most affected include those species more typically associated with higher water velocities.

It is difficult to define what effect the WCTP has had on offsetting the effects of further declines in rainfall. It is probable that warmer stream temperatures in autumn and early winter, reduced winter rainfall and increased late spring rainfall all combine to alter life history patterns of aquatic macroinvertebrates. Some species, such as the stoneflies and leptophlebiid mayflies, may be better able to cope by way of extended periods of egg hatching and the ability to alternate between slow and fast larval development dependent on environmental conditions. Studies conducted by Bunn (1988) during the early 1980's in the Wungong and North Dandalup catchments, suggested many macroinvertebrate species that inhabit perennial streams have fast and slow univoltine[1] cycles or are capable of cohort splitting. Consequently community structure in south-west streams is less complex and has a high degree of seasonality that is atypical of temperate streams of Australia and New Zealand. The higher degree of seasonality implies many species evolved during periods when the south-west was drier than it is today (Bunn 1988).

Briers *et al.* (2004) similarly established a relationship between climatic conditions and the growth of aquatic insects in North American streams. Mayfly nymphs were found to grow faster during warmer years when stream temperature was warmer (*i.e.* they had a shortened life cycle), with emergence of adults varying by almost two months between years. By contrast, Briers *et al*. (2004) found no relation between growth in stonefly nymphs and climate variation. This was considered to be due to the fact that they were less dependent on temperature and they displayed a semivoltine lifecycle.

Despite the fact that many species that inhabit south-west perennial systems may already be pre-adapted to drought conditions, it is predicted that on-going decline in rainfall will have a pronounced effect on community structure. Prolonged drought, the late onset of flows and short flow duration are likely to result in loss of species richness and abundance as some species will not be able to complete their life-cycles. Boulton (2003) found prolonged drought "eliminated or decimated" atyid shrimps, stoneflies and caddis-flies. Although these taxa persisted though early stages of drought, they did not recruit successfully the following year, even with a return to higher-than-baseflow conditions. This would appear to be the case for macroinvertebrates at Vardi Road and would also account for the shifts in taxa richness and abundance observed at reference sites relative to historic faunal assemblages.

There is also likely to be a minimum threshold for flow duration in seasonal creeks, below which fauna cannot complete their life-cycles. Thus, even fauna that are pre-adapted to seasonal flow may not survive if the duration of flow falls below a critical minimum.

Continued monitoring will be able to detect future changes in biodiversity at WCTP sites, using reference sites to separate the effects of climate change.

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[1] Univoltine = breeding once per year; semivoltine = having a lifecycle that takes longer than one year to complete.

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# 6. Appendices

## Appendix 1 — Photographs of sampling sites taken in September 2010

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*

*Sampling site on More Seldom Seen Brook, very low water levels*

*V-notch weir on More Seldom Seen Brook, down-stream of sampling site*

*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, showing large permanent pool (trout habitat) upstream of road culverts*

*Sampling site on Wilson Brook in the North Dandalup catchment – view downstream*

*Electrofishing at Wilson Brook*

## 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 ARL (2006) for descriptions of ratings. NA = not assessed.

| Site | Baseline Foreshore Condition in 2005 | Baseline Stream Environmental Rating in 2005 | Condition/Rating 2006 - 20010 | |
|---|---|---|---|---|
| | | | 2006 | 2007 - 2010 |
| 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 September 2010 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 | Turbid. NTU | Depth m | Width m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Foster Bk | 28/09/10 | 830 | 1 | 0.02935333 | 97.8 | 10.92 | 10.5 | 6.82 | 192 | 0 | 0.15 | 2 |
| Foster Bk | 28/09/10 | | 2 | 0.06350667 | 99.5 | 11.34 | 10.4 | 6.59 | 190.8 | 0 | 0.05 | 1.5 |
| Foster Bk | 28/09/10 | | 3 | 0.06132667 | 92.6 | 10.38 | 10.4 | 6.59 | 192.3 | 0 | 0.1 | 1 |
| Foster Bk | 28/09/10 | | 4 | 0.09039333 | 96.1 | 10.8 | 10.9 | 6.74 | 192.8 | 0 | 0.1 | 1 |
| Foster Bk | 28/09/10 | | 5 | 0.05551333 | 99.4 | 11.16 | 11.4 | 6.96 | 194 | 0 | 0.05 | 2 |
| Foster Bk | 28/09/10 | | 6 | 0.04679333 | 96.6 | 10.8 | 11 | 6.79 | 193.8 | 0 | 0.05 | 1 |
| 31 Mile Bk | 27/09/10 | 1100 | 1 | 0.04316 | 114.6 | 12.2 | 11.9 | 6.56 | 365 | 0 | 0.2 | 3 |
| 31 Mile Bk | 27/09/10 | | 2 | 0.06423333 | 108.9 | 11.8 | 11.6 | 6.75 | 366 | 0 | 0.15 | 3 |
| 31 Mile Bk | 27/09/10 | | 3 | 0.02935333 | 101.1 | 10.9 | 11.4 | 6.5 | 367 | 0 | 0.1 | 2.5 |
| 31 Mile Bk | 27/09/10 | | 4 | 0.05551333 | 94.9 | 9.4 | 11.1 | 6.46 | 367 | 0 | 0.05 | 2.5 |
| 31 Mile Bk | 27/09/10 | | 5 | 0.05188 | 97.5 | 9.6 | 11.5 | 6.48 | 367 | 0 | 0.15 | 2.5 |
| 31 Mile Bk | 27/09/10 | | 6 | 0.05478667 | 97 | 9.71 | 11.1 | 6.46 | 367 | 0 | 0.1 | 1.5 |
| Waterfall Gully | 29/09/10 | 1100 | 1 | 0.05042667 | 115.6 | 11.96 | 13.9 | 6.79 | 155 | 0 | 0.3 | 2 |
| Waterfall Gully | 29/09/10 | | 2 | 0.09620667 | 116.1 | 12.03 | 13.9 | 6.82 | 155.1 | 0 | 0.35 | 1 |
| Waterfall Gully | 29/09/10 | | 3 | 0.12825333 | 112.6 | 11.58 | 14.1 | 7.07 | 156.3 | 0 | 0.2 | 1.5 |
| Waterfall Gully | 29/09/10 | | 4 | 0.12276222 | 113.5 | 11.38 | 14.2 | 7.05 | 156 | 0 | 0.1 | 1.5 |
| Waterfall Gully | 29/09/10 | | 5 | 0.10928667 | 117.2 | 12.08 | 14.6 | 6.85 | 156 | 0 | 0.2 | 1.2 |
| Waterfall Gully | 29/09/10 | | 6 | 0.06568667 | 109.4 | 11.29 | 14.4 | 7.06 | 156.4 | 0 | 0.18 | 2.2 |
| Wilson Bk | 28/09/10 | 1200 | 1 | 0.06714 | 99.2 | 10.5 | 11.3 | 6.2 | 223 | 0 | 0.3 | 2 |
| Wilson Bk | 28/09/10 | | 2 | 0.017 | 88.8 | 10.47 | 11.2 | 6.23 | 224 | 0 | 0.25 | 3 |
| Wilson Bk | 28/09/10 | | 3 | 0.03371333 | 86.8 | 9.65 | 11.2 | 6.2 | 224 | 0 | 0.2 | 2 |
| Wilson Bk | 28/09/10 | | 4 | 0.03008 | 93.8 | 10.3 | 12.1 | 6.13 | 224 | 0 | 0.15 | 4.5 |
| Wilson Bk | 28/09/10 | | 5 | 0.03008 | 94.5 | 10.38 | 11.3 | 6.1 | 224 | 0 | 0.05 | 4.8 |
| Wilson Bk | 28/09/10 | | 6 | 0.02354 | 87.1 | 9.18 | 11.3 | 6.09 | 224 | 0 | 0.05 | 4.8 |
| TA1 | 27/09/10 | 1200 | 1 | 0.05769333 | 89 | 8.58 | 17.5 | 6.6 | 383 | 0 | 0.05 | 2.3 |
| TA1 | 27/09/10 | | 2 | 0.05769333 | 81.8 | 7.82 | 17.2 | 6.32 | 445 | 0 | 0.1 | 2.3 |
| TA1 | 27/09/10 | | 3 | 0.017 | 83.4 | 8.07 | 17.4 | 6.3 | 445 | 0 | 0.1 | 2 |
| TA1 | 27/09/10 | | 4 | 0.017 | 79.4 | 7.7 | 17.2 | 6.36 | 449 | 0 | 0.15 | 2 |
| TA1 | 27/09/10 | | 5 | 0.017 | 76.8 | 7.55 | 16.7 | 6.34 | 446 | 0 | 0.05 | 2 |
| TA1 | 27/09/10 | | 6 | 0.017 | 76.9 | 7.52 | 16.5 | 6.41 | 374 | 0 | 0.1 | 2 |

## Appendix 3 — Continued

| Site | Date | Start Time | Rep# | Ave. Velocity m/s | DO % | DO mg/L | Temp deg C | pH | Econd. uS/cm | Turbid. NTU | Depth m | Width m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TA2 | 27/09/10 | 1400 | 1 | 0.08385333 | 86.6 | 8.57 | 15 | 6.38 | 238 | 0 | 0.1 | 1.2 |
| TA2 | 27/09/10 | | 2 | 0.05478667 | 94.7 | 9.7 | 15 | 6.88 | 237 | 0 | 0.1 | 1.5 |
| TA2 | 27/09/10 | | 3 | 0.08312667 | 91.5 | 9.37 | 14.3 | 6.07 | 231 | 0 | 0.1 | 1.5 |
| TA2 | 27/09/10 | | 4 | 0.017 | 86.3 | 8.88 | 14.3 | 6.07 | 290 | 0 | 0.1 | 2 |
| TA2 | 27/09/10 | | 5 | 0.12337111 | 78.9 | 7.99 | 15 | 5.73 | 220 | 0 | 0.1 | 2.2 |
| TA2 | 27/09/10 | | 6 | 0.08748667 | 81.1 | 8.27 | 14.9 | 5.78 | 221 | 0 | 0.16 | 1.5 |
| Vardi Rd | 27/09/10 | 1600 | 1 | 0.08821333 | 99.7 | 10.18 | 14.5 | 6.61 | 324 | 0 | 0.1 | 2.5 |
| Vardi Rd | 27/09/10 | | 2 | 0.12700667 | 107 | 10.35 | 14.4 | 6.54 | 258 | 0 | 0.15 | 2.5 |
| Vardi Rd | 27/09/10 | | 3 | 0.05406 | 94.7 | 9.7 | 14.2 | 6.56 | 324 | 0 | 0.05 | 3.5 |
| Vardi Rd | 27/09/10 | | 4 | 0.05842 | 93.4 | 9.51 | 14.4 | 6.63 | 324 | 0 | 0.1 | 3.5 |
| Vardi Rd | 27/09/10 | | 5 | 0.03734667 | 95.7 | 9.78 | 14.3 | 6.62 | 259 | 0 | 0.1 | 3.5 |
| Vardi Rd | 27/09/10 | | 6 | 0.10347333 | 98.1 | 10.07 | 14.3 | 6.66 | 324 | 0 | 0.2 | 2.75 |
| More Seldom Seen Bk | 29/09/10 | 900 | 1 | 0 | 70.5 | 7.98 | 11.2 | 4.99 | 251 | 0 | 0.05 | 0.5 |
| More Seldom Seen Bk | 29/09/10 | | 2 | 0 | 80.2 | 8.84 | 11.6 | 4.94 | 244 | 0 | 0.1 | 0.4 |
| Jack Rocks | 28/09/10 | 1430 | 1 | 0 | 89.7 | 7.85 | 21.8 | 6.07 | 258 | 0 | 0.18 | 8 |
| Jack Rocks | 28/09/10 | | 2 | 0 | 81.3 | 7.35 | 20.9 | 6.04 | 259 | 0 | 0.4 | 6 |
| Jack Rocks | 28/09/10 | | 3 | 0 | 65.2 | 7.3 | 16.1 | 5.9 | 259 | 0 | 0.3 | 6 |
| Jack Rocks | 28/09/10 | | 4 | 0 | 51.3 | 5.4 | 14.6 | 5.86 | 258 | 0 | 0.3 | 6.7 |
| Jack Rocks | 28/09/10 | | 5 | 0 | 42.6 | 4.35 | 15 | 5.89 | 247 | 0 | 0.2 | 5.8 |
| Jack Rocks | 28/09/10 | | 6 | 0 | 82.8 | 7.5 | 20.7 | 6.32 | 255 | 0 | 0.45 | 6 |

## Appendix 3 — Continued

| Site | Date | Start Time | Rep# | %Habitat variables | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Boulders / Bedrock | Cobbles | Pebbles | Gravel | Sand | Clay | Silt | Leaf Pack | Epiphytes | Filamentous algae | Submerged macrophytes | Emergent macrophytes | Canopy cover |
| Foster Bk | 28/09/10 | 08:30 | 1 | 0 | 35 | 5 | 50 | 10 | 0 | 0 | 0 | 35 | 0 | 0 | 0 | 30 |
| Foster Bk | 28/09/10 | | 2 | 0 | 14 | 5 | 70 | 5 | 0 | 0 | 0 | 60 | 0 | 0 | 0 | 30 |
| Foster Bk | 28/09/10 | | 3 | 5 | 20 | 30 | 40 | 5 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 50 |
| Foster Bk | 28/09/10 | | 4 | 0 | 10 | 30 | 40 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 |
| Foster Bk | 28/09/10 | | 5 | 0 | 5 | 5 | 70 | 10 | 5 | 5 | 0 | 5 | 0 | 0 | 5 | 60 |
| Foster Bk | 28/09/10 | | 6 | 0 | 5 | 20 | 65 | 5 | 5 | 0 | 0 | 60 | 0 | 0 | 0 | 70 |
| 31 Mile Bk | 27/09/10 | 11:00 | 1 | 0 | 5 | 0 | 20 | 55 | 5 | 15 | 0 | 0 | 0 | 0 | 0 | 20 |
| 31 Mile Bk | 27/09/10 | | 2 | 0 | 3 | 5 | 30 | 50 | 0 | 12 | 0 | 30 | 0 | 0 | 0 | 20 |
| 31 Mile Bk | 27/09/10 | | 3 | 0 | 0 | 2 | 50 | 45 | 0 | 3 | 0 | 15 | 0 | 0 | 0 | 25 |
| 31 Mile Bk | 27/09/10 | | 4 | 0 | 5 | 0 | 55 | 30 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 30 |
| 31 Mile Bk | 27/09/10 | | 5 | 0 | 0 | 15 | 60 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 |
| 31 Mile Bk | 27/09/10 | | 6 | 0 | 30 | 0 | 70 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 0 | 30 |
| Waterfall Gully | 29/09/10 | 11:00 | 1 | 5 | 5 | 10 | 50 | 25 | 0 | 5 | 0 | 40 | 0 | 0 | 0 | 20 |
| Waterfall Gully | 29/09/10 | | 2 | 0 | 0 | 5 | 60 | 30 | 0 | 5 | 0 | 30 | 0 | 0 | 0 | 20 |
| Waterfall Gully | 29/09/10 | | 3 | 0 | 0 | 0 | 5 | 76 | 20 | 2 | 0 | 0 | 0 | 0 | 0 | 50 |
| Waterfall Gully | 29/09/10 | | 4 | 0 | 0 | 15 | 74 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 50 |
| Waterfall Gully | 29/09/10 | | 5 | 0 | 0 | 15 | 15 | 70 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 50 |
| Waterfall Gully | 29/09/10 | | 6 | 0 | 0 | 30 | 65 | 5 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 20 |
| Wilson Bk | 28/09/10 | 12:00 | 1 | 0 | 5 | 10 | 35 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90 |
| Wilson Bk | 28/09/10 | | 2 | 0 | 0 | 5 | 50 | 45 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 60 |
| Wilson Bk | 28/09/10 | | 3 | 0 | 0 | 7 | 75 | 15 | 0 | 3 | 0 | 7 | 0 | 0 | 0 | 60 |
| Wilson Bk | 28/09/10 | | 4 | 0 | 5 | 15 | 65 | 10 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 70 |
| Wilson Bk | 28/09/10 | | 5 | 0 | 5 | 10 | 70 | 15 | 0 | 0 | 0 | 50 | 0 | 0 | 0 | 60 |
| Wilson Bk | 28/09/10 | | 6 | 0 | 0 | 30 | 50 | 5 | 0 | 15 | 0 | 30 | 0 | 0 | 0 | 70 |
| TA1 | 27/09/10 | 12:00 | 1 | 0 | 0 | 2 | 80 | 16 | 0 | 2 | 10 | 0 | 0 | 0 | 0 | 5 |
| TA1 | 27/09/10 | | 2 | 2 | 0 | 2 | 68 | 25 | 0 | 3 | 20 | 0 | 0 | 0 | 0 | 20 |
| TA1 | 27/09/10 | | 3 | 0 | 0 | 10 | 60 | 18 | 0 | 2 | 0 | 30 | 0 | 0 | 0 | 0 |
| TA1 | 27/09/10 | | 4 | 0 | 0 | 2 | 85 | 11 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 5 |
| TA1 | 27/09/10 | | 5 | 1 | 1 | 2 | 71 | 20 | 0 | 5 | 0 | 20 | 0 | 0 | 0 | 5 |
| TA1 | 27/09/10 | | 6 | 0 | 1 | 30 | 50 | 15 | 0 | 4 | 0 | 10 | 0 | 0 | 0 | 50 |

## Appendix 3 — Continued

| Site | Date | Start Time | Rep# | %Habitat variables | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Boulders / Bedrock | Cobbles | Pebbles | Gravel | Sand | Clay | Silt | Leaf Pack | Epiphytes | Filamentous algae | Submerged macrophytes | Emergent macrophytes | Canopy cover |
| TA2 | 27/09/10 | 14:00 | 1 | 0 | 0 | 1 | 40 | 30 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 0 |
| TA2 | 27/09/10 | | 2 | 20 | 5 | 10 | 50 | 13 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| TA2 | 27/09/10 | | 3 | 5 | 5 | 40 | 40 | 9 | 0 | 1 | 0 | 5 | 0 | 0 | 0 | 10 |
| TA2 | 27/09/10 | | 4 | 5 | 0 | 40 | 40 | 9 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 30 |
| TA2 | 27/09/10 | | 5 | 0 | 7 | 5 | 45 | 40 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 10 |
| TA2 | 27/09/10 | | 6 | 12 | 2 | 10 | 50 | 25 | 0 | 1 | 0 | 5 | 0 | 0 | 0 | 0 |
| Vardi Rd | 27/09/10 | 16:00 | 1 | 15 | 20 | 15 | 15 | 33 | 0 | 2 | 0 | 35 | 0 | 0 | 0 | 0 |
| Vardi Rd | 27/09/10 | | 2 | 0 | 10 | 5 | 70 | 14 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vardi Rd | 27/09/10 | | 3 | 17 | 20 | 0 | 50 | 12 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 20 |
| Vardi Rd | 27/09/10 | | 4 | 0 | 30 | 35 | 25 | 9 | 0 | 1 | 0 | 30 | 0 | 0 | 0 | 0 |
| Vardi Rd | 27/09/10 | | 5 | 0 | 25 | 20 | 40 | 14 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vardi Rd | 27/09/10 | | 6 | 0 | 30 | 20 | 45 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 |
| More Seldom Seen Bk | 29/09/10 | 09:00 | 1 | 0 | 0 | 2 | 26 | 20 | 2 | 50 | 0 | 0 | 40 | 0 | 0 | 40 |
| More Seldom Seen Bk | 29/09/10 | | 2 | 0 | 0 | 5 | 33 | 10 | 2 | 50 | 0 | 0 | 40 | 0 | 0 | 40 |
| Jack Rocks | 28/09/10 | 14:30 | 1 | 0 | 2 | 5 | 18 | 5 | 0 | 70 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jack Rocks | 28/09/10 | | 2 | 0 | 1 | 10 | 54 | 25 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 5 |
| Jack Rocks | 28/09/10 | | 3 | 0 | 0 | 0 | 50 | 5 | 0 | 45 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jack Rocks | 28/09/10 | | 4 | 0 | 0 | 5 | 60 | 20 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 80 |
| Jack Rocks | 28/09/10 | | 5 | 0 | 0 | 2 | 60 | 5 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 75 |
| Jack Rocks | 28/09/10 | | 6 | 0 | 1 | 9 | 60 | 20 | 0 | 10 | 15 | 0 | 0 | 0 | 0 | 70 |

## Appendix 4 — Total macroinvertebrate abundance ($m^{-2}$) recorded at each site in September 2010

Species Codes: F = female; L = larvae; P = pupa; imm. = immature larva; dam. = specimen damaged.

Cons. Cat. (conservation category): C = cosmopolitan (Australia and beyond, however not necessarily worldwide); A = Australia; I = indeterminate; I* = indeterminate but probably occurs only in SW; S = endemic to SW but commonly occurring; L = endemic to SW but with a restricted distribution.

| Phylum/Class/Order | Family/Species | *Cons. Cat.* | TA1 | TA2 | Vardi Rd | More Seldom Seen Bk | Waterfall Gully | 31 Mile Bk | Foster Bk | Wilson Bk | Jack Rocks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NEMERTEA | Nemertea sp. | *I* | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NEMATODA | Nematoda sp. | *I* | 240 | 224 | 96 | 0 | 144 | 176 | 16 | 64 | 0 |
| PLATYHELMINTHES | Turbellaria sp. | *I* | 96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ANNELIDA | Oligochaeta | *I* | 752 | 2896 | 4240 | 80 | 10976 | 1184 | 1136 | 2144 | 176 |
| ARACHNIDA | Hydracarina spp. | *I* | 192 | 544 | 1472 | 0 | 176 | 112 | 160 | 192 | 0 |
| | Orabatidae spp. | *I* | 0 | 192 | 0 | 32 | 32 | 16 | 0 | 32 | 0 |
| CRUSTACEA | | | | | | | | | | | |
| COPEPODA | Copepoda spp. | *S* | 416 | 32 | 64 | 0 | 0 | 2368 | 16 | 112 | 560 |
| OSTRACODA | Ostracoda spp. | *I* | 608 | 96 | 48 | 0 | 0 | 480 | 0 | 0 | 368 |
| AMPHIPODA | **Ceinidae** | | | | | | | | | | |
| | *Austrochiltonia subtenuis* | *A* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 64 | 96 |
| | **Paramelitidae** | *S* | 176 | 2096 | 0 | 976 | 5536 | 2256 | 0 | 0 | 0 |
| | **Perthidae** | | | | | | | | | | |
| | Perthia sp. | *S* | 0 | 32 | 16 | 48 | 0 | 0 | 0 | 80 | 64 |
| DECAPODA | Parastacidae (imm.) | | | | | | | | | | |
| ARACHNIDA | Hydracarina spp. | *I* | 192 | 544 | 1472 | 0 | 176 | 112 | 160 | 192 | 0 |
| | Orabatidae spp. | *I* | 0 | 192 | 0 | 32 | 32 | 16 | 0 | 32 | 0 |
| COLLEMBOLA | Collembola spp. | *I* | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 |
| | Entomobryoidea sp. | *I* | 0 | 16 | 0 | 0 | 0 | 16 | 0 | 0 | 0 |
| | Poduroidea sp. | *I* | 0 | 0 | 0 | 416 | 0 | 0 | 0 | 0 | 0 |
| INSECTA | | | | | | | | | | | |
| EPHEMEROPTERA | Ephemeroptera (imm.) | *I* | 0 | 912 | 0 | 0 | 0 | 0 | 0 | 64 | 0 |
| | **Baetidae** | | | | | | | | | | |
| | Baetidae sp. (imm.) | *I* | 0 | 32 | 0 | 0 | 128 | 0 | 0 | 0 | 0 |
| | Cloeon sp. | *A* | 0 | 0 | 0 | 0 | 32 | 0 | 0 | 0 | 0 |
| | *Offadens soror* | *A* | 0 | 0 | 0 | 0 | 672 | 0 | 0 | 16 | 0 |
| | **Leptophlebiidae** | | | | | | | | | | |
| | Leptophlebiidae sp. (dam.) | *I* | 144 | 2800 | 48 | 0 | 208 | 1008 | 368 | 64 | 0 |
| | *Neboissophlebia occidentalis* | *S* | 0 | 0 | 0 | 0 | 160 | 0 | 0 | 0 | 0 |
| | Nousia sp. AV16 | *S* | 0 | 0 | 0 | 0 | 608 | 0 | 0 | 0 | 0 |
| | *Nyungara bunni* | *S* | 0 | 128 | 0 | 0 | 256 | 16 | 32 | 0 | 0 |
| PLECOPTERA | Plecoptera spp. (imm.) | *S* | 64 | 0 | 0 | 0 | 0 | 496 | 0 | 0 | 0 |
| | **Gripopterygidae** | | | | | | | | | | |
| | Gripopterygidae spp. (imm.) | *S* | 32 | 704 | 64 | 0 | 0 | 2240 | 80 | 48 | 0 |
| | *Leptoperla australica* | *S* | 0 | 80 | 96 | 0 | 16 | 2144 | 0 | 0 | 32 |
| | *Newmanoperla exigua* | *S* | 0 | 544 | 32 | 0 | 0 | 0 | 16 | 0 | 0 |
| ODONATA | Anisoptera spp. (imm.) | *I* | 0 | 48 | 0 | 0 | 160 | 0 | 0 | 80 | 0 |
| | **Gomphidae** | | | | | | | | | | |
| | *Armagomphus armiger* | *S* | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 |
| | *Austrogomphus (Z) lateralis* | *S* | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 |
| | **Libellulidae** | | | | | | | | | | |
| | Orthetrum caledonicum | *A* | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 |
| | **Synthemistidae** | | | | | | | | | | |
| | Austrosyntemis cyanitincta | *S* | 0 | 0 | 0 | 0 | 128 | 0 | 0 | 0 | 0 |
| | **Telephlebiidae** | | | | | | | | | | |
| | Austroaeschna anacantha | *S* | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 |

## Appendix 4 — Continued

| Phylum/Class/Order | Family/Species | *Cons. Cat.* | TA1 | TA2 | Vardi Rd | More Seldom Seen Bk | Waterfall Gully | 31 Mile Bk | Foster Bk | Wilson Bk | Jack Rocks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| COLEOPTERA | **Curculionidae** | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Curculionidae sp. (L) | *I* | 16 | 0 | 32 | 0 | 0 | 16 | 32 | 0 | 0 |
| | **Dytiscidae** | | | | | | | | | | |
| | Dytiscidae sp. (L) | *I* | 0 | 48 | 0 | 16 | 0 | 0 | 0 | 0 | 64 |
| | *Allodessus bistrigatus* | *A* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| | Allomatus sp. (L) | *S* | 0 | 32 | 16 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Necterosoma sp. | *I* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 48 |
| | Paroster sp. (L) | *I* | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Platynectes sp. (L) | *I* | 96 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Sternopriscus sp. | *S* | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Sternopriscus sp. (L) | *S* | 0 | 64 | 0 | 0 | 0 | 0 | 0 | 0 | 400 |
| | Sternopriscus browni | *S* | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Sternopriscus marginatus | *S* | 48 | 0 | 48 | 0 | 0 | 0 | 0 | 16 | 0 |
| | Tiporus sp. (L) | *I* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| | Tribe Bidessini spp. (L) | *I* | 320 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 64 |
| | *Dineutus australis* | *A* | 0 | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 0 |
| | **Hydrochidae** | | | | | | | | | | |
| | Hydrochus sp. | *I* | 0 | 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Scirtidae** | | | | | | | | | | |
| | Scirtidae sp. (L) | *I* | 1040 | 896 | 2176 | 128 | 32 | 336 | 608 | 224 | 16 |
| DIPTERA | **Athericidae** | *I* | 16 | 32 | 0 | 32 | 0 | 48 | 0 | 0 | 0 |
| | **Ceratopogonidae** | *I* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Ceratopogonidae (P) | *I* | 0 | 0 | 0 | 0 | 32 | 0 | 16 | 0 | 0 |
| | Ceratopogoninae spp. | *I* | 1344 | 368 | 896 | 64 | 1200 | 384 | 64 | 880 | 96 |
| | Dasyheleinae sp. | *I* | 0 | 208 | 0 | 0 | 96 | 0 | 32 | 0 | 16 |
| | **Chironomidae** | | | | | | | | | | |
| | Chironomidae spp. (P) | *I* | 752 | 96 | 96 | 96 | 32 | 144 | 656 | 32 | 128 |
| | Chironomidae sp. (V14) | *S* | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 |
| | **Aphroteniinae** | | | | | | | | | | |
| | *Aphroteniella ?filicornis* (V23) | *A* | 0 | 0 | 0 | 0 | 544 | 16 | 0 | 224 | 0 |
| | *Aphroteniella tenuicornis* | *A* | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 | 0 |
| | **Chironominae** | | | | | | | | | | |
| | *Botryocladius freemani* | *S* | 16 | 48 | 0 | 0 | 112 | 0 | 64 | 16 | 0 |
| | *Chironomus aff. altermans* | *C* | 32 | 16 | 0 | 0 | 16 | 16 | 0 | 0 | 3920 |
| | *Dicrotendipes* sp. (V47) | *S* | 16 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 768 |
| | *?Paratendipes* sp. (V12) | *I* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 560 | 0 |
| | *Polypedilum* sp. (V3) | *I* | 0 | 16 | 96 | 0 | 80 | 16 | 48 | 160 | 32 |
| | *Polypedilum watsoni* | *A* | 0 | 128 | 0 | 0 | 96 | 16 | 0 | 240 | 16 |
| | *Rheotanytarsus* sp. (V18) | *I* | 0 | 0 | 80 | 0 | 0 | 0 | 16 | 16 | 0 |
| | *Riethia ?stictoptera* (V5) | *I* | 32 | 112 | 592 | 0 | 32 | 128 | 0 | 112 | 32 |
| | *Riethia ?zeylandica* (V4) | *I* | 0 | 0 | 0 | 0 | 320 | 0 | 0 | 608 | 0 |
| | *Stempellina sp.* (V7) | *I* | 16 | 256 | 32 | 0 | 304 | 0 | 0 | 64 | 0 |
| | *Tanytarsus* sp. (V6) | *I* | 1856 | 576 | 1136 | 16 | 3424 | 256 | 32 | 112 | 2352 |
| | **Orthocladinae** | | | | | | | | | | |
| | *Cricotopus annuliventris* | *C* | 4448 | 1520 | 608 | 0 | 160 | 48 | 528 | 64 | 16 |
| | *Parakiefferiella* sp. (nr *variegatus*) (VSC9) | *I* | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 |
| | *Paralimnophyes* sp. (V42) | *I* | 96 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 32 |
| | *Strictocladius ?uniserialis* (V8) | *S* | 96 | 64 | 0 | 1104 | 592 | 992 | 368 | 224 | 0 |
| | *Thienemanniella* sp. (V19) | *A* | 176 | 192 | 112 | 0 | 80 | 64 | 288 | 16 | 0 |

## Appendix 4 — Continued

| Phylum/Class/Order | Family/Species | *Cons. Cat.* | TA1 | TA2 | Vardi Rd | More Seldom Seen Bk | Waterfall Gully | 31 Mile Bk | Foster Bk | Wilson Bk | Jack Rocks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unknown orthoclad genus (V15) | *I* | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| | Unknown orthoclad genus (V31) | *I* | 608 | 160 | 0 | 624 | 16 | 48 | 352 | 32 | 16 |
| | Unknown orthoclad genus (V59) | *I* | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 0 | 0 |
| | Unknown orthoclad genus (VSC11) | *I* | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 |
| | **Tanypodinae** | | | | | | | | | | |
| | *Paramerina levidensis* | *S* | 560 | 48 | 32 | 0 | 16 | 0 | 48 | 96 | 400 |
| | *Pentaneura* sp. (V10) | *I* | 64 | 16 | 0 | 0 | 256 | 32 | 0 | 144 | 0 |
| | ?*Zavrelimyia* (V20) | *I* | 16 | 0 | 48 | 0 | 0 | 0 | 32 | 400 | 0 |
| | **Culicidae** | | | | | | | | | | |
| | Adedes sp. | *I* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 |
| | **Empididae** | *I* | 0 | 16 | 16 | 16 | 0 | 48 | 80 | 32 | 0 |
| | **Ephydridae** | *I* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 |
| | **Psychodidae** | *I* | 0 | 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Simuliidae** | *I* | 0 | 960 | 0 | 0 | 704 | 288 | 48 | 16 | 0 |
| | **Tanyderidae** | *I* | 16 | 16 | 32 | 0 | 16 | 0 | 0 | 16 | 48 |
| | **Tipulidae** | *I* | 64 | 16 | 0 | 0 | 128 | 16 | 16 | 48 | 0 |
| | **Thaumaleidae** | *I* | 32 | 0 | 0 | 0 | 640 | 0 | 0 | 0 | 0 |
| TRICHOPTERA | Trichoptera sp. (imm.) | *I* | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Ecnomidae** | | | | | | | | | | |
| | Ecnomus sp. | *I** | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 |
| | Daternomina sp. | *I** | 0 | 0 | 0 | 0 | 32 | 0 | 0 | 0 | 0 |
| | **Hydrobiosidae** | | | | | | | | | | |
| | Hydrobiosidae sp. | *I** | 0 | 0 | 0 | 0 | 128 | 0 | 0 | 0 | 0 |
| | Taschorema pallescens | *S* | 0 | 0 | 0 | 0 | 112 | 0 | 0 | 0 | 0 |
| | **Hydropsychidae** | | | | | | | | | | |
| | Hydropsychidae sp. (imm.) | *I** | 0 | 80 | 0 | 0 | 16 | 0 | 0 | 0 | 0 |
| | *Smicrophylax australis* | *S* | 0 | 0 | 0 | 16 | 720 | 0 | 0 | 0 | 0 |
| | **Hydroptilidae** | | | | | | | | | | |
| | Hydroptilidae sp. (imm.) | *I** | 0 | 224 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Orthotricia sp. | *I** | 0 | 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Oxyethira sp. | *I** | 0 | 304 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Leptoceridae** | | | | | | | | | | |
| | Leptoceridae sp. (imm.) | *I* | 0 | 64 | 0 | 0 | 16 | 0 | 0 | 0 | 0 |
| | Notalina sp. AV14 | *S* | 0 | 0 | 0 | 0 | 0 | 32 | 16 | 0 | 0 |
| | Notalina sp. AV15 | *S* | 128 | 112 | 64 | 0 | 0 | 32 | 32 | 32 | 0 |
| | Notalina sp. AV16 | *S* | 0 | 0 | 0 | 0 | 0 | 32 | 0 | 0 | 0 |
| | *Lectrides parilis* | *S* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 |
| | Triplectides sp. AV1 | *S* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 0 |
| | Triplectides sp. AV21 | *S* | 176 | 0 | 0 | 0 | 16 | 0 | 48 | 0 | 0 |
| | *Triplectides australicus* | *A* | 0 | 0 | 0 | 48 | 0 | 16 | 0 | 0 | 0 |
| | Maydenoptila sp. | *I** | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Maydenoptila baynesi* | *S* | 0 | 64 | 0 | 0 | 0 | 0 | 0 | 32 | 0 |
| | **Philopotamidae** | | | | | | | | | | |
| | Philopotamidae sp. (imm.) | *I** | 0 | 0 | 0 | 0 | 16 | 16 | 16 | 0 | 0 |
| | *Hydrobiosella michaelseni* | *S* | 16 | 48 | 0 | 0 | 0 | 0 | 32 | 0 | 0 |
| | *Total abundance m* $^{-2}$ | | *15,072* | *19,264* | *13,760* | *3,744* | *29,632* | *15,712* | *5,568* | *7,680* | *9,840* |
| | *Total number of 'species'* | | *43* | *59* | *29* | *17* | *56* | *41* | *37* | *45* | *29* |