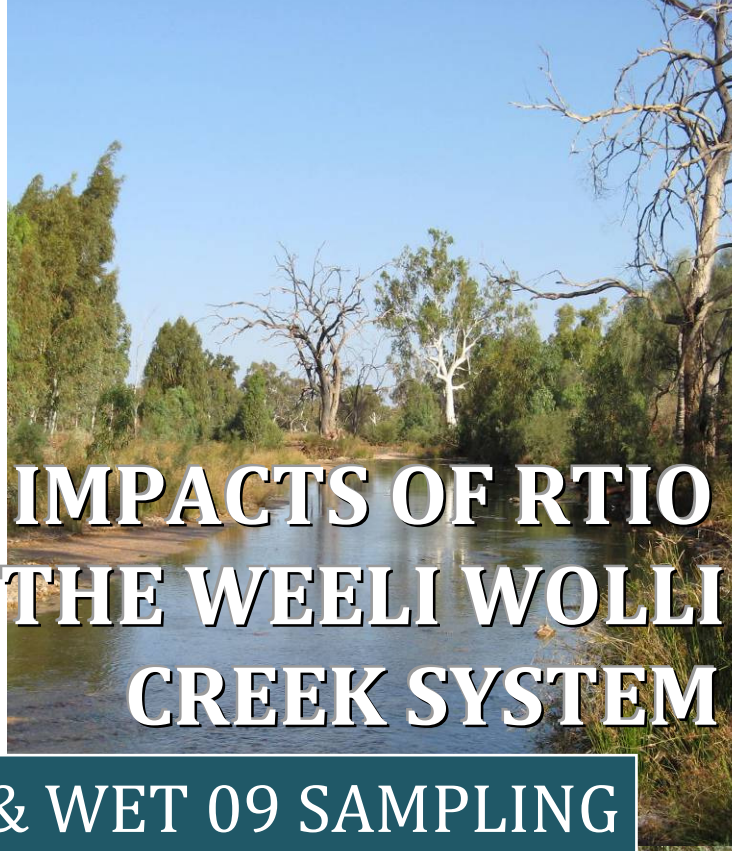
RIO TINTO



# CUMULATIVE IMPACTS OF RTIO MINING ON THE WEELI WOLLI CREEK SYSTEM

## DRY 08 & WET 09 SAMPLING
## FINAL REPORT

*Wetland Research & Management*

July 2010

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## Disclaimer



This document has been printed on 'Reflex Green Recycled Paper'.

Frontispiece (top to bottom): Marillana Creek at MAR2-5; MAR2-3; and, riffle at MAR1-3 (all photos taken by WRM personnel).

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# 1 INTRODUCTION

## 1.1 Background

The Rio Tinto Iron Ore (RTIO) mine at Yandi is located in the East Pilbara region of Western Australia. A number of temporary creeklines traverse the mine area, including Marillana, Yandicoogina, Phil's and Weeli Wolli creeks (Figures 1 & 2). The mine has been operating since 1996, and as part of mine operations de-watering of the Yandi JSE and Central pits has been necessary since 1998, with excess water discharged directly into Marillana Creek. Since late 2007, excess water has also been discharged into Weeli Wolli Creek (from discharge outlet D06; see Figure 2). For the period 1998-2009, average annual discharge into Marillana Creek from all outlets combined was 0.61 GL/year (Figure 3). Peak average discharge into Marillana Creek was 1.29 GL/year in 2009. Average annual discharge into Weeli Wolli Creek between 2008 and 2009 was 0.15 GL/year (Figure 3). Projected average discharge into Marillana Creek and Weeli Wolli Creek is anticipated to be 1.06 GL/year and 0.92 GL/year, respectively (Figure 3). Upstream of RTIO Yandi on Marillana Creek, the BHP-BIO Yandi mine (operating since 1994) also dewaters their developing pit, with discharge occurring into the upstream section of Marillana creek. It is likely that discharge from BHP-BIO will increase over the next few years as an increase in their abstraction rate to a peak of 15GL/year has been approved, with excess water likely being discharged into Marillana Creek. Downstream of these mining operations, Marillana Creek flows into Weeli Wolli Creek (see Figures 1 & 2), into which RTIO's Hope Downs 1 (HD1) operation also discharges their dewatering water. Discharge from HD1 is predominantly via a single gabion structure adjacent to the main creek, however a system of spur lines deliver water as seepage flows to important trees and pools upstream of the gabion, in the area of the historic spring and permanent pools. Approximately 10% of dewatering discharge is released via the system of spur lines, with the remainder released from the gabion. The total volume discharged from HD1 into Weeli Wolli Creek varies between years, but was approx. 25.55 GL/year during 2008/09.

Discharge from Yandi (RTIO & BHPBIO) operations pose potential impacts to the aquatic ecosystem of Marillana Creek, and also to the lower Weeli Wolli Creek system downstream of the confluence with Marillana; this section of Weeli Wolli Creek is also impacted by discharge water from HD1, adding to the cumulative impact on this section of the creekline. An added issue is the proposed listing of the Fortescue Marshes as a Ramsar Wetland of International Importance. Weeli Wolli flows to the north, where it drains into the Fortescue River via the Fortescue Marsh. The Marsh is approximately 20 km downstream from the Marillana - Weeli Wolli Creek confluence. Historically the two systems are only connected during flooding associated with intense cyclonic events. With additional discharge from BHP-BIO's Yandi, RTIO's Yandi and RTIO's HD1 operations, surface flows along Weeli Wolli will continue to increase, and the concern from the regulators is ensuring that permanent flows do not reach the Marsh. Prior to dewatering discharge at HD1, the spring resulted in perennial surface flow for approximately 2 km along the upper section of Weeli Wolli Creek. Since the commencement of discharge from HD1, surface flows in Weeli Wolli Creek now extend approximately 20 km downstream of historic perennial flow, and currently extend past Yandi operations, beyond the confluence with Marillana Creek, downstream of Gray's Crossing.

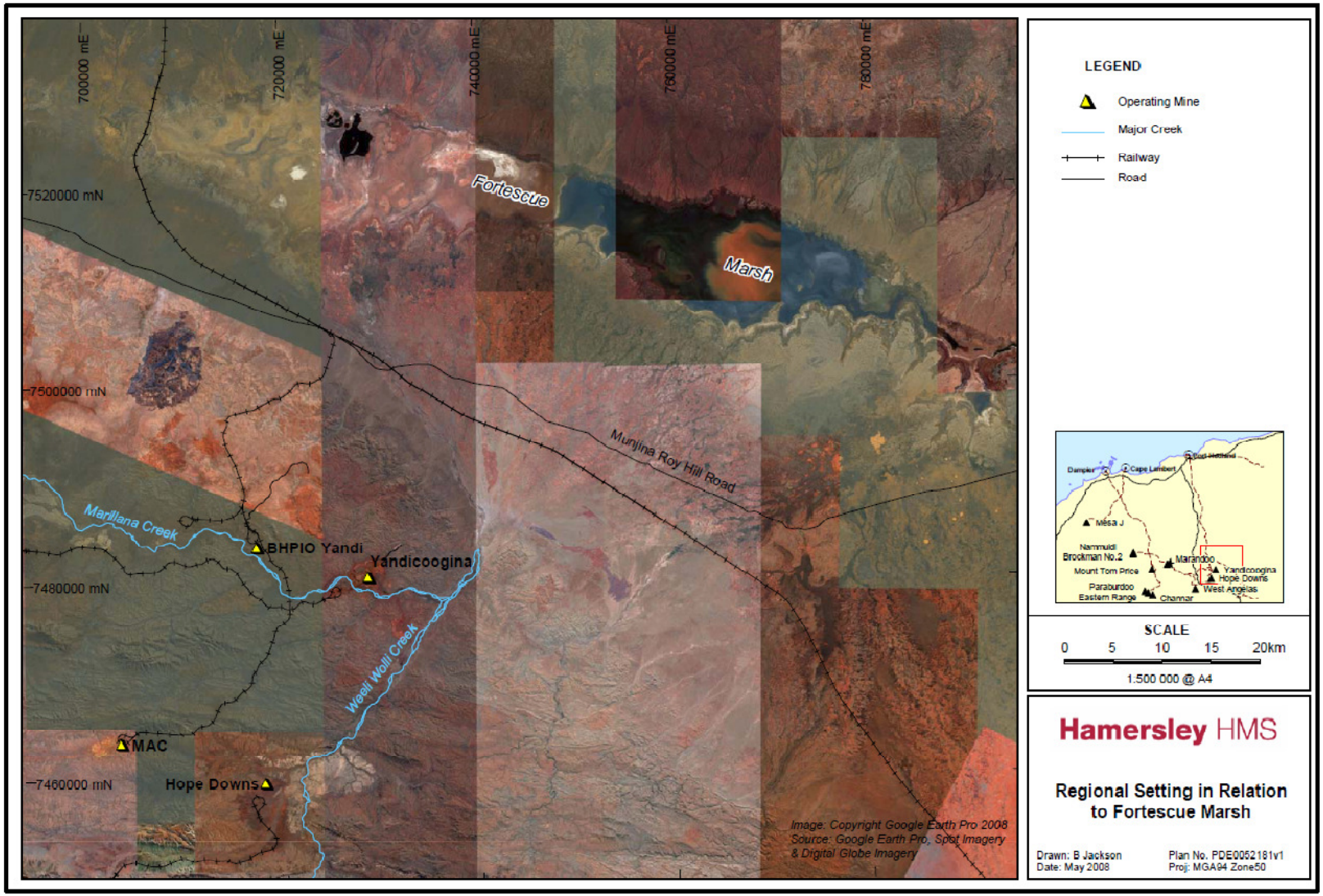



**Figure 1.** Map showing the location of Marillana Creek and Weeli Wolli Creek with respect to the Fortescue Marshes in the Pilbara Region of Western Australia.

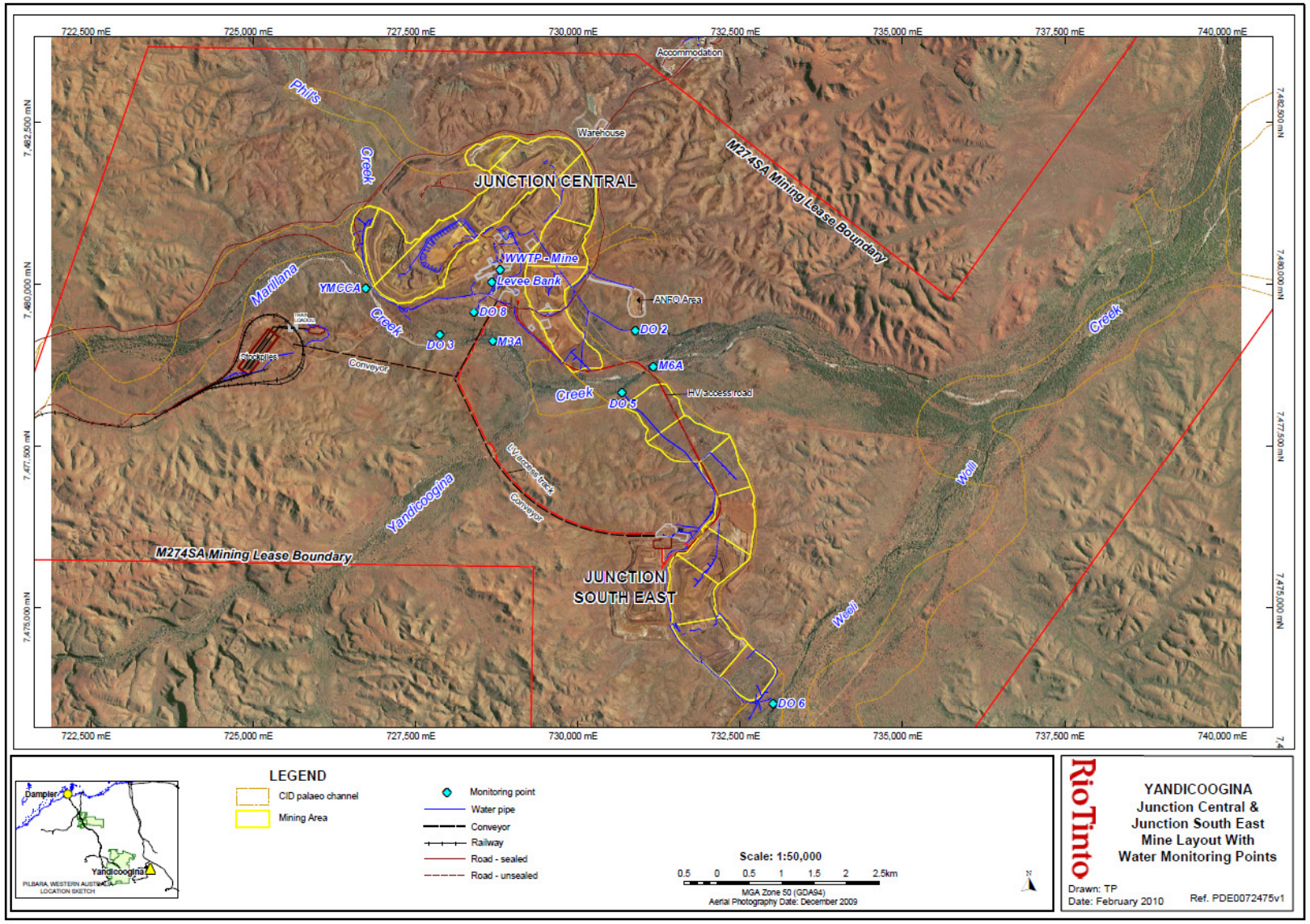



**Figure 2.** Map showing the location of all discharge outlets (D01-D09) across the Yandi mine lease.

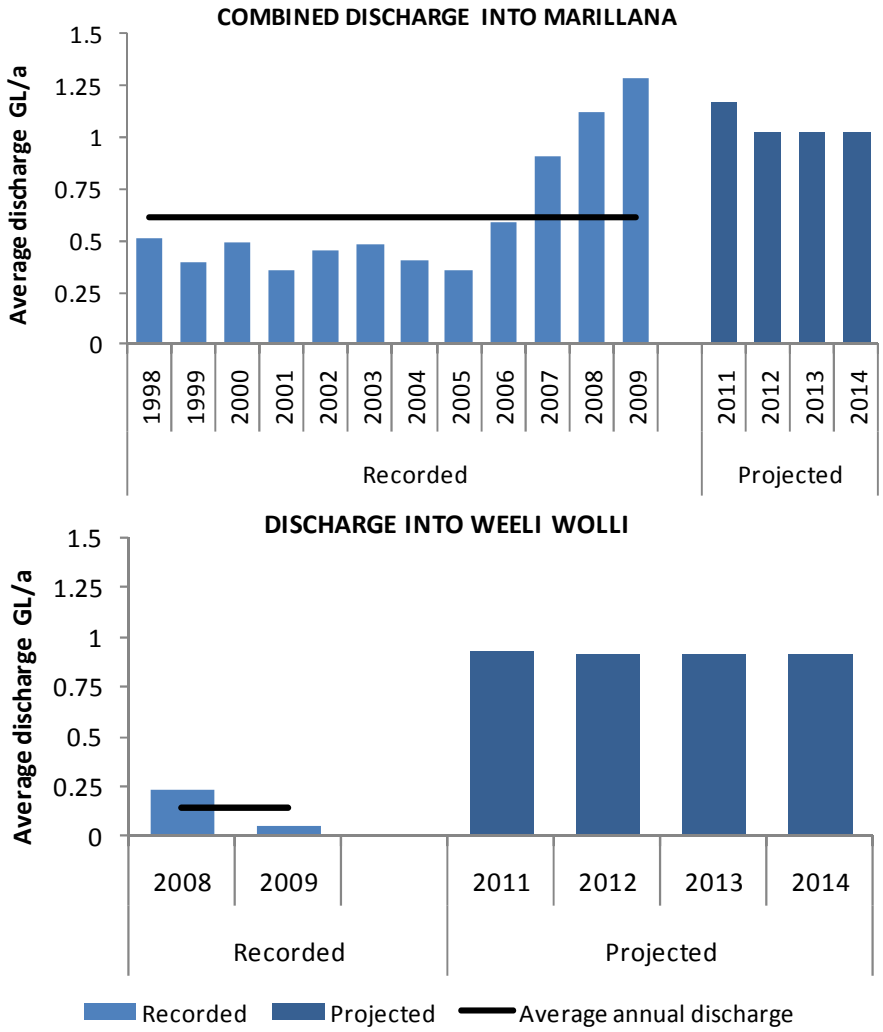



**Figure 3.** Current and projected average discharge (GL/year) into Marillana Creek for all outlets combined (top), and into Weeli Wolli Creek (bottom). Information provided by RTIO.

The specific and cumulative effects of these operations need to be assessed. Therefore, RTIO commissioned *Wetland Research and Management* to undertake a study of the aquatic biota of Marillana Creek. The purpose of this was to a.) assess specific effects of RTIO's (and BHPIO's) Yandi operations on Marillana Creek, and b.) provide data that supports the HD1 Living Water Survey, to assess Cumulative Impacts on the Weeli Wolli system. To this end, Marillana Creek was broken into two reaches of differing discharge regimes to document current ecological condition. The two study reaches were; 1.) downstream of BHP-BIO's discharge but upstream of RTIO's Yandi discharge, and 2.) downstream of RTIO's Yandi discharge as far as surface flows reach (approx. 0.5 km upstream of the confluence with Weeli Wolli).

Similarly, the Living Water Survey aimed to characterise Weeli Wolli Creek in four reaches of differing flow regime to document current ecological condition. The four study reaches were; (1.) the spring where permanent pools were located, 2.) within the reach of historic permanent flow downstream of the spring, 3.) within the area of creek which was highly ephemeral and dry for much of the year but is now perennial as far as the confluence with

Marillana Creek due to discharge[1], and 4.) the now perennial reach below the confluence with Marillana Creek[2], which varies in length depending on season and dewatering discharge.

This report presents the findings from two rounds of sampling at both Marillana and Weeli Wolli creeks (October 2008 & May 2009; see WRM 2009a).

## 1.2 Study objectives

The aim of this study was to document current ecological condition of Marillana Creek and Weeli Wolli Creek with respect to water quality and aquatic biota assemblages (microinvertebrates, macroinvertebrates, hyporheic fauna[3] and fish) to establish baseline conditions, assess current effects of RTIO's Yandi mine, and provide data to feed into a Cumulative Impacts study of the Weeli Wolli system.

[1] Discharge from RTIO's Yandi at outlet D06 is into Reach Three on Weeli Wolli Creek.

[2] As this reach is downstream of the confluence with Marillana Creek, it is also influenced by discharge from RTIO and BHP-BIO's Yandi mines.

[3] Aquatic invertebrate fauna which reside in the area below the streambed where water percolates through spaces between the rocks and cobbles.

# 2 METHODS

## 2.1 Study area

Marillana Creek and Weeli Wolli Creek are located approximately 75 km north-west of Newman, in the Pilbara Region of Western Australia. The main drainage system in the area is the Fortescue River, which arises near Newman, flows north and then northwest into the Fortescue Marsh (see Figure 1).

Marillana Creek drains eastward before joining Weeli Wolli Creek. Streamflow is seasonal, with flows usually occurring in response to heavy rainfall events. On average, Marillana Creek historically flows for 30 to 60 days a year. Annual streamflow in the area around Yandi can range from negligible to tens of millions of cubic metres.

Weeli Wolli Creek is approximately 70 km in length, and has a catchment area of 4100 $km^2$. A dense network of ephemeral tributary streamlines is associated with the system. Weeli Wolli flows to the north, where it drains into the Fortescue River via the Fortescue Marsh. The creek is fed by Weeli Wolli Spring which arises as a result of groundwater flow being "dammed" by the Brockman Formation, which forces groundwater to the surface, appearing as the perennial spring.

Weeli Wolli Spring is considered to be of high ecological, social and cultural value (EPA 2001, Kendrick 2001, Gardiner 2003, van Leeuwen 2009). It has high environmental significance in the Pilbara region because it is a permanent water body. Due to the aridity of the region, such systems are rare. Halse *et al.* (2002) suggested that such systems provide an important "source of animals for colonisation of newly flooded pools and maintenance of populations of invertebrate species at the regional level". The creek is also of significance to indigenous people as it holds mythological and ceremonial importance (EPA 2001), and has social value in the form of local tourism (van Leeuwen 2009). In 2009 the spring was nominated for listing as a Threatened Ecological Community at the State level, on the basis of floristic communities as well as the diverse aquatic invertebrate and significant stygofauna communities (van Leeuwen 2009).

## 2.2 Sites and sampling design

Marillana Creek was broken into two main reaches, reflecting differences in mining operations and discharge:

- Reach One – downstream of BHP-BIO's Yandi discharge and upstream of RTIO's Yandi discharge,
- Reach Two - downstream of RTIO's Yandi discharge as far as flows reach (just upstream of the confluence with Weeli Wolli) (Figure 4).

Weeli Wolli Creek was also stratified into separate reaches of differing historic flow regime. Four reaches along Weeli Wolli Creek were sampled, including:

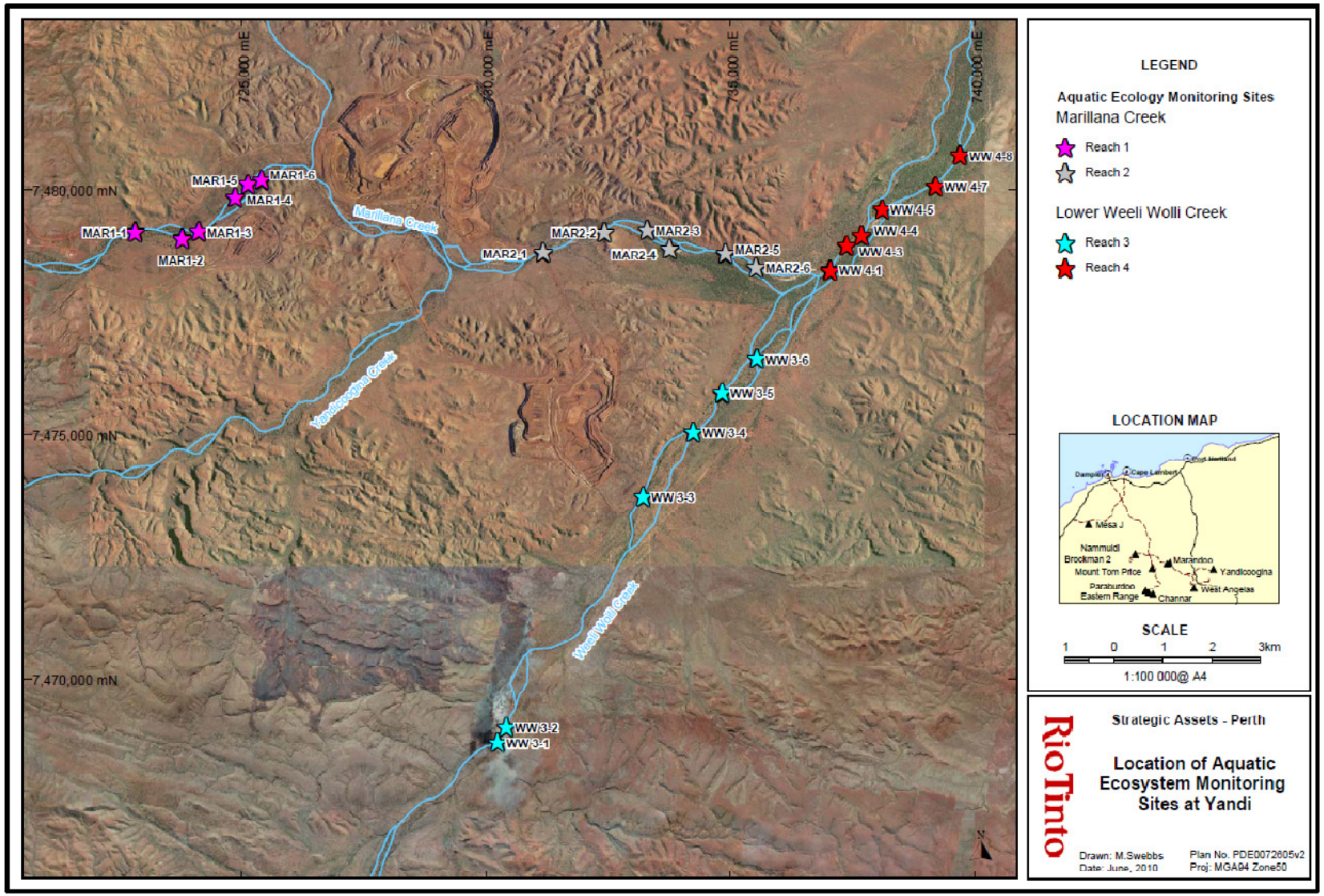



**Figure 4.** Location of the reaches and sampling sites along Marillana Creek and lower Weeli Wolli Creek.

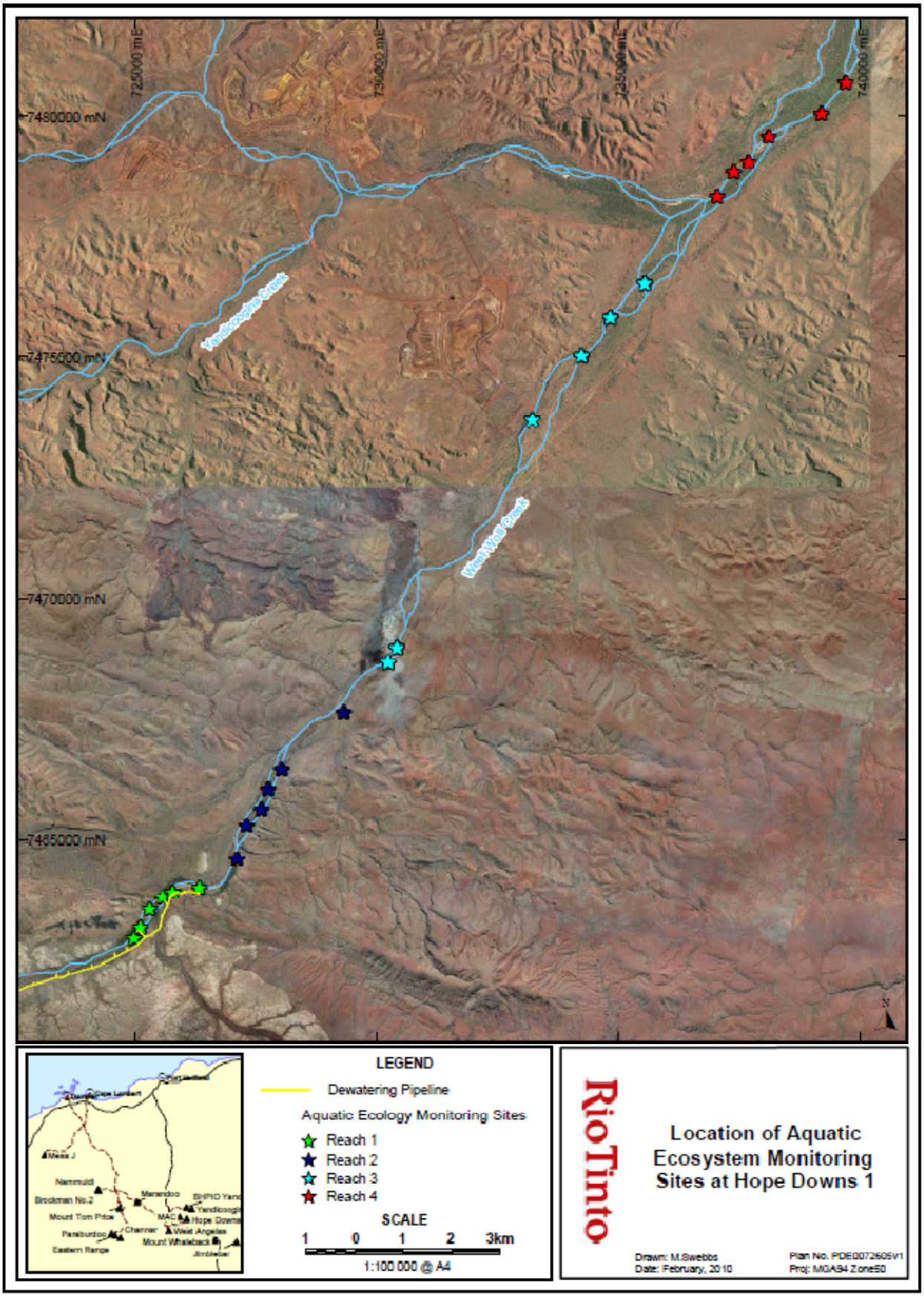



**Figure 5.** Location of the reaches and sampling sites along Weeli Wolli Creek.

- Reach One – in the area of Weeli Wolli Spring where permanent pools historically were located,
- Reach Two - within the historic reach of continuous permanent flow downstream of the spring,
- Reach Three - downstream of this point to the junction with Marillana Creek, where the creek historically was highly ephemeral and dry for much of the year, and
- Reach Four - the now permanent reach below the Marillana Creek confluence towards Fortescue Marshes (WRM 2009a; see Figures 4 and 5).

Six replicate samples were taken within each reach to characterise the fauna and conditions along each reach, and to provide adequate statistical power for analyses (Tables 1 and 2). Replicates were located to provide a geographical spread within each reach, but positions were influenced by access (Figures 4 and 5).

Site photographs are provided in Appendix 1.

**Table 1.** GPS location (UTM WGS84) of sites sampled along Marillana Creek.

| *Reach* | *Historic flows* | *Site* | *GPS Location* | |
|---|---|---|---|---|
| | | | *Easting* | *Northing* |
| 1 | Upstream of RTIO's Yandi discharge | MAR1-1 | 50 722832 | 7479165 |
| | | MAR1-2 | 50 723796 | 7479028 |
| | | MAR1-3 | 50 724135 | 7479167 |
| | | MAR1-4 | 50 724876 | 7479864 |
| | | MAR1-5 | 50 725143 | 7480136 |
| | | MAR1-6 | 50 725416 | 7480219 |
| 2 | Downstream of RTIO's Yandi discharge | MAR2-1 | 50 731178 | 7478739 |
| | | MAR2-2 | 50 732424 | 7479151 |
| | | MAR2-3 | 50 733306 | 7479198 |
| | | MAR2-4 | 50 733764 | 7478806 |
| | | MAR2-5 | 50 734906 | 7478710 |
| | | MAR2-6 | 50 735531 | 7478436 |

## 2.3 Water quality

At each site a number of water quality variables were recorded *in situ* using portable WTW field meters, including pH, electrical conductivity (µS/cm), dissolved oxygen (% and mg/L), and water temperature (°C). Water depth was measured using a graduated pole. Undisturbed water samples were taken for laboratory analyses of ionic composition, nutrients and metals. Samples collected for nutrients and metals were filtered through 0.45 µm Millipore nitrocellulose filters. All water samples were kept cool in an esky while in the field, and frozen as soon as possible for subsequent transport to the laboratory. All laboratory analyses were conducted by the Natural Resources Chemistry Laboratory, Chemistry Centre, WA (a NATA accredited laboratory). Water quality variables measured are summarised in Table 3.

**Table 2.** GPS location (UTM WGS84) of sites sampled along Weeli Wolli Creek.

| *Reach* | *Historic flows* | *Site* | *GPS Location* | |
|---|---|---|---|---|
| | | | *Easting* | *Northing* |
| 1 | springs and permanent pools | WW1-1 | 50 724996 | 7463013 |
| | | WW1-2 | 50 725118 | 7463229 |
| | | WW1-3 | 50 725314 | 7463617 |
| | | WW1-4 | 50 725578 | 7463854 |
| | | WW1-5 | 50 725784 | 7463974 |
| | | WW1-6 | 50 726338 | 7464051 |
| 2 | permanent flows | WW2-1 | 50 727121 | 7464649 |
| | | WW2-2 | 50 727314 | 7465349 |
| | | WW2-3 | 50 727622 | 7465670 |
| | | WW2-4 | 50 727760 | 7466098 |
| | | WW2-5 | 50 728036 | 7466500 |
| | | WW2-6 | 50 729320 | 7467676 |
| 3 | highly ephemeral flows, where the creek was dry for much of the year | WW3-1 | 50 730243 | 7468720 |
| | | WW3-2 | 50 730424 | 7469027 |
| | | WW3-3 | 50 733220 | 7473739 |
| | | WW3-4 | 50 734243 | 7475063 |
| | | WW3-5 | 50 734838 | 7475862 |
| | | WW3-6 | 50 735545 | 7476564 |
| 4 | Highly ephemeral flows, where the creek was dry for much of the year (but has been influenced by discharge from BHP's Yandi mine) | WW4-1 | 50 737041 | 7478376 |
| | | WW4-3 | 50 737381 | 7478874 |
| | | WW4-4 | 50 737684 | 7479082 |
| | | WW4-5 | 50 738105 | 7479616 |
| | | WW4-7 | 50 739194 | 7480091 |
| | | WW4-8 | 50 739700 | 7480735 |

Water quality data were compared against ANZECC/ARMCANZ (2000) water quality guidelines. ANZECC/ARMCANZ (2000) provides trigger values for a range of water quality parameters for the protection of aquatic ecosystems. These trigger values may be adopted in the absence of adequate site-specific data. ANZECC/ARMCANZ (2000) recommends different levels of species protection applied to different levels of ecosystem condition. The 99% value is applied to high conservation/ecological value ecosystems, the 95% value to slightly to moderately disturbed ecosystems and the 90% or 80% values to highly disturbed ecosystems. In the ANZECC/ARMCANZ (2000) water quality management framework, the decision about the ecosystem condition is typically a joint one between stakeholders. Based on the observed condition of creeks in the vicinity of Weeli Wolli Creek, it is suggested that either the 99% or possibly the 95% values are applied. When applying trigger values (TVs), ANZECC/ARMCANZ (2000) state the following:

> "*Trigger values are concentrations that, if exceeded, would indicate a potential environmental problem, and so 'trigger' a management response, e.g. further investigation and subsequent refinement of the guidelines according to local conditions*." (Section 2.1.4); and
>
> "*Exceedances of the trigger values are an 'early warning' mechanism to alert managers of a potential problem. They are not intended to be an instrument to assess 'compliance' and should not be used in this capacity*." (Section 7.4.4).

**Table 3.** All water quality parameters measured.

| *Parameter* | *Units* | *Parameter* | *Units* |
|---|---|---|---|
| pH | pH units | Aluminium (Al) | mg/L |
| Electrical conductivity | µS/cm | Arsenic (As) | mg/L |
| Dissolved oxygen | % saturation | Boron (B) | mg/L |
| Dissolved oxygen | mg/L | Barium (Ba) | mg/L |
| Water temp | ℃ | Cadmium (Cd) | mg/L |
| Average water depth | m | Cobalt (Co) | mg/L |
| Maximum water depth | m | Chromium (Cr) | mg/L |
| Sodium (Na) | mg/L | Copper (Cu) | mg/L |
| Potassium (K) | mg/L | Iron (Fe) | mg/L |
| Calcium (Ca) | mg/L | Manganese (Mn) | mg/L |
| Magnesium (Mg) | mg/L | Molybdenum (Mo) | mg/L |
| Chloride (Cl) | mg/L | Nickel (Ni) | mg/L |
| $CO_3$ | mg/L | Lead (Pb) | mg/L |
| $HCO_3$ | mg/L | Selenium (Se) | mg/L |
| $SO_4$ | mg/L | Uranium (U) | mg/L |
| Alkalinity | mg/L | Vanadium (V) | mg/L |
| Hardness | mg/L | Zinc (Zn) | mg/L |
| Nitrate ($NO_3$) | mg/L | | |
| Ammonium ($NH_3$) | mg/L | | |
| Total Nitrogen (total N) | mg/L | | |
| Total Phosphorus (total P) | mg/L | | |

Hence, TVs should not be used in a 'pass-fail' approach to water quality management. Their main purpose is to inform managers and regulators that changes in water quality are occurring and may need to be investigated. In the case of baseline data collection, the guidelines may be used to establish background levels relative to TVs, and show where certain elements may be naturally elevated (i.e. due to geological features). This allows future discrimination of mine effects from natural enrichment. Where background levels are elevated, then it is desirable to establish site-specific TVs.

The guidelines recommend, that where an appropriate default TV does not exist, or the default TV is consistently lower than natural background concentrations, natural background data should be used to derive the TV. In these instances, the 80$^{th}$ percentile (and 20$^{th}$ percentile in the case of variables that require an upper and lower guidelines, e.g. pH) of a baseline dataset should be used. This value is then compared to the median value of the subject water (i.e. the dewatering water) (for further details see Sections 3.3.2.4 and 7.4.4 of ANZECC/ARMCANZ 2000). It is also recommended that TV are based on at least two years of monthly monitoring data.

## 2.4 Microinvertebrates

Microinvertebrate samples were collected from each site by gentle sweeping over an approximate 15 m distance with a 53 µm mesh pond net. Care was taken not to disturb the benthos (bottom sediments). Samples were preserved in 70% ethanol and sent to Dr Russ Shiel of Adelaide University for processing. Dr Shiel is a world authority on microfauna, with extensive experience in fauna survey and impact assessment across Australasia.

Microinvertebrate samples were processed by identifying the first 200-300 individuals encountered in an agitated sample decanted into a 125 $mm^2$ gridded plastic tray, with the tray then scanned for additional missed taxa also taken to species, and recorded as 'present'. Specimens were identified to the lowest taxon possible, i.e. species or morphotypes. Where specific names could not be assigned, vouchers were established. These vouchers are held by Dr Shiel at Adelaide University, Adelaide, Australia.

## 2.5 Hyporheic fauna

At each site, hyporheic sampling was conducted by digging a hole approximately 20 cm deep and 40 cm diameter in alluvial gravels in dry streambed adjacent to the waters edge. The hole was allowed to infiltrate with water, and then the water column was swept with a modified 53 µm mesh plankton net immediately after the hole had filled, and again after approx. 30 minutes, after other sampling had been conducted.

Samples were preserved in 70% ethanol and returned to the laboratory for processing. Any hyporheic fauna present was removed from samples by sorting under a low power dissecting microscope. Specimens were sent to appropriate taxonomic experts for identification and confirmation of their status as hyporheic fauna.

Chironomidae (non-biting midges) were sent to Dr Don Edward (The University of Western Australia), Amphipoda to Dr Terrie Finston (The University of Western Australia) for genetic analysis, Copepoda and Ostracoda to Dr Russ Shiel (Adelaide University).

All taxa recorded from hyporheic samples were classified using Boulton's (2001) categories;

- stygobite – obligate groundwater species, with special adaptations to survive such conditions
- permanent hyporheos stygophiles - epigean[4] species which can occur in both surface- and groundwaters, but is a permanent inhabitant of the hyporheos
- occasional hyporheos stygophiles – use the hyporheic zone seasonally or during early life history stages
- stygoxene (species that appear rarely and apparently at random in groundwater habitats, there by accident or seeking refuge during spates or drought; not specialised for groundwater habitat).

4 Epigean – living or occurring on or near the surface of the ground.

## 2.6 Macroinvertebrates

Macroinvertebrate sampling was conducted with a 250 µm mesh FBA pond net to selectively collect the macroinvertebrate fauna. In order to allow comparisons to be made between sites and systems, a standardised sampling approach was adopted, whereby riffle habitats were selectively sampled at each site. This standardises for habitat and avoids issues with greater diversity due to greater habitat diversity on any reach. Each sample was washed through a 250 µm sieve to remove fine sediment, leaf litter and other debris (Plate 1). Samples were then preserved in 70% ethanol.

**Plate 1.** Using the 250 µm sieve at MAR2-4 to remove fine sediment, leaf litter and other debris.

In the laboratory, macroinvertebrates were removed from samples by sorting under a low power dissecting microscope. Collected specimens were then identified to the lowest possible level (genus or species level) and enumerated to $\log_{10}$ scale abundance classes (*i.e.* 1 = 1 - 10 individuals, 2 = 11 - 100 individuals, 3 = 101-1000 individuals, 4 = >1000). In-house expertise was used to identify invertebrate taxa using available published keys and through reference to the established voucher collections held by WRM. External specialist taxonomic expertise was sub-contracted to assist with Chironomidae (non-biting midges) (Dr Don Edward, The University of Western Australia).

## 2.7 Fish

Fish fauna were sampled using a variety of methods in order to effectively collect as many individuals as possible in each reach. Fish sampling methods included electrofishing, seine nets, gill nets and dip nets.

Electrofishing was conducted with a Smith-Root Model 12-B battery powered backpack electrofisher (Plate 2). Electrofishing is an extremely useful and efficient sampling tool in rivers with clear, low salinity, slow flow water. All meso-habitats within a 40 metre reach were shocked with the intention of recovering as many species/ individuals as possible. Shocking was not continuous, but targeted areas of optimum habitat, whereby the operator would shock, move to a new habitat before shocking again, and so prevent fish being driven along in front of the electrical field.

Smaller species and juveniles were sampled by beach seine (10 m net, with a 2 m drop and 6 mm mesh) deployed in shallow areas where there was little vegetation or large woody debris. Generally, two seines were conducted at each site to maximise the number of individuals caught.

**Plate 2.** Electrofishing at MAR2-1.

**Principles of electrofishing**: a DC voltage is passed from a negative electrode (cathode) to a positive electrode (anode) whilst the electrodes are immersed in the water. If a fish is caught in the electrical field generated, a process referred to as 'Galvanotaxis' occurs. This is the involuntary movement of the fish towards the anode, until it reaches an electrical field strong enough to stun it ('galvanoarcosis'). The Smith-Root electrofisher uses a pulsed DC current, which is more effective than a flat DC signal because the body of the fish flexes with each pulse, accentuating the involuntary swimming action towards the anode. Once the current is switched-off, or the fish removed from the electrical field, the fish quickly recovers. Some damage to fish may occur if they are caught in a high electrical field close to the anode for an extended period. The operator of the electrofisher carries the anode (in the form of a modified pond net) whilst trailing the cathode (a stainless steel cable approximately 3.5 m long, referred to as a 'rat tail'). The Smith-Root backpack electrofisher has an effective range of approximately 3 m. Galvanotaxis can be used to 'pull' fish and crayfish out from under debris, logs, boulders and bank undercuts.

Gillnetting involved setting 10 m light-weight fine mesh gill nets with a 2 m drop (of varying stretched mesh net size 13mm and 19 mm) at each site. Nets were left for the duration of sampling at that particular site.

All fish were identified in the field, measured and then released alive. Fish nomenclature followed that of Allen *et al.* (2002). Measuring the fish captured provided information on the size structure, breeding and recruitment of the fish population.

## 2.8 Data analysis

### 2.8.1 Univariate analysis

Univariate statistics were performed using SPSS software (Version 17.0 for Windows). Independent samples were used as replicates and two-way analysis of variance (ANOVA) was applied to test for significant differences in species richness (of microinvertebrates and macroinvertebrates) between reaches, systems and/or seasons. Two-way ANOVA was also undertaken on some physico-chemical parameters, including water temperature, total nitrogen concentration, magnesium, sulphate, etc.

A Levene's test was used in the first instance to test for equality of variances. Tukeys post-hoc tests were utilised in the case of significant differences to locate reach differences.

### 2.8.2 Multivariate analysis

Multivariate analyses were performed using the PRIMER package v 6 (Plymouth Routines in Multivariate Ecological Research; Clarke and Gorley 2006) to investigate differences in aquatic fauna assemblages (macroinvertebrates and microinvertebrates) across reaches, seasons and sampling events, and relationships with physico-chemical characteristics from each site. The PRIMER package, developed for multivariate analysis of marine fauna

samples, has been applied extensively to analysis of freshwater invertebrate data. Analyses applied to the data included some or all of the following:

1. Describing pattern amongst the fauna assemblage data (macroinvertebrates and microinvertebrates) using ordination techniques based on Bray-Curtis similarity matrices (Bray and Curtis 1957). The clustering technique uses a hierarchical agglomerative method where samples of similar assemblages are grouped and the groups themselves form clusters at lower levels of similarity. A group average linkage was used to derive the resultant dendrogram. Ordination of data was by Multi-Dimensional Scaling (MDS) (Clarke and Warwick 2001). Ordinations were depicted as two-dimensional plots based on the site by site similarity matrices. For environmental data, the Euclidean Distance Measure was used to create resemblances, and the data was first transformed (where necessary) and normalised.
2. Cluster analysis to produce SIMPROF results which were overlain on the ordination where necessary.
3. For any groups found in (1) or selected *a priori* (*i.e.* reach and season), Two-way Crossed Analysis of Similarity (ANOSIM) – effectively an analogue of the univariate two-way ANOVA – was conducted to determine if reaches and sampling events were significantly different from one another. The ANOSIM test statistic reflects the observed differences *between* groups (*e.g.* between reaches) with the differences amongst replicates *within* the groups. The test is based upon rank similarities between samples in the underlying Bray-Curtis similarity matrix. The analysis presents the significance of the overall test (Significance level of sample statistic), and significance of each pairwise comparison (Significance level %), with degree of separation between groups (R-statistic), 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. A significance level <5% = significant effect/difference.
4. The SIMPER routine was used to examine which taxa were contributing to the differences of any groups that were found to be different according to the ANOSIM procedure or otherwise found to be separated in cluster or ordination analyses.
5. The relationship between the environmental and biotic data was assessed in two ways:
    - The BIOENV routine was used to calculate the minimum suite of parameters that explain the greatest percent of variation (i.e. the parameters which most strongly influence the species ordination)
    - For visualisation, the numeric value of key environmental data (as determined by BIOENV) were superimposed onto MDS ordinations, as circles of differing sizes – so-called 'bubble plots'.
6. Differences in multivariate dispersions among groups (i.e. seasons) was investigated using PERMDISP (Anderson 2006) in PERMANOVA (Anderson 2005). PERMDISP can be undertaken on the basis of any distance measure (i.e. Euclidean Distance) or similarity (i.e. Bray-Curtis) measure of choice. The test can be considered in two steps, 1) calculation of the distances from observations to their centroids, and 2) comparison of the average of these distances among groups, using ANOVA (Anderson 2006). A p-value is obtained using permutation of the observations. The approach is a multivariate analogue to Levene's Test (Levene 1960).

# 3 RESULTS AND DISCUSSION

## 3.1 Water quality

As mentioned previously, water quality data were compared against ANZECC/ARMCANZ (2000) water quality guidelines. The default trigger values for physical and chemical stressors applicable to tropical northern Australia are provided in Appendix 2.

### 3.1.1 Physico-chemistry

**Dissolved oxygen (DO)**

Dissolved oxygen levels in the current study ranged from 56% (MAR1-1) to 180% (MAR2-4) during October 2008, and 44% (MAR1-3) to 133% (MAR2-3) in May 2009 (Appendix 3). During the dry season of Oct-08, all but two sites (MAR2-2 & MAR2-6) recorded DO levels outside the recommended ANZECC/ARMCANZ (2000) guidelines for the protection of lowland river systems in the tropical north of Australia (Appendices 2 and 3). Low DO can impact the aquatic ecosystem through a slowing in growth rates of aquatic fauna, reproductive difficulties, stress, increased susceptibility to disease, and in some cases increased mortality. Low DO also promotes the accelerated release of nutrients and heavy metals from sediments, which can have a toxic effect on aquatic flora and fauna. In most cases, the 'low' DO levels (<85%) recorded during the current study were unlikely to be low enough to have an ecological impact. DO concentrations less the ~20% typically represent environmental conditions of 'stress' to resident aquatic fauna, particularly fish with high metabolic demand for oxygen. DO values as low as this were not recorded during the current study. However, oxygen needs of aquatic biota differ between species and between life history stages. The 'high' DO values recorded during the current study may be cause for concern. Super-saturation (DO>100%) occurs when net photosynthesis exceeds total oxygen consumption and is common in areas of high macrophyte and algal growth. Such sites would experience oxygen stress overnight, as respiration by plants, algae, bacteria and other aquatic fauna deplete DO. Super-saturated DO can also lead to fish bubble disease. One site in particular, MAR2-4 in October 2008, recorded exceptionally high DO levels (180%). Super-saturation can occur in systems with good light penetration and nutrient inputs which lead to excessive algal and macrophyte growth.

**pH**

Most river systems in Western Australia (including those in the Pilbara *e.g* Robe, Harding and lower Fortescue at Millstream) have a natural pH range circum-neutral. In the absence of baseline data, ANZECC/ARMCANZ (2000) guidelines recommend average pH should be between 6 and 8 in lowland rivers of tropical northern Australia. Generally, the pH values recorded during the current study were within these guidelines and were circum-neutral to slightly basic. During the dry season, pH ranged from 7.7 (MAR1-6) to 8.3 (MAR2-4 & MAR2-6), and during the wet from 7.6 (MAR1-3) to 8.6 (MAR2-3). The slightly basic pH recorded from Marillana Creek is not likely to cause adverse impacts to aquatic biota. WRM (2009b) reported similarly basic pH from Marillana Creek previously, while Johnson and Wright (2003), Streamtec (2004), and WRM (2009a, b, 2010) recorded slightly basic pH from other systems in the East Pilbara, including Weeli Wolli Creek, Coondiner Creek, Kalgan Creek and the Fortescue River (WRM 2009b).

**Electrical conductivity (Ec)**

All sites were fresh as classified by the DoE (2003)[5] (Appendix 3). Conductivity ranged from 905 µS/cm (MAR2-4) to 1040 µS/cm (MAR1-6) during the dry season of 2008, and from 939 µS/cm (MAR1-1, MAR2-5 & MAR2-6) to 1010 µS/cm (MAR1-6) in the wet season (Appendix 3). Whilst all conductivity values were above ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems, all sites were considered fresh and their conductivity is likely to be of little ecological consequence. There is a general acceptance that when conductivity is less than 1500 µS/cm, freshwater ecosystems experience little ecological stress (Hart *et al.* 1991, Horrigan *et al.* 2005).

**Ions**

Alkalinity refers to the capacity of water to neutralise acid and is an expression of buffering capacity. It essentially relates to the amount of bases[6] in water which buffer against sudden changes in pH (McDonald and Wood 1993, Riethmuller *et al.* 2001, Lawson 2002). Bases are able to buffer water by absorbing hydrogen ions when the water is acid and releasing them when the water becomes basic (Lawson 2002). Therefore, alkalinity is important for aquatic fauna as it can protect against rapid pH changes (Riethmuller *et al.* 2001). Alkalinity of less than 20 mg/L is considered low; waters would be poorly buffered and the removal of carbon dioxide during photosynthesis would result in rapidly rising pH (Sawyer and McCarty 1978, Romaire 1985, Lawson 2002). If alkalinity is naturally low (< 20 mg/L) there can be no greater than a 25% reduction in alkalinity. In the current study, alkalinity was high at all sites along the length of Marillana Creek (Appendix 3). Alkalinity ranged from 255 mg/L at MAR1-2 to 315 mg/L at MAR2-1 during the dry, and 255 mg/L (MAR1-1) to 300 mg/L (MAR2-1 & MAR2-2) in the wet (Appendix 3). This suggests that the buffering capacity of waters along Marillana Creek is high.

The ionic composition of waters is determined by rain-borne salts (*i.e.* wind-blown dusts) and geology (*e.g*. weathering of soils) of the catchment (DeDeckker and Williams 1986). However, the composition over the warmer months, particularly in shallow reaches, will be altered by evapo-concentration and precipitation of less soluble salts, such as calcium carbonate and magnesium sulphate (Hart and McKelvie 1986). The ionic composition of inland waters in Australia is known to vary widely, but the proportions of calcium, magnesium and bicarbonate are often enriched compared to seawater (DeDeckker and Williams 1986).

The composition of major ions along Marillana Creek was typically dominated by sodium and hydrogen bicarbonate ($Na^+ > Ca^{2+} > Mg^{2+} > K^+$: $HCO_3^- > Cl^- > SO_4^{2-} > CO_3^-$). This did not change between seasons. The dominance of major ions at Marillana Creek was the same as that reported from Weeli Wolli Creek downstream of the confluence with Marillana Creek (i.e. WW Reach Four; WRM 2009a, 2010).

[5] Fresh defined as < 1500 µS/cm, Brackish = 1500 – 4500 µS/cm, Saline = 4500 – 50,000 µS/cm, Hypersaline > 50,000 µS/cm (DoE 2003). Classifications were presented as TDS (mg/L) in DoE (2003) so a conversion factor of 0.68 was used to convert to conductivity µS/cm as recommended by ANZECC/ARMCANZ (2000).

[6] Bases are ions which release hydroxyl ions (OH-) when dissolved in water. Generally these bases are principally bicarbonate and carbonate ions (Lawson 2002).

**Nutrients**

Total nitrogen levels along Marillana Creek varied between reach and season, ranging from 0.05 mg/L at MAR1-5 in the dry, to 1.8 mg/L at MAR2-1 also in the dry season (Figure 6 and Appendix 3). The ANZECC/ ARMCANZ (2000) trigger value[7] was exceeded at two sites in the dry season (MAR2-1 & MAR2-2), and six sites in the wet (MAR1-1, MAR1-2, MAR2-1, MAR2-2, MAR2-3 & MAR2-4) (Figure 6 and Appendix 3). Total phosphorus ranged from 0.005 mg/L (at all sites except MAR1-3) in the dry, to 0.04 mg/L (MAR1-1 & MAR2-1) during the wet season (Figure 6 and Appendix 3). The ANZECC/ARMCANZ (2000) trigger value[8] was exceeded at all sites during the wet season (Figure 6 and Appendix 3).

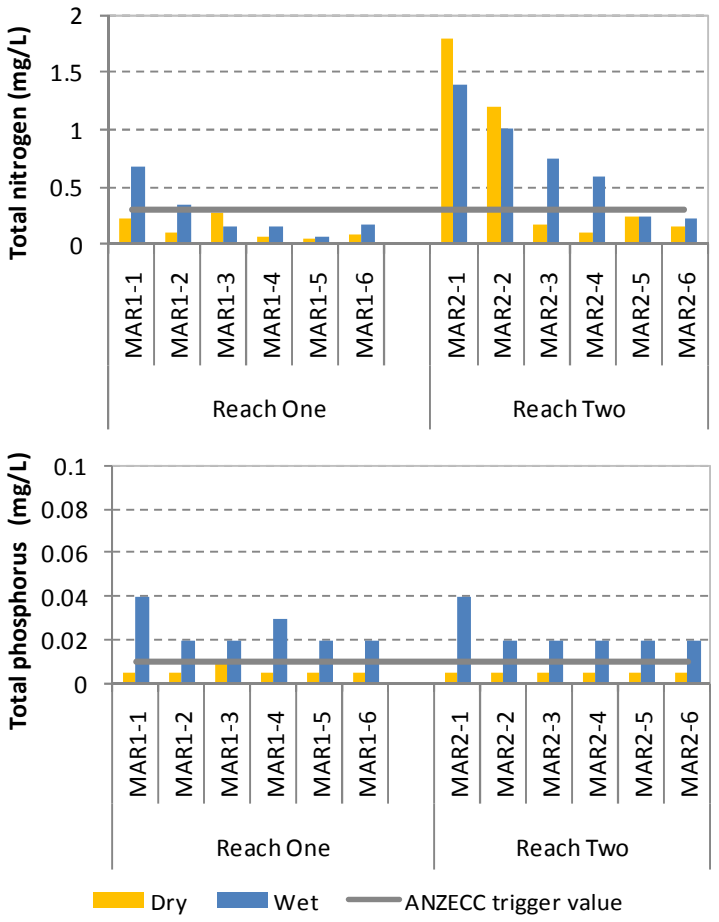



**Figure 6.** Nutrient levels (mg/L) recorded from Marillana Creek during the wet (Oct-08) and dry season (May-09), showing total nitrogen (top) and total phosphorus (bottom). The ANZECC/ARMCANZ (2000) trigger value is indicated by the grey line.

Total nitrogen levels recorded from Marillana Creek were significantly different between reach (Two-way ANOVA; df = 1, p= 0.01) but not season (Two-way ANOVA; df = 1, p = 0.13; Table 4). Significantly higher total nitrogen levels were recorded from Reach Two when compared to Reach One (Figure 7 and Table 4). The cause of the elevated total nitrogen levels from the downstream Marillana reach is unknown, but may be coming from any number of potential sources, including current pastoral activities and cattle stocking, past cattle use and leaching from soils, and/or some influence from Yandi operations such as elevated total nitrogen in groundwater discharge water, contamination of groundwater from ammonium nitrate storage or septic systems, and/or elevated total nitrogen in mine process water discharged into the creek. Although elevated nitrogen levels are not uncommon in creeks of this area due to pastoral activities and cattle stocking, the significantly higher levels recorded from Marillana Reach Two do suggest another source may be present, as cattle were seen along the length of Marillana Creek

[7] The ANZECC/ARMCANZ (2000) guidelines recommend that total nitrogen should not exceed 0.3 mg/L in tropical northern Australian lowland rivers.

[8] The ANZECC/ARMCANZ (2000) guidelines recommend that total phosphorus should not exceed 0.01 mg/L in tropical northern Australian lowland rivers.

during sampling. Elevated total nitrogen and total phosphorus levels have been recorded from mine process water which is discharged from the levee bank discharge point upstream of Marillana Reach Two (Table 5 & see Figure 3 for the location of the discharge point). However, potential sources for the increased total nitrogen from MAR-Two need to be investigated further before any conclusions can be drawn.

**Table 4.** Two-way ANOVA of nutrient data by reach and season.

| *Type* | *Source* | *df* | *F-value* | *p-value* |
|---|---|---|---|---|
| **Log total nitrogen** | **Reach** | 1 | 8.95 | 0.007 |
| | **Season** | 1 | 2.54 | 0.127 |
| | **Reach*Season** | 1 | 0.01 | 0.904 |
| | **Total** | 23 | | |
| **Log total phosphorus** | **Reach** | 1 | 0.81 | 0.379 |
| | **Season** | 1 | 210.60 | 0.000 |
| | **Reach*Season** | 1 | 0.05 | 0.816 |
| | **Total** | 23 | | |

**Table 5.** Total nitrogen (mg/L) and total phosphorus (mg/L) concentrations in mine process water recorded from the levee bank discharge point at RTIOs Yandi. Data provided by RTIO Yandi. Shading indicates the value exceeds ANZECC/ARMCANZ (2000) guidelines.

| *Year* | *Sample date* | *Total N (mg/L)* | *Total P (mg/L)* |
|---|---|---|---|
| **2009** | 27/01/2009 | 1.7 | 1.7 |
| | 25/02/2009 | 2.9 | 1.6 |
| | 24/03/2009 | 15 | 9.2 |
| | 15/04/2009 | 20 | 5 |
| | 26/05/2009 | 17 | 20 |
| | 17/06/2009 | 26 | 13 |
| | 28/07/2009 | 19 | 23 |
| | 27/08/2009 | 57 | 0.83 |
| | 16/09/2009 | 6.9 | 10 |
| | 28/10/2009 | 12 | 8.9 |
| | 30/11/2009 | 3.1 | 7.3 |
| **2010** | 19/01/2010 | 2.5 | 5.9 |
| | 15/02/2010 | 3.1 | 7.4 |

Total phosphorus levels of Marillana Creek were significantly different between season (Two-way ANOVA; df = 1, p= 0.00), but not reach (Two-way ANOVA; df = 1, p = 0.38; Table 4). In this case, significantly greater phosphorus levels were recorded during the wet season (Figure 7 and Table 4).

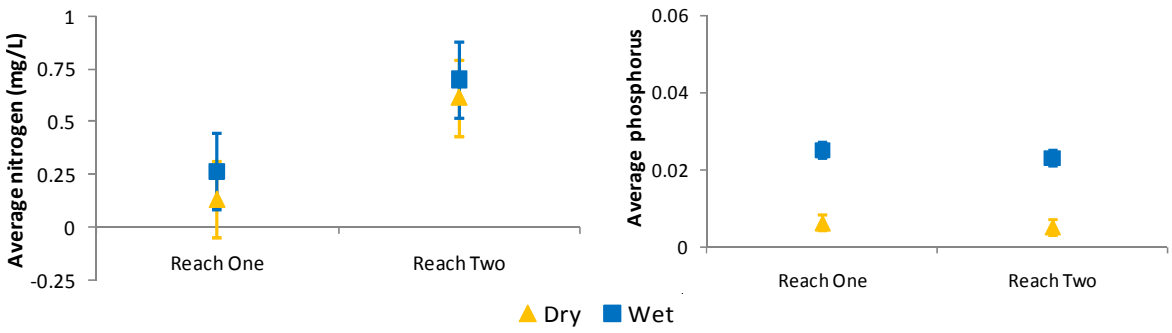



**Figure 7.** Average nutrient concentration (±se) per reach and season, showing average total nitrogen (left) and average total phosphorus (right).

### 3.1.2 Patterns in water quality data

Patterns were evident within the water quality ordination, with samples forming groups according to reach and season (Figure 8). Water quality was found to be significantly different between reach (Two-way crossed ANOSIM; sample statistic = 0.63; significance of sample statistic p = 0.0001) and season (Two-way crossed ANOSIM; sample statistic = 0.73; significance of sample statistic p = 0.0001). Samples within each grouping, however, seemed to be highly variable (Figure 8). Dry season samples from Marillana Reach One formed the tightest group in the ordination (Figure 8), suggesting that samples within this group were most similar to each other, than any other group.

Water quality variables influencing the separation of samples amongst seasons were total phosphorus and zinc, with total phosphorus being higher in the wet season and zinc being lower in the wet season (Figure 9). The concentration of total nitrogen influenced the separation of samples amongst reaches, and was higher from Reach Two (Figure 9).

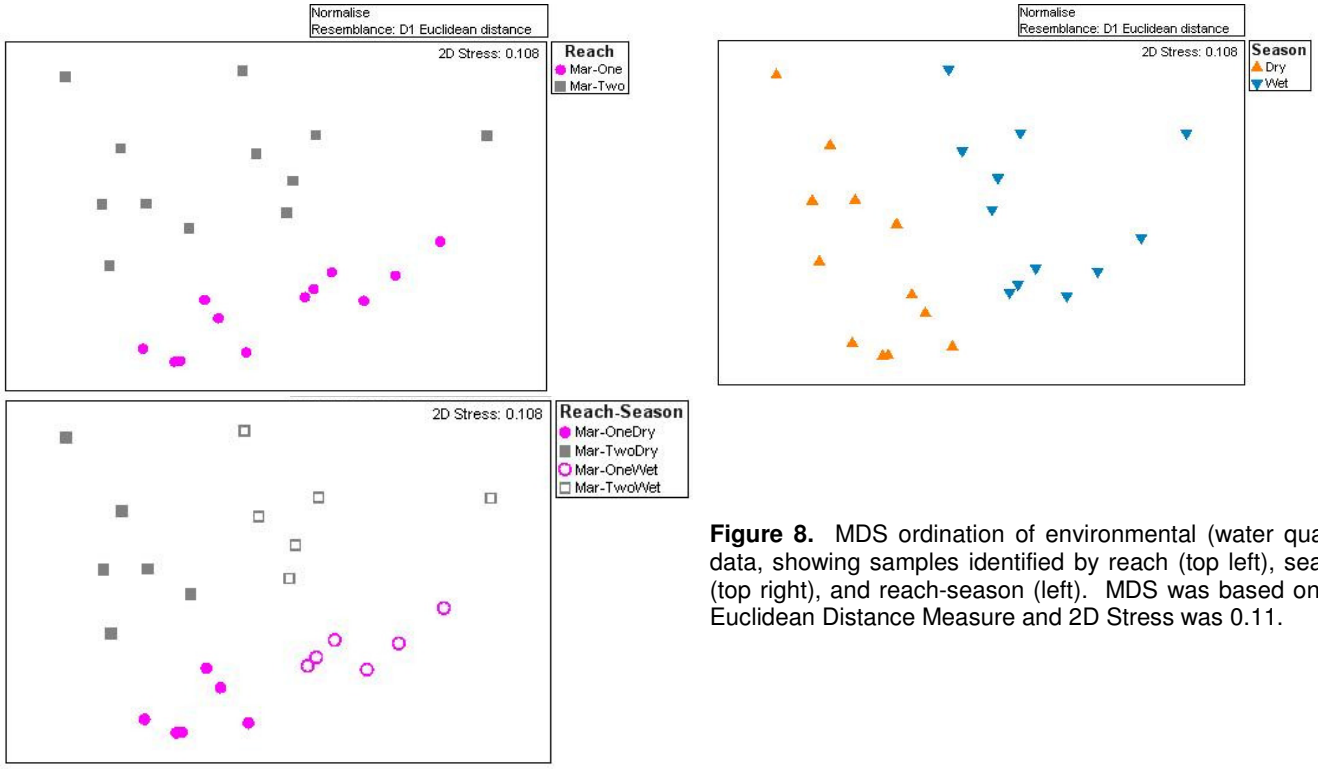



**Figure 8.** MDS ordination of environmental (water quality) data, showing samples identified by reach (top left), season (top right), and reach-season (left). MDS was based on the Euclidean Distance Measure and 2D Stress was 0.11.

### 3.1.3 Comparisons with Weeli Wolli water quality data

Using all water quality data collected from Weeli Wolli and Marillana Creek in October 2008 and May 2009, patterns were evident in ordination space (Figure 10). Water quality was significantly separate between systems (i.e. Weeli Wolli compared with Marillana Creek; One-way ANOSIM; sample statistic = 0.57, significance of sample statistic p = 0.0001).

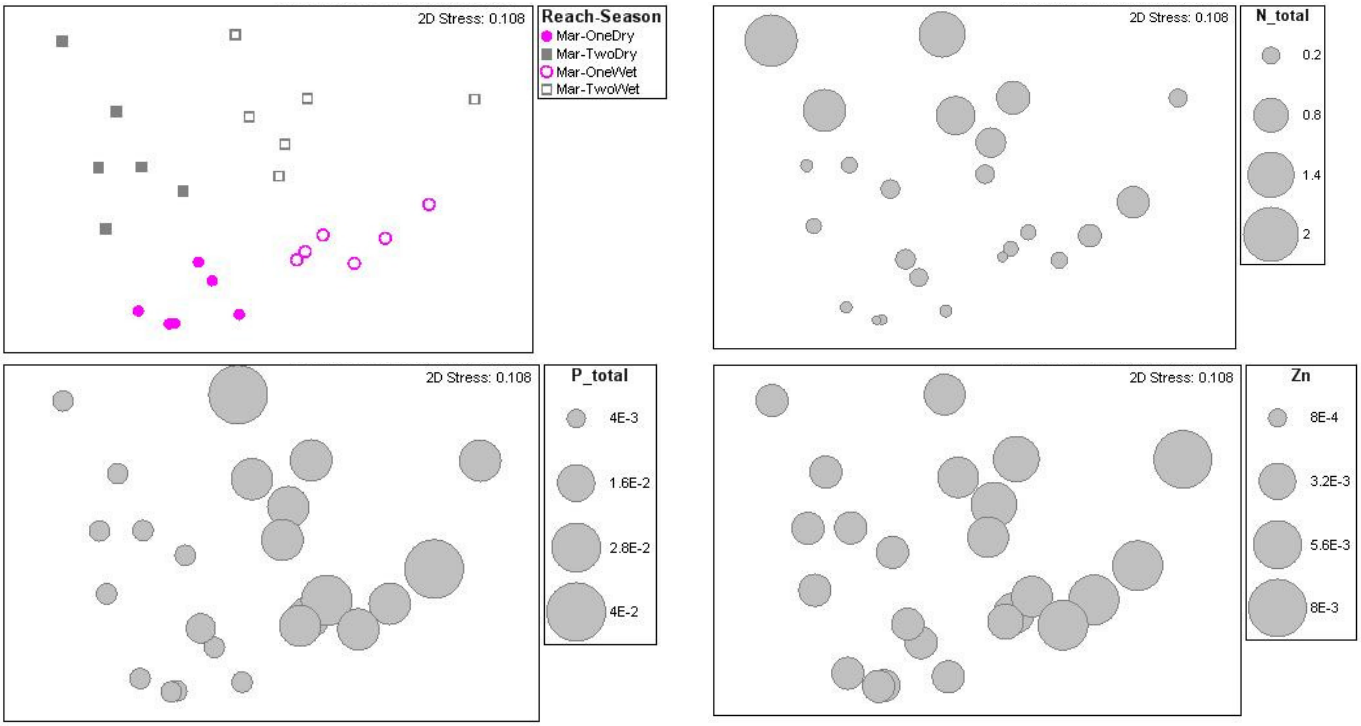



**Figure 9.** Bubble plots showing water quality parameters which contributed to the separation between reaches (top right; total nitrogen), and seasons (bottom; total phosphorus and zinc).

In addition, water quality was significantly different amongst season (Two-way crossed ANOSIM; sample statistic = 0.74, significance of sample statistic p = 0.0001) and reach (Figure 10 & Table 6; Two-way crossed ANOSIM; sample statistic = 0.79, significance of sample statistic p = 0.0001). All reaches were in fact significantly separate from one another, but a longitudinal pattern was also evident, with samples from Weeli Wolli Reach One being most similar to Reach Two (R=0.69) and least similar to Weeli Wolli Reach Four (R=0.92); and samples from Weeli Wolli Reach Four being most similar to Marillana Reach Two (R=0.68), and least similar to Marillana Reach One (R=0.91; Table 6). The two most similar reaches were those along Marillana Creek; MAR One and MAR Two (R=0.42; Table 6).

**Table 6.** Pair-wise ANOSIM results of water quality amongst reach, showing R-values (sample statistic)[9], * = groups significantly different.

| | *WW One* | *WW Two* | *WW Three* | *WW Four* | *MAR One* |
|---|---|---|---|---|---|
| **WW One** | | | | | |
| **WW Two** | 0.69* | | | | |
| **WW Three** | 0.87* | 0.37* | | | |
| **WW Four** | 0.92* | 0.97* | 0.86* | | |
| **MAR One** | 0.99* | 1.00* | 0.99* | 0.91* | |
| **MAR Two** | 0.83* | 0.87* | 0.78* | 0.68* | 0.42* |

[9] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barley separable.

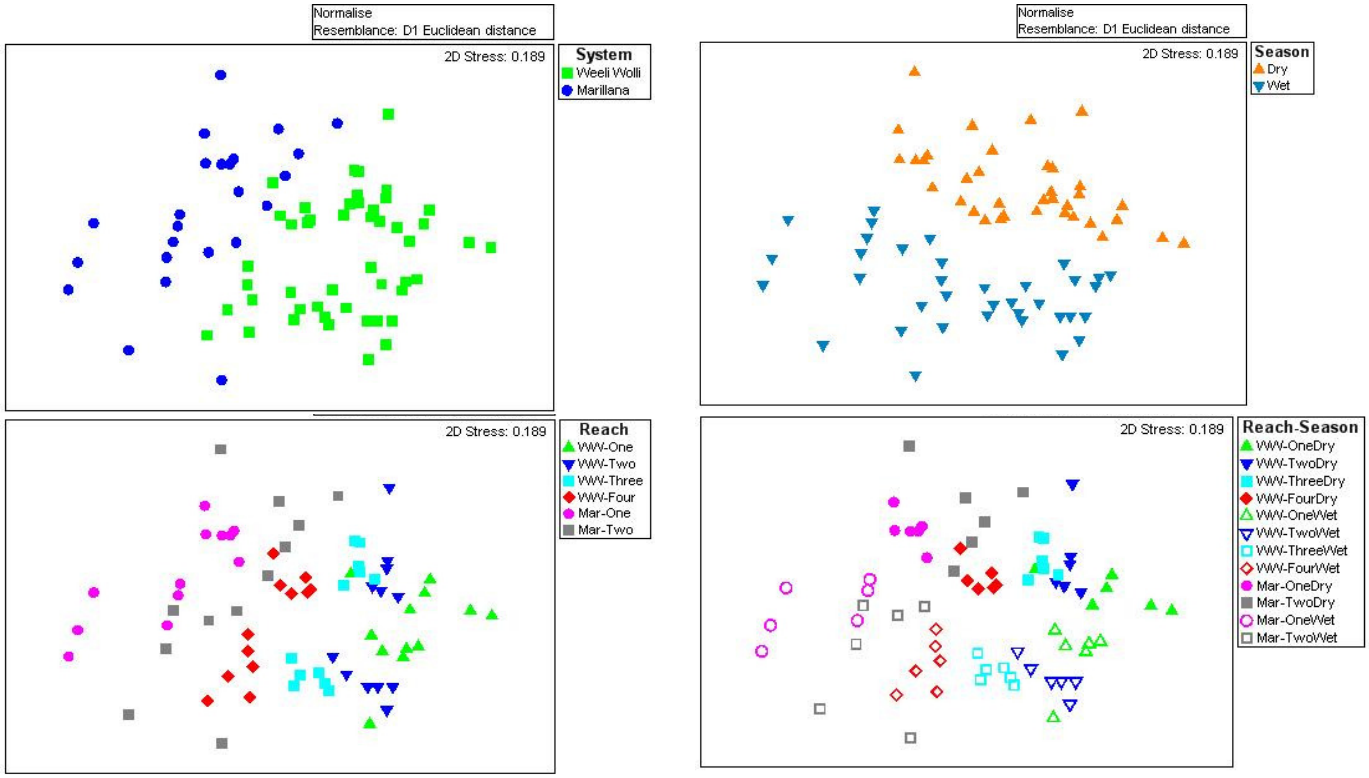



**Figure 10.** MDS ordination of environmental (water quality) data from Weeli Wolli Creek and Marillana Creek, showing samples identified by system (top left), season (top right), reach (bottom left), and reach-season (bottom right). MDS was based on the Euclidean Distance Measure and 2D Stress was 0.19.

In order to see more clearly the separations amongst reaches, individual ordinations were undertaken for each season and significant SIMPROF clusters overlain on the MDS (Figures 11 & 12). The dry season plot clearly shows Marillana Creek samples from both reaches grouped with Weeli Wolli Reach Four samples (Figure 11). This suggests that during the dry season, the water quality of Marillana Creek was similar to that recorded from the downstream Weeli Wolli reach (WW Reach Four). It appears that water quality of the downstream reach of Weeli Wolli Creek is influenced by Marillana Creek.

Weeli Wolli Reaches Two and Three formed their own group, and Weeli Wolli Reach One also formed a distinct group (Figure 11). One site from Marillana Creek, MAR2-6, separated from other Marillana and WW-Four sites based on its higher concentration of ammonia (NH3; Figure 11) Other water quality variables influencing the ordination were barium[10], which was highest from Marillana Creek and WW-Four, and sodium, which was lower from WW-One (Figure 11).

[10] No trigger value exists within the ANZECC/ARMCANZ (2000) guidelines for barium, so it is not known whether the higher values reported from Marillana Creek and Weeli Wolli Reach Four are of ecological concern.

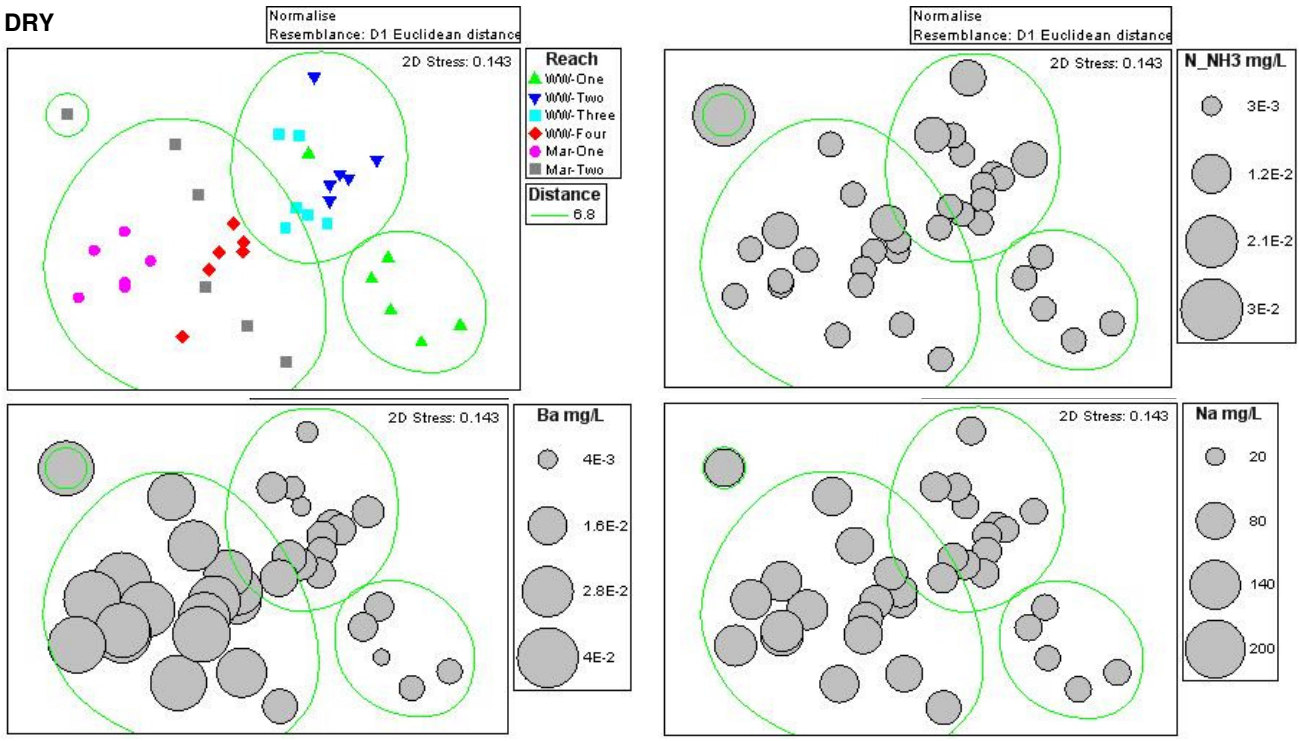



**Figure 11.** Dry season MDS ordination of environmental (water quality) data from Weeli Wolli Creek and Marillana Creek (top left). Samples are identified by reach and are grouped within significant SIMPROF clusters at a Euclidean Distance of 6.8. The MDS was based on the Euclidean Distance Measure and 2D Stress was 0.14.

This pattern was slightly different in the wet season, with WW-Four forming its own distinct group, separate from Marillana Creek sites (Figure 12). Once again, WW-One formed its own group, and WW-Two and WW-Three formed another separate group. In this case, all sites within Marillana Creek were found to have similar water quality, with the exception of MAR2-1 (Figure 12).

Water quality variables found to contribute to the patterns in the ordination included total nitrogen, barium, copper, and manganese (Figure 12). The concentration of total nitrogen was highest from MAR2-1, and influenced the separation of this site from all others, including other Marillana Creek sites (Figure 12). As was recorded during the dry season, Barium was again higher from Marillana Creek and WW-Four sites. Higher copper concentrations were recorded from Weeli Wolli Reach One, and higher manganese from WW-Two and WW-Three (Figure 12). However, the concentrations of both these dissolved metals were still below ANZECC/ARMCANZ (2000) guidelines for the protection of 99% of species, and are therefore not of ecological concern.

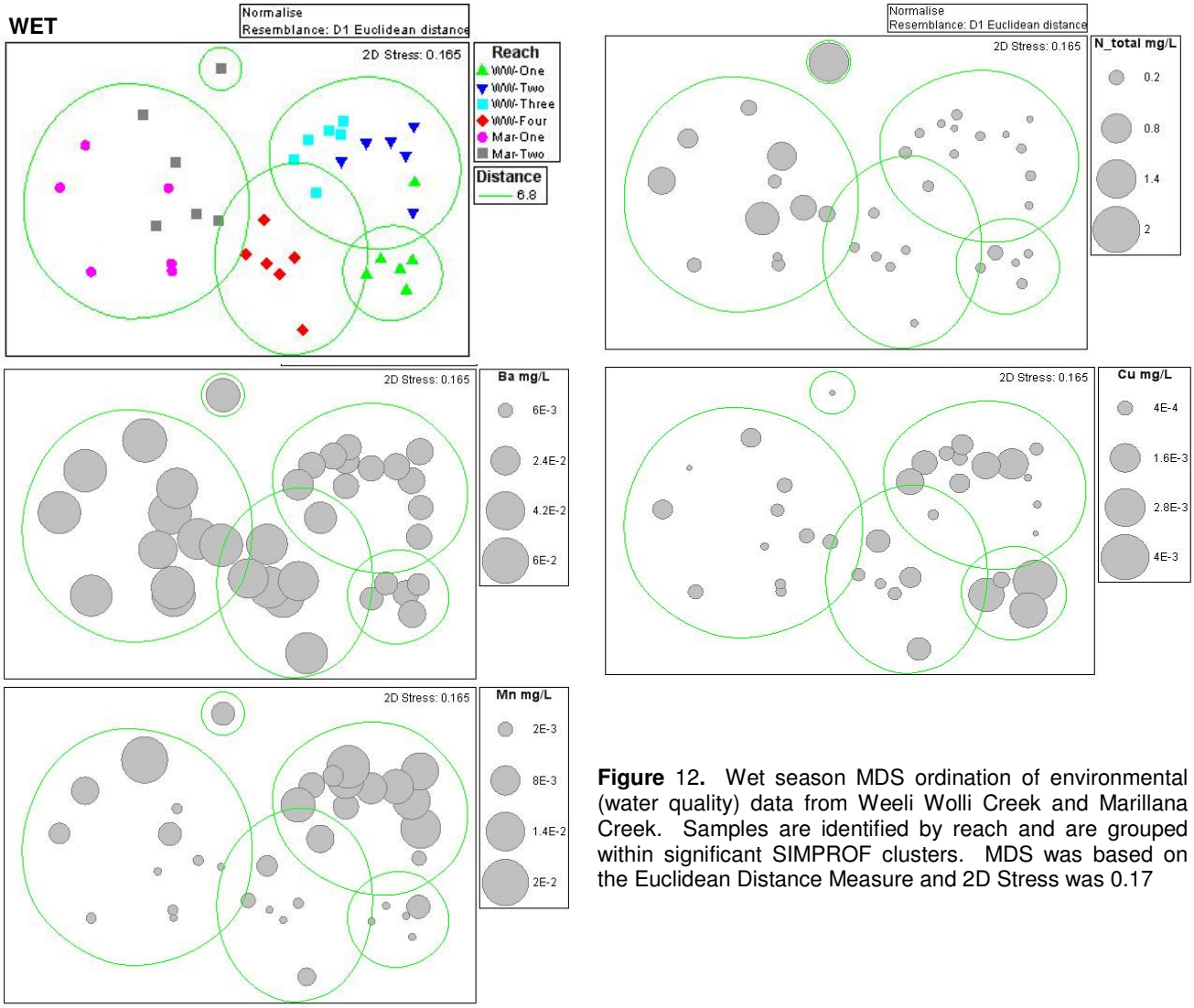



**Figure** 12**.** Wet season MDS ordination of environmental (water quality) data from Weeli Wolli Creek and Marillana Creek. Samples are identified by reach and are grouped within significant SIMPROF clusters. MDS was based on the Euclidean Distance Measure and 2D Stress was 0.17

## 3.2 Microinvertebrates

### 3.2.1 Taxonomic composition and species richness

A total of 59 taxa of microinvertebrates were recorded from Marillana Creek during the current study, with 45 being recorded in October 2008, and 41 taxa in May 2009 (Appendix 4). The microinvertebrate fauna comprised Protista (Ciliophora & Rhizopoda), Rotifera (Bdelloidea & Monogonata), Cladocera (water fleas), Copepoda (Cyclopoida) and Ostracoda (seed shrimp).

The microinvertebrate fauna were typical of tropical systems reported elsewhere (e.g. Koste and Shiel 1983, Tait *et al.* 1984, Smirnov and De Meester 1996, Segers *et al*. 2004). For example, Brachionidae within the Rotifera were poorly represented. This family tends to dominate temperate rotifer plankton, but is overshadowed by Lecanidae in tropical waters, as was the case here. Within the Cladocera fauna, daphniids tend to predominate in temperate waters, with low representation in the tropics. No daphniids were recorded from Marillana Creek during the current study, however, one species has been recorded from Flat Rocks upstream of the Yandi mine on Marillana Creek during the Regional Survey (Jess Delaney, WRM, unpub. data). In tropical systems throughout the world, daphniids tend to be replaced by sidids, moinids, and in the case of heavily vegetated or shallow waters, by chydorids, as seen here (see Appendix 4).

Microinvertebrate taxa richness varied greatly between reach and season (Figure 11). During the dry season of October 2008, the greatest number of microinvertebrate taxa was recorded from MAR2-3 (19 taxa), and the least from MAR1-6 (5 taxa). During the wet, the greatest number of taxa was recorded from MAR1-3 (20 taxa). No microinvertebrate taxa were collected from MAR1-6 during the wet season (Figure 13 and Appendix 4). More microinvertebrate taxa were recorded during the dry season (Figures 13 and 14).

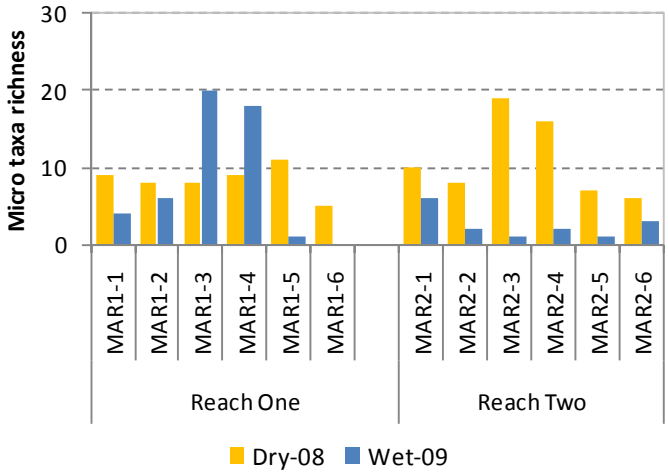



**Figure 13**. Microinvertebrate taxa richness recorded from each site along Marillana Creek during both seasons.

Using microinvertebrate data from Weeli Wolli Creek in the analysis, there was no significant difference in the average number of taxa between reach (Two-way ANOVA; df = 5, p= 0.14; Figure 14 and Table 7). There was, however, a significant difference in microinvertebrate taxa richness between season (Two-way ANOVA; df = 1, p= 0.02; Table 7), with a greater number of taxa being recorded during the dry (Figure 14). There was no interaction between reach and season (Table 7). Microinvertebrate taxa richness was highly variable within reach and within season as seen by the large standard error bars, particularly during the dry season (see Figure 14).

**Table 7.** Two-way ANOVA results for macroinvertebrate taxa richness by reach and season (including Weeli Wolli data), showing degrees of freedom, f-value and p-value.

| *Source* | *df* | *F* | p |
|---|---|---|---|
| **Reach** | 5 | 1.76 | 0.14 |
| **Season** | 1 | 6.31 | 0.02 |
| **Reach*Season** | 5 | 1.76 | 0.13 |
| **Total** | 69 | | |

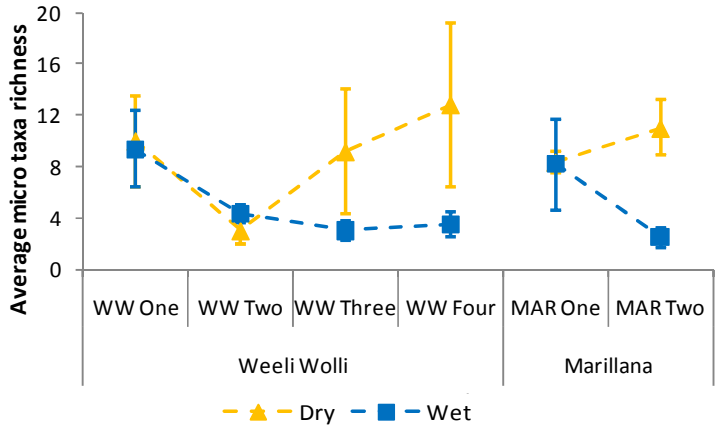
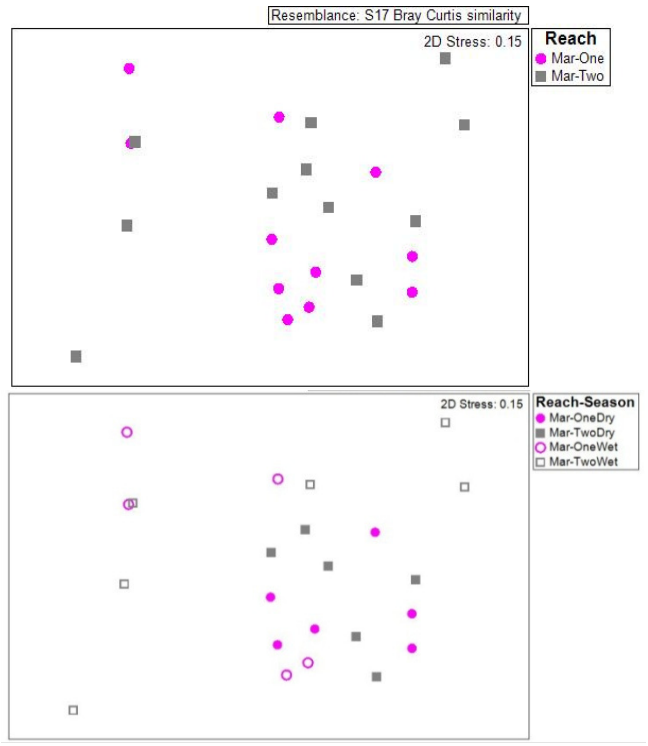



**Figure 14.** Average microinvertebrate taxa richness (±se) from all reaches (including those along Weeli Wolli Creek) showing data for both the dry (October 2008) and wet season (May 2009).

### 3.2.2 Patterns in microinvertebrate assemblage structure

No microinvertebrates were recorded from MAR1-6 during the wet season and this had an over-riding effect on the microinvertebrate abundance ordination for Marillana Creek. This site was therefore removed from further multivariate analysis.

No patterns were evident within the microinvertebrate abundance ordination (Figure 15). There was no significant difference in the microinvertebrate assemblages between reach (Two-way crossed ANOSIM; sample statistic = 0.025; significance of sample statistic p = 0.361). While there did appear to be some separation of samples between season (Figure 15), groups were found to be barely separable (Two-way crossed ANOSIM; sample statistic = 0.34; significance of sample statistic p = 0.0004). However, dry season samples did appear to be less variable than wet season samples (Figure 15). The variability within each season, as measured by the deviation of samples from their centroid (i.e. centre of each sampling group in ordination space), was significantly lower during the dry season (PERMDISP; f = 13.52, df1 = 1, df2 = 21; p = 0.003; Figure 16).



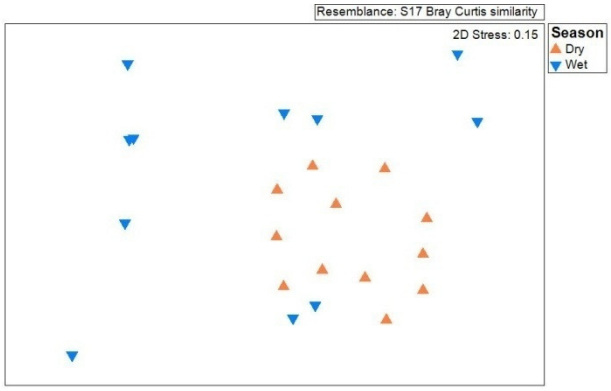




**Figure 15.** MDS ordination of microinvertebrate $\log_{10}$ abundance data with MAR1-6 removed from analyses, showing samples identified by reach (top left), season (top right), and reach-season (left). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.15.

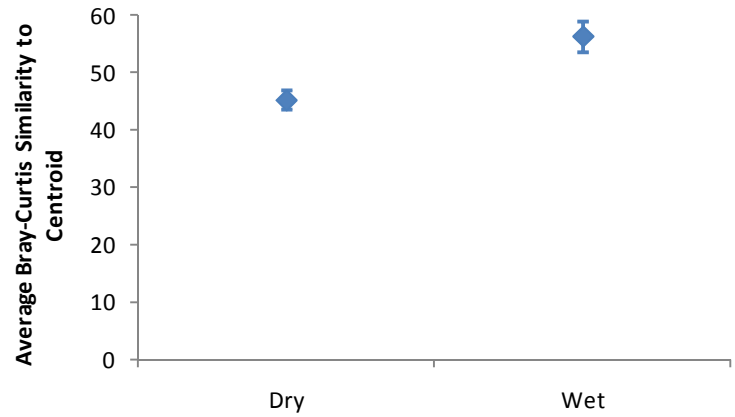



**Figure 16.** Average Bray-Curtis similarities to centroids (±se) for each season, using Marillana Creek microinvertebrate abundance data.

### 3.2.3 Comparison of microinvertebrate assemblages with Weeli Wolli Creek

The multivariate ordination incorporating all microinvertebrate abundance data recorded from Weeli Wolli and Marillana creeks during October 2008 and May 2009, showed no clear patterns (Figure 17). There was no significant separation between system (One-way ANOSIM; sample statistic = -0.07; significance level of sample statistic p = 0.969; Figure 17), indicating that the microinvertebrate assemblages of Marillana Creek were generally similar to those from Weeli Wolli Creek in October 2008 and May 2009. Season groups were also found to be barely separable (Two-way Crossed ANOSIM; sample statistic = 0.25; significance level of sample statistic p = 0.0001; Figure 17). Overall, differences in microinvertebrate assemblages between reach were also barely separable (Two-way

Crossed ANOSIM; sample statistic = 0.18; significance level of sample statistic p = 0.0001). The greatest similarity (i.e. lowest R-value and no significant difference) was between Marillana reaches One and Two (Table 8). The greatest separation of microinvertebrate assemblages was between Weeli Wolli Reach One and Marillana Reach Two (Table 8).

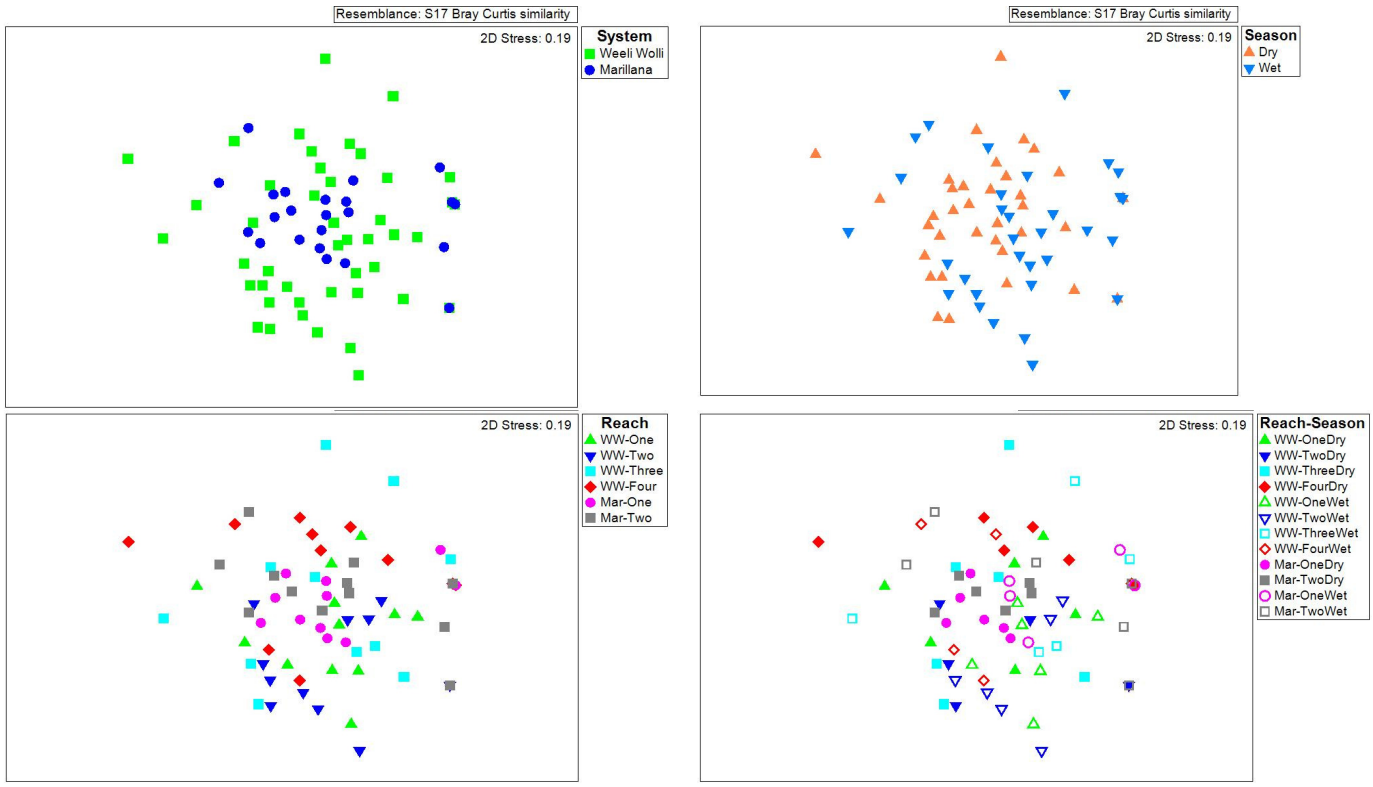



**Figure 17.** MDS ordination of microinvertebrate log10 abundance data from Weeli Wolli Creek and Marillana Creek, showing samples identified by system (top left), season (top right), reach (bottom left), and reach-season (bottom right). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.19.

**Table 8.** Pair-wise ANOSIM results of microinvertebrate $log_{10}$ abundance data amongst reach, showing R-values (sample statistic)[11], * = groups significantly different.

| | *WW One* | *WW Two* | *WW Three* | *WW Four* | *MAR One* |
|---|---|---|---|---|---|
| **WW One** | | | | | |
| **WW Two** | 0.16 | | | | |
| **WW Three** | 0.20* | 0.14 | | | |
| **WW Four** | 0.22* | 0.19* | 0.15* | | |
| **MAR One** | 0.23* | 0.23* | 0.07 | 0.20* | |
| **MAR Two** | 0.37* | 0.32* | 0.11 | 0.18* | 0.02 |

[11] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barley separable.

## 3.3 Hyporheic fauna

### 3.3.1 Taxonomic composition and species richness

A total of 22 taxa were recorded from hyporheic samples collected along Marillana Creek in October 2008, and 58 taxa were recorded in May 2009 (Appendix 5). Of the taxa recorded in the dry season of October 2008, the vast majority were classified as stygoxene (72%) and do not have specialised adaptations for groundwater habitats. However, 5% of the taxa were classified as occasional hyporheos stygophiles, 5% were stygobites[12], and 9% were possible hyporheic taxa. There were no taxa classified as permanent hyporheic stygophiles, and 9% were unknown due to insufficient taxonomy and/or information (Figure 18). Of the taxa recorded during the wet season, most were stygoxene taxa (81%), with 9% being considered hyporheos fauna[13] (5% occasional hyporheos stygophiles, 2% stygobites, and 2% possible hyporheic taxa) (Figure 18). Classifications followed those by Boulton (2001), however, this type of analysis should be treated with some caution as results are likely affected by available information on life history, taxonomic resolution, and interpretation of classification categories.

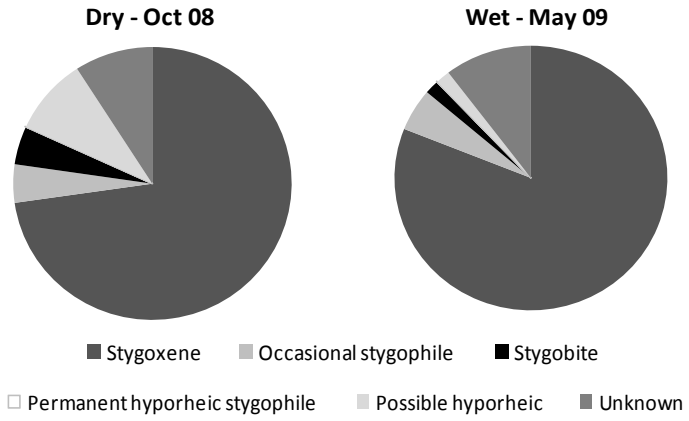



**Figure 18.** Proportion of species from each hyporheic classification category, showing data collected in Oct-08 (left) and May-09 (right).

The results from this study are similar to those reported previously in the Pilbara (Halse *et al.* 2002, WRM 2009a, WRM 2010), in that <20% of taxa collected in hyporheic habitats were entirely dependent on groundwater for their persistence as a species. Halse *et al*. (2002) suggested that it is not surprising that the hyporheos is dominated by species with some affinity for surface water, because the hyporheos is an "ecotone between productive, species-rich surface water systems and nutrient-poor groundwater systems with lower number of species per sampling unit".

Hyporheos fauna were recorded from both reaches of Marillana Creek during both seasons (Figure 19). The greatest number of occurrences of hyporheos taxa was recorded from Reach Two in the wet season of May 2009, and the least from Reach One during the dry of October 2008 (Figure 19).

[12] A stygobite is an aquatic animal that is restricted to groundwater and/or hyporheic environments (i.e. stygofauna). They have adaptations to survive such conditions, including elongated appendages and antennas, no eyes, and a lack of pigmentation. There are likely to be a greater percentage of stygobites at Weeli Wolli than reported here because genetic studies have so far determined that at least four species of stygal amphipod occur along Weeli Wolli and Marillana creeks.

[13] Hyporheos fauna – animals restricted to hyporheic environments.

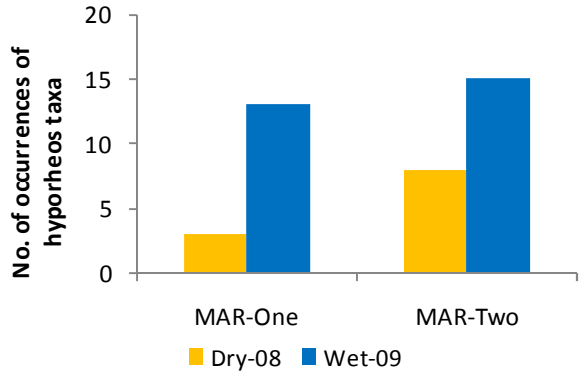



**Figure 19.** Number of occurrences of taxa considered hyporheos recorded from each reach along Marillana Creek during the dry 2008 and May 2009.

### 3.3.2 Hyporheos taxa

Species considered to be restricted to the hyporheos were the stygobitic amphipod ?*Chydaekata* sp., possible hyporheos species Oligochaeta spp. and *Diacyclops* sp. (copepodites), and the occasional stygophiles Baetidae Genus 1 WA sp.1 (mayfly larvae), *Limbodessus occidentalis* and Dytiscidae spp. larvae (Appendix 5).

The stygobitic amphipods collected from hyporheic samples were recorded as ?*Chydaekata* sp. because preliminary results from genetic analysis suggest that at least two species of stygal amphipod occur at Marillana Creek, including *Chydaekata* sp. and species D-Mar (Dr Terrie Finston, UWA, pers. comm.). The *Chydaekata* sp. seem to be the most abundant species along the creek, and are currently known from multiple bores in Marillana and Weeli Wolli creeks. Other species of *Chydaekata*, whose distributions are restricted to distinct tributaries, are known from Ethel Creek, Spearhole Creek, Tuccamunna Creek, and Roy Hill (Finston *et al.* 2007). Species D is currently undescribed, but it has been recorded previously from Marillana Creek and Weeli Wolli Creek (Dr Terrie Finston, UWA, pers. comm.; our WW WRM report 2010). No morphological data exist for Species D so genetic analysis is currently the only means of distinguishing this species. Stygal amphipods were recorded from both reaches along Marillana Creek during the current study (see Appendix 5) and were also abundant along all reaches of Weeli Wolli Creek (WRM 2010).

Of the copepod species collected from hyporheic samples, at least one was considered a possible hyporheic species, the Cyclopodidae *Diacyclops* sp. (copepodites). These copepodites were too small (juvenile) to identify accurately, but may have been *Diacyclops humphreysi* which was recently recorded from hyporheic samples of Weeli Wolli Creek (WRM 2010). This species is relatively common and widespread throughout Western Australia (Karanovic 2006). In the Pilbara, it has been recorded from the Marandoo[14] area (Biota 2008), Barrow Island (Biota 2005), the coastal side of the North-West Coastal Highway between the Fortescue River and Dampier (Bennelongia 2007), Cape Preston

[14] *D. humphreysi* was recorded from bores within the Marandoo area by Biota (2008). This species was also recorded from the Marandoo area during the DEC Pilbara Biological Survey from Warp2 (May 2004) and Tom Price North (July 2003) (Biota 2008).

(Bennelongia 2008) and the Pardoo area, approximately 70 km east of Port Hedland (Coffey 2009). Given the likelihood of the *Diacyclops* sp. (copepodites) collected during the current study being juvenile *D. humphreysi*, they were considered possible hyporheic taxa. *Diacyclops* sp. (copepodites) were recorded from MAR1-4 during the dry season (see Appendix 5).

Other taxa considered possible hyporheics were the Oligochaeta spp. In the past, Oligochaeta from hyporheic samples taken from Weeli Wolli Creek were formally identified by Dr Adrian Pinder (DEC), with at least five species considered to be occasional stygophiles (WRM 2009a). Oligochaetes were not able to be definitively identified, but were considered possible hyporheic species given the presence of occasional stygophiles from the adjacent Weeli Wolli Creek.

The occasional stygophile Baetidae Genus 1 WA sp.1 was collected from benthos (surface water macroinvertebrate samples) and hyporheos during the current study. This species is known to be common in surface waters and hyporheic habitats of Weeli Wolli Creek (Halse *et al*. 2002, WRM 2009a, WRM 2010). It occurs widely across north-western Australia (Suter 1997). Baetidae Genus 1 WA sp.1 were collected from hyporheic samples from sites MAR2-1, MAR-2-5 and MAR2-6 (see Appendix 5).

The dytiscid beetle *Limbodessus occidentalis*[15] recorded from MAR-One (1-3) during the wet season is also an occasional hyporheos stygophile. This species is known from both epigean and stygal habitats. It has been recorded from calcrete aquifers while sampling bores at Moorarie and Killara North, but is most commonly recorded from the edge of pools in sandy riverbeds and interstitially to at least two meters from the water's edge in an upstream direction (Watts and Humphreys 2004). This species has been previously recorded from interstitial samples taken from Weeli Wolli in September 2003 during surveys conducted by the DEC (Adrian Pinder, DEC, unpub. data) and more recently during the Living Water Study undertaken by the authors (WRM 2009a).

[15] Previously known as *Boongurrus occidentalis* sp. nov. (Watts and Humphreys 2004). The genus *Boongurrus* has since been synomised with *Limbodessus* (Balke and Ribera 2004).

## 3.4 Macroinvertebrates

### 3.4.1 Taxonomic composition and species richness

A total of 115 taxa of macroinvertebrates were recorded from the 12 riffle habitat sites along Marillana Creek during October 2008 and May 2009 (Table 9 and Appendix 6). Of these, 104 were recorded in October (dry) and 68 were recorded in May (wet) (Table 9 and Appendix 6). The macroinvertebrate fauna included Cnidaria (freshwater hydra), Mollusca (freshwater snails), Oligochaeta (aquatic segmented worms), Crustacea (side swimmers), Acarina (water mites), Ephemeroptera (mayfly larvae), Odonata (dragonfly and damselfly larvae), Hemiptera (true aquatic bugs), Coleoptera (aquatic beetles), Diptera (two-winged fly larvae), Trichoptera (caddisfly larvae), and Lepidoptera (aquatic moth larvae).

**Table 9.** Composition of macroinvertebrates recorded from Marillana Creek in October 08 (dry season) and May 09 (wet).

| *Macroinvertebrates* | *No. of taxa* | |
|---|---|---|
| | Oct-08 | May-09 |
| Cnidaria (freshwater hydra) | 1 | 0 |
| Mollusca (snails & bivalves) | 3 | 2 |
| Oligochaeta (aquatic worms) | 1+ | 1+ |
| Crustacea (side swimmers) | 0 | 1+ |
| Acarina (water mites) | 2+ | 2+ |
| Ephemeroptera (mayflies) | 5 | 3 |
| Odonata (dragonflies & damselflies) | 6 | 6 |
| Hemiptera (true bugs) | 13 | 3 |
| Coleoptera (aquatic beetles) | 19 | 12 |
| Diptera (two-winged flies) | 40 | 28 |
| Trichoptera (caddis-flies) | 11 | 7 |
| Lepidoptera (moths) | 3 | 3 |
| **Total number of taxa** | **104** | **68** |

The taxonomic listing includes records of larval and pupal stages for groups such as Diptera and Coleoptera. Current taxonomy is not sufficiently developed to allow identification of larval and pupal stages of all members of these groups to species level. In many instances, it is likely that these stages are the same species as the larval/adult stages recorded from the same location. However, because this could not be definitively determined, they were treated as separate taxa. In any case, different life stages often have different functional roles in the ecosystem and therefore it makes sense to treat them as separate taxa.

Taxa richness varied between reach and season. During the dry season of October 2008, the greatest number of macroinvertebrate taxa was recorded from MAR2-5 and MAR2-6 (55 taxa), and the least from MAR2-2 (32 taxa). During the wet, the greatest number of taxa was again collected from MAR2-6 (33 taxa), and the least from MAR1-1 (23 taxa) (Figure 20 and Appendix 6). More macroinvertebrate taxa were recorded during the dry season (Figures 20 and 21).

Using macroinvertebrate data from Weeli Wolli Creek in the analysis, there was a significant difference in the average number of macroinvertebrate taxa between reach (Two-way ANOVA; df = 5, p= 0.002) and season (Two-way ANOVA; df = 1, p= 0.000; see Table 10 and Figure 21). There was also a significant interaction between the wet and dry seasons for WW Reach Two, and between seasons for Marillana Reach Two (Figure 21). Significantly lower taxa richness was recorded from WW Reach Two[16] compared with all other reaches on Weeli Wolli and Marillana Creek (Table 10 and Figure 21). Across all reaches in Weeli Wolli and Marillana Creek, macroinvertebrate taxa richness was significantly greater in the dry season (Table 10 and Figure 21).

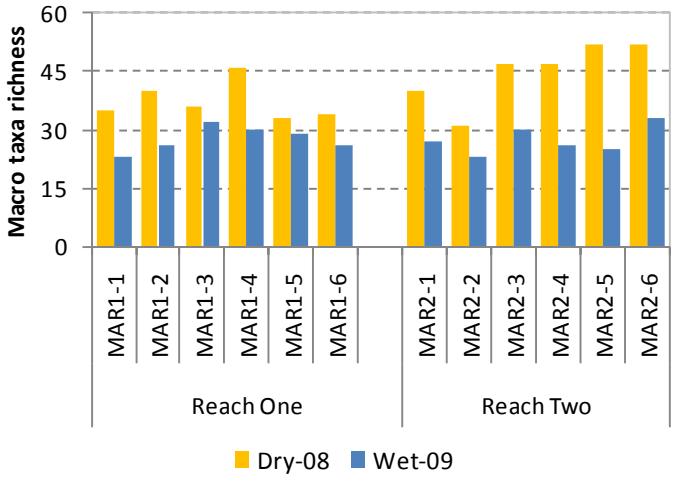



**Figure 20**. Macroinvertebrate taxa richness recorded from each site along Marillana Creek during both seasons.

**Table 10.** Two-way ANOVA results for macroinvertebrate taxa richness by reach and season (including Weeli Wolli data), showing degrees of freedom, f-value and p-value. Tukeys post-hoc results are presented in ascending order of mean taxa richness, with groups of no difference in means joined by a black line.

| *Source* | *df* | *F* | p | Tukeys post-hoc | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | WW 2 | MAR 1 | WW 3 | MAR 2 | WW 4 | WW 1 |
| **Reach** | 5 | 4.27 | 0.002 | | | | | | |
| **Season** | 1 | 31.05 | 0.000 | | | | | | |
| **Reach*Season** | 5 | 2.38 | 0.049 | | | | | | |
| **Total** | 71 | | | | | | | | |

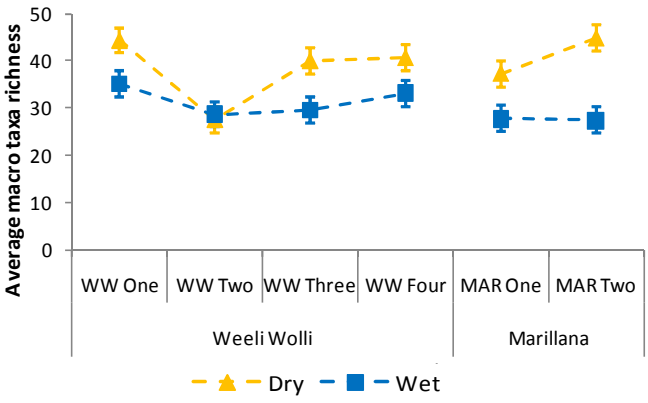



**Figure 21.** Average macroinvertebrate taxa richness (±se) from all reaches (including those along Weeli Wolli Creek) showing data for both the dry (October 2008) and wet season (May 2009).

[16] Weeli Wolli Reach Two is the reach immediately below the gabion and is likely impacted by greatly increased flows which will likely adversely affect species preferring low flows/low velocity

### 3.4.2 Conservation significance of macroinvertebrates

While the majority of taxa collected during October 2008 and May 2009 were common, ubiquitous species with distributions extending across Northern Australia (4%), Australasia (23%), and the world (cosmopolitan species; 5%), a number of taxa were endemic to Western Australia (1%) or, more specifically, the Pilbara region of Western Australia (3%). Taxa endemic to Western Australia included the mayfly Baetidae Genus 1 WA sp1 and the dragonfly *Austrogomphus gordoni*. Taxa with distributions restricted to the Pilbara region of Western Australia included the stygal amphipod *Chydaekata* sp., the dragonfly *Nannophlebia injabandi*, and the hydrophilid beetle *Laccobius billi*. Over 64% of macroinvertebrate taxa were classified as indeterminate, due to insufficient taxonomy/knowledge.

Indeterminate taxa made up the greatest proportion of taxa from each reach during each season (Figure 22). This was generally followed by Australasian taxa, with distributions across Australia and the south-east Asian region, and then cosmopolitan or Northern Australian species (Figure 22). A greater proportion of taxa endemic to the Pilbara were recorded from Marillana Creek during the wet season (Figure 22). No Western Australian endemic taxa were recorded from either reach during the dry season.

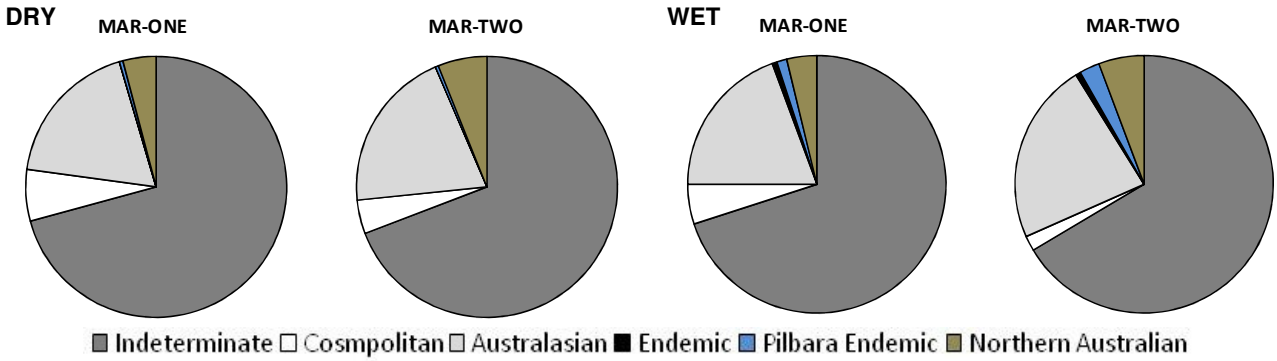



**Figure 22.** Proportions of species from each conservation category recorded from both reaches during the October 2008 dry season (left) and the May 2009 wet season (right).

### 3.4.3 Patterns in macroinvertebrate assemblage structure

The macroinvertebrate abundance ordination showed some clear patterns (Figure 23). In a similar manner to the water quality data, there was a distinct seasonal effect, with samples taken during the dry season separating from those taken during the wet (Figure 23). This was found to be significant (Two-way crossed ANOSIM; sample statistic = 0.54; significance of sample statistic p = 0.0001). While there did appear to be some separation of samples based on reach, there was also some overlap (Figure 23). Further analysis revealed that while macroinvertebrate assemblages were significantly separate between reach, the groups were barely separable[17] (Two-way crossed ANOSIM; sample statistic = 0.11; significance of sample statistic p = 0.0001). This is likely due to the large variability evident

[17] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barely separable.

within reaches, as well as similarities between reaches, represented as overlap in ordination space (Figure 23).

Water quality variables found to be contributing to patterns within the macroinvertebrate ordination of Marillana Creek were dissolved oxygen, chloride, sodium, log total phosphorus and sulphate (BIOENV; Rho =0.56, significance of sample statistic p = 0.01). Sodium concentrations were lower from Reach Two during the wet, sulphate was higher during the dry season, and log total phosphorus was higher during the wet (Figure 24).

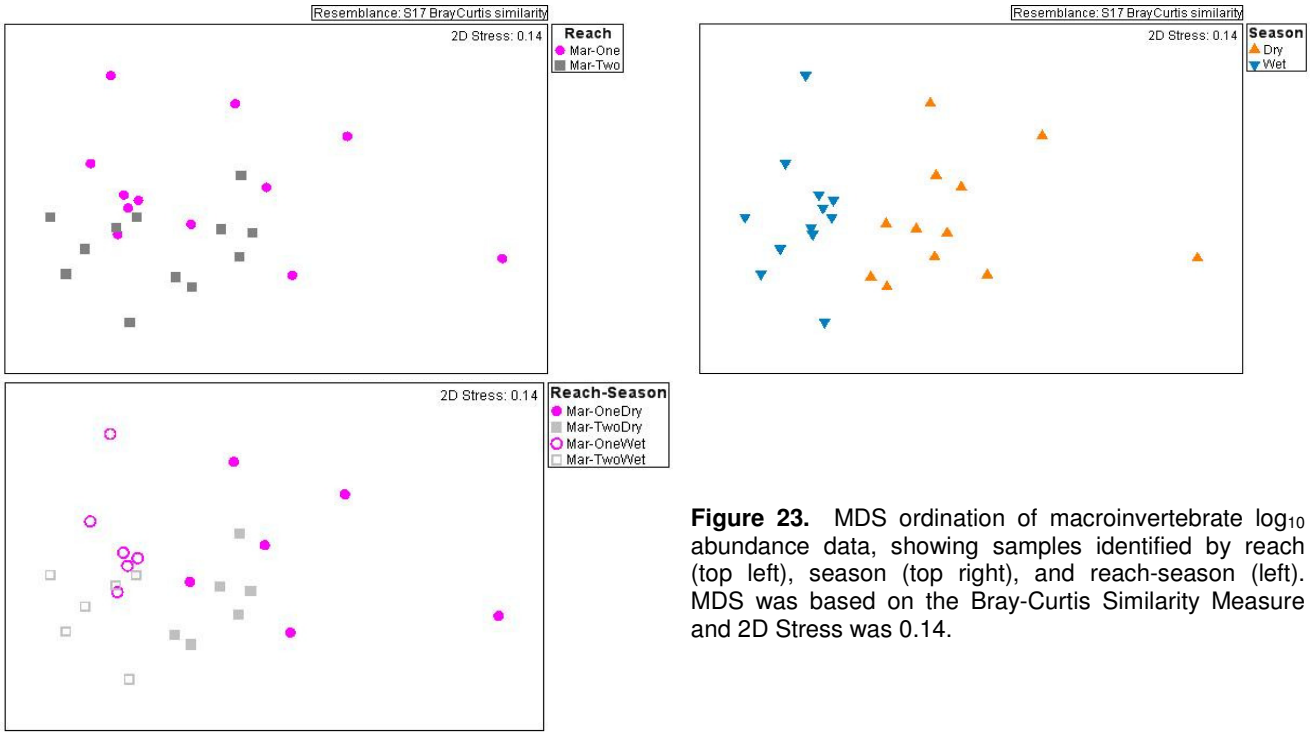



**Figure 23.** MDS ordination of macroinvertebrate $log_{10}$ abundance data, showing samples identified by reach (top left), season (top right), and reach-season (left). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.14.

### 3.4.4 Comparison of macroinvertebrate assemblages with Weeli Wolli Creek

Analyses were also completed using all macroinvertebrate $log_{10}$ abundance data recorded from Weeli Wolli Creek and Marillana Creek during October 2008 (dry season) and May 2009 (wet). Groupings within the macroinvertebrate ordination incorporating all data were less clear than within the water quality ordination (Figures 8 & 25). Firstly, there was no separation between systems (One-way ANOSIM; sample statistic = 0.01, significance of sample statistic p = 0.38), suggesting that on a broad scale the macroinvertebrate assemblages of Marillana Creek were similar to those from Weeli Wolli Creek in October 2008 and May 2009 (Figure 25). The consistent seasonal trend, however, was evident within the macroinvertebrate assemblages of Weeli Wolli and Marillana creeks, with a significant separation between seasons being found (Figure 25; Two-way crossed ANOSIM; sample statistic = 0.46, significance of sample statistic p = 0.0001). Overall, macroinvertebrate assemblages were also significantly separate amongst reaches, but some reaches were barely separable and recorded low R-values (Figure 25 & Table 11; Two-way crossed ANOSIM; sample statistic = 0.29, significance of sample statistic p = 0.0001). The greatest separation was between WW-Two and both Marillana Creek reaches (MAR-One, R=0.52; and MAR-Two, R=0.49; Table 11). There was considerable overlap in the

macroinvertebrate assemblages between a number of reaches, suggesting these reaches had similar faunal assemblages (Figure 25). The greatest similarity (i.e. lowest R-value) was between both Marillana reaches (R=0.11; Table 11). These reaches were also similar to the downstream Weeli Wolli reach, WW-Four (Table 11).

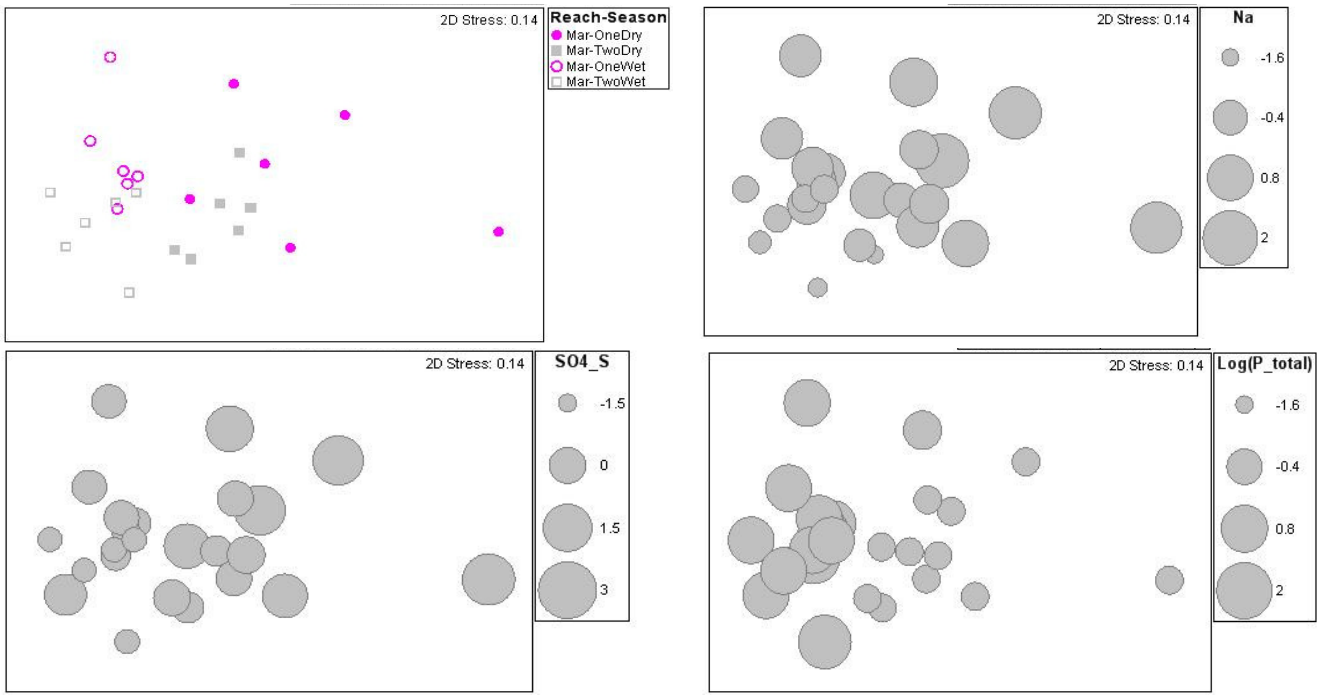



**Figure 24.** Bubble plots of water quality variables influencing the macroinvertebrate ordination, including sodium, sulphate and log total phosphorus.

**Table 11.** Pair-wise ANOSIM results of macroinvertebrate $log_{10}$ abundance data amongst reach, showing R-values (sample statistic)[18], * = groups significantly different.

| | *WW One* | *WW Two* | *WW Three* | *WW Four* | *MAR One* |
|---|---|---|---|---|---|
| **WW One** | | | | | |
| **WW Two** | 0.40* | | | | |
| **WW Three** | 0.47* | 0.21* | | | |
| **WW Four** | 0.24* | 0.38* | 0.18* | | |
| **MAR One** | 0.26* | 0.52* | 0..34* | 0.15* | |
| **MAR Two** | 0.41* | 0.49* | 0.31* | 0.14* | 0.11* |

[18] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barley separable.

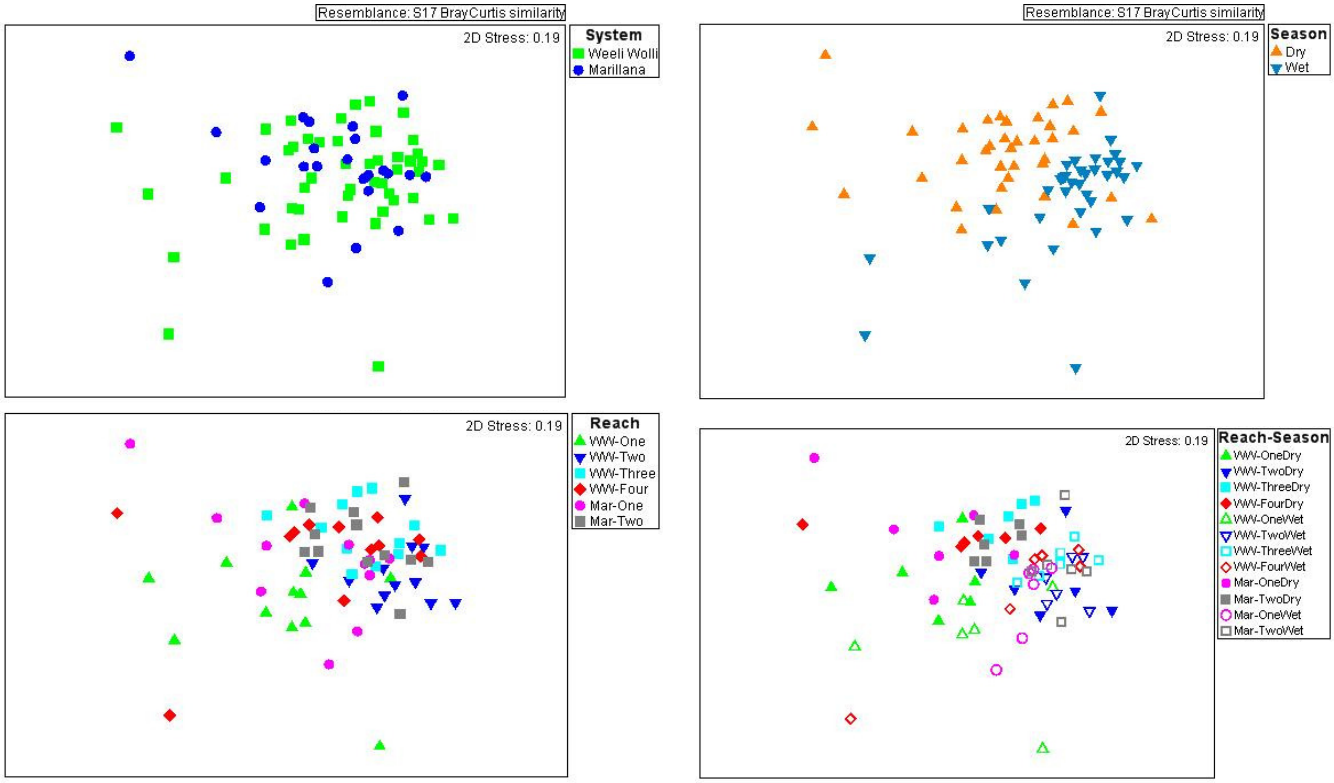



**Figure 25.** MDS ordination of macroinvertebrate log10 abundance data from Weeli Wolli Creek and Marillana Creek, showing samples identified by system (top left), season (top right), reach (bottom left), and reach-season (bottom right). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.19.

## 3.5 Fish

### 3.5.1 Species richness

The fish fauna of the Pilbara is characterised by low species diversity but high levels of endemicity, with over 42% of species recorded restricted to the region (Unmack 2001, Allen *et al.* 2002). Masini (1988) found the relatively clear waters of permanent and semi-permanent waterbodies supported the best developed fish assemblages in the region. In a study of the biogeography of Australian fish fauna, Unmack (2001) recognised ten distinct freshwater fish biogeographic provinces, of which the Pilbara Province was one. This region was considered distinct because its fauna did not cluster with other drainages in multivariate (parsimony and UPGMA) analysis of fish distribution patterns (Unmack 2001).

Three of the eleven freshwater fish species known from the Fortescue River were recorded from Marillana Creek during October 2008 and May 2009. These were the spangled perch *Leiopotherapon unicolor*, Hyrtl's tandan (eel-tailed catfish) *Neosiluris hyrtlii*[19] (Plate 3), and western rainbowfish *Melanotaenia australis.* All species were collected from both reaches in each season (Table 11). These three fish were also the only species collected from Marillana Creek during previous regional surveys (WRM 2009b), and are the only species known from Weeli Wolli Creek (Streamtec 2004, WRM 2009a, 2010).

**Plate 3.** Hyrtl's tandan catfish, *Neosiluris hyrtlii* (photo taken and provided by Mark Allen ©.

### 3.5.2 Abundance

A total of 1008 freshwater fish were collected from Marillana Creek during the October 2008 surveys, and 1149 during May 2009 (Table 12). Western rainbowfish were the most abundant species collected from both reaches during both seasons (Table 12). A greater abundance of fish was recorded from the downstream reach (Reach Two).

**Table 12.** Total number of fish caught from Marillana Creek during the dry (Oct-08) and wet seasons (May-09).

| ***October 2008*** | | | | |
|---|---|---|---|---|
| | ***Rainbowfish*** | ***Perch*** | ***Catfish*** | ***Total*** |
| **Reach 1** | 360 | 12 | 4 | 376 |
| **Reach 2** | 526 | 16 | 90 | 632 |
| **Total** | **886** | **28** | **94** | **1008** |
| ***May 2009*** | | | | |
| | ***Rainbowfish*** | ***Perch*** | ***Catfish*** | ***Total*** |
| **Reach 1** | 494 | 14 | 19 | 527 |
| **Reach 2** | 511 | 55 | 56 | 622 |
| **Total** | **1005** | **69** | **75** | **1149** |

[19] Taxonomy of *N hyrtlii* in the Pilbara is currently under revision as genetic analysis suggests it is a different species from *N. hyrtlii* in the Kimberley and eastern Australia. Therefore, the name for this species may change in the future.

### 3.5.3 Length-frequency analysis

Breeding characteristics of fish species in the Pilbara, such as fecundity and the size at first maturity, vary between river systems and rainfall zone. Beesley (2006) found life history strategies of fish species in the Fortescue River lay between 'opportunistic' and 'periodic', reflecting the seasonal yet unpredictable nature of rainfall in the region.

**Western rainbowfish**

Breeding in western rainbowfish (*Melanotaenia australis*) occurs throughout the year, with multiple spawning bouts which take full advantage of the regions intermittent rainfall and streamflow (Beesley 2006). Morgan *et al.* (2002) captured small juveniles on most sampling occasions in the Fitzroy River. The size at first maturity varies between river systems, but western rainbowfish generally attain a maximum size of 110 mm TL[20] (Morgan *et al.* 2002).

Length-frequency plots of western rainbowfish from Marillana Creek show that individuals of all age-classes were present in the population, from juveniles and sub-adults to large adults (Figure 26). This suggests successful breeding and recruitment. A greater proportion of new recruits (< 30 mm SL[21]) were collected from both reaches during May 2009 following wet season rains (MAR-One = 38%; MAR-Two = 27%), than during the dry (MAR-One = 19%; MAR-Two = 11%; Figure 26). The majority of new recruits were recorded from the upper reach (MAR-One; Figure 26).

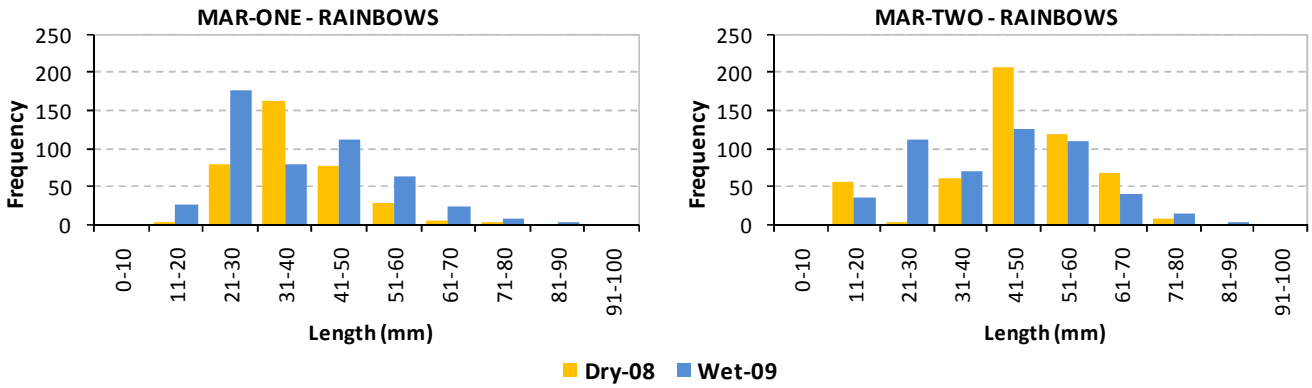



**Figure 26.** Length-frequency histograms for western rainbowfish collected from MAR-One (left) and MAR-Two (right) during the dry-08 and wet-09.

**Hyrtl's tandan catfish**

Very little is known of the breeding ecology of Hyrtl's tandan (*Neosiluris hyrtlii*). It is thought that individuals may mature in their first year at a size of approximately 135 mm TL for both sexes (Lake 1971, Bishop *et al.* 2001). Species of *Neosilurus* catfish usually attain a maximum size of only 200 mm however, *N. hyrtlii*, along with *N. ater*, can reach up to 400 mm TL (Lake 1971, Bishop *et al.* 2001). Breeding is thought to occur in the early wet season (Morgan *et al.* 2002, Bishop *et al.* 2001). It is at this time when initial flooding increases the

[20] TL = total length, measured from the tip of the snout to the tip of the longer lobe of the caudal fin.

[21] SL = standard length, measured from the tip of the snout to the posterior end of the last vertebra or to the posterior end of the midlateral portion of the hypural plate (i.e. this measurement excludes the length of the caudal fin). Standard length was measured in the current study.

area and diversity of aquatic habitat available, while also initiating increases in plankton and other foods (Bishop *et al.* 2001).

The greatest number of smaller Hyrtl's catfish (<70 mm SL) was recorded from the lower reach (MAR-Two) during the dry season (Figure 27). Few catfish were collected from MAR-One in either season, but those that were would be considered sub-adults to adults (Figure 27). Catfish of all age-classes were recorded from MAR-Two, including few juveniles, sub-adults, adults, and a number of larger sized adults (>150 mm SL; Figure 27).

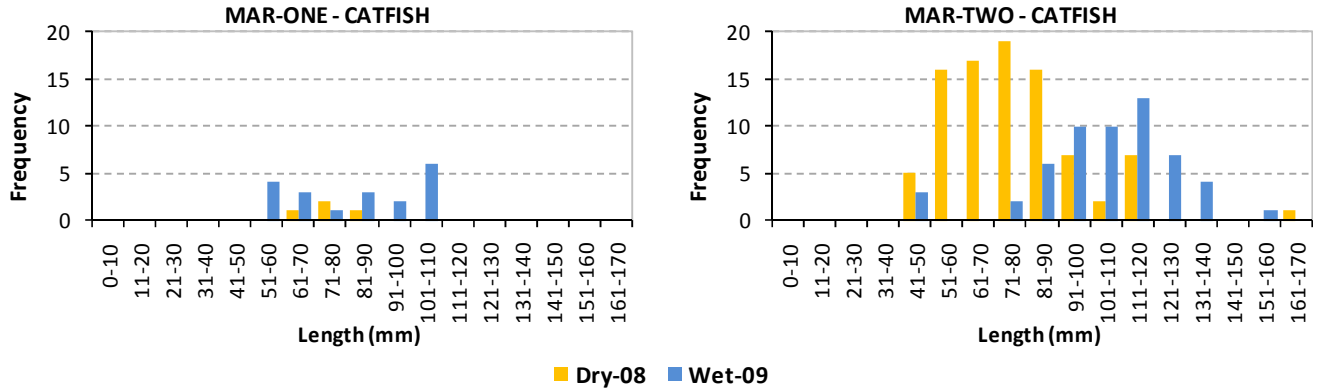



**Figure 27.** Length-frequency histograms for Hyrtl's tandan catfish collected from MAR-One (left) and MAR-Two (right) during the dry-08 and wet-09.

**Spangled perch**

Breeding in spangled perch (*Leiopotherapon unicolor*) of the Pilbara occurs during the summer wet season, between late November and March (Beesley 2006, Morgan *et al*. 2002). During this time, multiple spawning events are known to occur (Beesley 2006). In the Fitzroy River, Morgan *et al.* (2002) collected mature specimens in summer and larvae at the end of the wet season, indicating that spawning coincided with the flooding of the river. Spangled perch mature in their first year at approx. 58 mm TL for males and 78 mm TL for females. They reach a maximum size of 300 mm TL.

Length-frequency analysis of spangled perch captured from Marillana Creek showed that no juveniles (< 50 mm) were caught (Figure 28). This perhaps reflects the secretive nature of this species and its ability to quickly evade capture by hiding in snags and other cover. Further sampling of the creek should locate juveniles should they be present. Although adults (> 70 mm) were collected from both reaches during both seasons, no larger individuals were captured at the maximum size range (between 200 mm and 310 mm). The greatest number of spangled perch were recorded during the wet season at MAR-Two, and these were mostly adults, with only a few sub-adults recorded (50-70 mm SL; Figure 28).

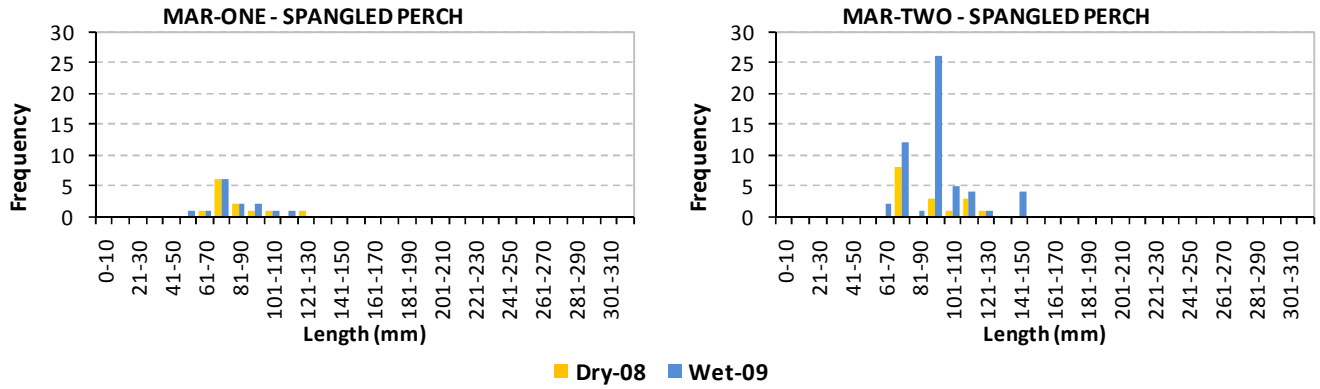



**Figure 28.** Length-frequency histograms for spangled perch collected from MAR-One (left) and MAR-Two (right) during the dry-08 and wet-09.

# 4 CONCLUSIONS

## 4.1 Water quality

The main water quality findings were:

- Super-saturated DO levels (>100%) were recorded from a number of sites along the creek in both seasons. These sites likely become anoxic overnight as respiration by plants, algae and fauna deplete DO. Super-saturated DO can also lead to fish bubble disease. One site in particular, MAR2-4 in October 2008, recorded exceptionally high DO levels (180%).
- Circum-neutral to slightly basic pH characteristic of Marillana Creek is not uncommon from similar waterbodies in the East Pilbara Region of W.A.
- All sites were fresh
- The high alkalinity levels recorded from all sites indicate that the buffering capacity of the waters of Marillana Creek is high
- The composition of major ions along Marillana Creek was typically dominated by sodium and hydrogen bicarbonate. This was similar to that reported from the lower end of Weeli Wolli Creek, downstream of the confluence with Marillana Creek
- Total nitrogen levels exceeded ANZECC/ARMCANZ (2000) guidelines at MAR2-1 and MAR2-2 in the dry season, and most sites during the wet. Total nitrogen levels were significantly higher from Reach Two. The cause of the elevated total nitrogen levels from the downstream Marillana reach is unknown, but may be coming from any number of potential sources, including pastoral activities and cattle stocking, local geology (i.e. soils or bedrock), and/or influence from Yandi discharge water and mining operations (see section 3.1.1). Potential sources for the increased total nitrogen from MAR-Two need to be investigated further before any conclusions can be drawn.
- Multivariate analyses showed that water quality was significantly different between reach and season. Dry season samples from Marillana Reach One formed the tightest group in the ordination, suggesting that samples within this group were most similar to each other, than any other group
- Using all water quality data collected from Weeli Wolli and Marillana Creek in October 2008 and May 2009, water quality was found to be significantly different between systems. Water quality was also significantly different amongst reach and season. During the dry season, Marillana Creek samples from both reaches grouped with Weeli Wolli Reach Four samples. This suggests that during the dry season, the water quality of Marillana Creek was similar to that recorded from the downstream Weeli Wolli reach (WW Reach Four). It appears that water quality of the downstream reach of Weeli Wolli Creek is influenced by Marillana Creek. During the wet season, WW-Four formed its own group, separate from Marillana Creek sites.

## 4.2 Microinvertebrates

The main microinvertebrate findings were:

- A total of 59 microinvertebrate taxa were recorded; 45 in October 2008 and 41 in May 2009

- The microinvertebrate fauna were typical of tropical systems reported elsewhere, with Branchionidae (Rotifera) being poorly represented, Lecanidae dominating the Rotifera, and the replacement of Daphniidae (Cladocera) with Chydoridae (Cladocera)
- Microinvertebrate taxa richness varied greatly between reach and season
- Using microinvertebrate data from Weeli Wolli Creek in the analysis, there was no significant difference in the average number of taxa between reach. There was, however, a significant difference between season , with a greater number of taxa being recorded in the dry season
- Multivariate analyses showed no significant difference in microinvertebrate assemblages between reach. While there did appear to be some separation of samples between season, groups were found to be barely separable. Dry season samples were significantly less variable than wet season samples
- The multivariate ordination incorporating all microinvertebrate abundance data recorded from Weeli Wolli and Marillana creeks during October 2008 and May 2009, showed no clear patterns. There was no significant separation between system, reach or season. The greatest similarity (i.e. lowest R-value and no significant difference) was between Marillana reaches One and Two. The greatest separation of microinvertebrate assemblages was between Weeli Wolli Reach One and Marillana Reach Two.

## 4.3 Hyporheic fauna

The main hyporheic fauna findings were:

- During the dry season, the vast majority of taxa collected in hyporheic samples were classified as stygoxene (72%) and do not have specialised adaptations for groundwater habitats. However, 5% of the taxa were classified as occasional hyporheos stygophiles, 5% were stygobites, and 9% were possible hyporheic taxa
- During the wet season, most taxa were stygoxene(81%), with 9% being considered hyporheos fauna (5% occasional hyporheos stygophiles, 2% stygobites, and 2% possible hyporheic taxa)
- Results from this study are similar to those reported previously in the Pilbara (Halse *et al.* 2002, WRM 2010), in that <20% of taxa collected in hyporheic habitats were entirely dependent on groundwater for their persistence as a species
- Hyporheos fauna were recorded from both reaches of Marillana Creek during both seasons. The greatest number of occurrences of hyporheos taxa was recorded from Reach Two in the wet season of May 2009, and the least from Reach One during the dry of October 2008
- Species considered to be restricted to the hyporheos were the stygobitic amphipod ?*Chydaekata* sp., possible hyporheos species Oligochaeta spp. and *Diacyclops* sp. (copepodites), and the occasional stygophiles Baetidae Genus 1 WA sp.1 (mayfly larvae), *Limbodessus occidentalis* and Dytiscidae spp. Larvae
- stygobitic amphipods collected from hyporheic samples were recorded as ?*Chydaekata* sp. because preliminary results from genetic analysis suggest that at least two species of stygal amphipod occur at Marillana Creek, including *Chydaekata* sp. and species D-Mar (Dr Terrie Finston, UWA, pers. comm.).

## 4.4 Macroinvertebrates

The main macroinvertebrate findings were:

- A total of 115 taxa of macroinvertebrates were recorded from the 12 riffle habitat sites along Marillana Creek during October 2008 and May 2009; 104 were recorded in October and 68 were recorded in May
- Taxa richness varied between reach and season, ranging from 23 taxa (MAR1-1 in the wet) to 55 (MAR 2-5 and MAR2-6 in the dry)
- Using macroinvertebrate data from Weeli Wolli Creek in the analysis, there was a significant difference in the average number of macroinvertebrate taxa between reach. Significantly lower taxa richness was recorded from WW Reach Two compared with all other reaches on Weeli Wolli and Marillana Creek. Across all reaches in Weeli Wolli and Marillana Creek, macroinvertebrate taxa richness was significantly greater in the dry than the wet season.
- The majority of taxa collected during October 2008 and May 2009 were common, ubiquitous species with distributions extending across Northern Australia (4%), Australasia (23%), and the world (cosmopolitan species; 5%). However, of interest was the collection of taxa endemic to Western Australia (1%) or, more specifically, the Pilbara region of Western Australia (3%). Taxa endemic to Western Australia included the mayfly Baetidae Genus 1 WA sp1 and the dragonfly *Austrogomphus gordoni*. Taxa with distributions restricted to the Pilbara region of Western Australia included the stygal amphipod *Chydaekata* sp., the dragonfly *Nannophlebia injabandi*, and the hydrophilid beetle *Laccobius billi*.
- A greater proportion of taxa endemic to the Pilbara were recorded from Marillana Creek during the wet season. No Western Australian endemic taxa were recorded from either reach during the dry season
- Multivariate analyses showed a distinct seasonal effect on macroinvertebrate assemblages of Marillana Creek. While there did appear to be some separation of samples based on reach, there was also some overlap, and analyses found the groups to be barely separable. This is likely due to the large variability evident within reaches, as well as similarities between reaches
- Analyses were also completed using all macroinvertebrate $\log_{10}$ abundance data recorded from Weeli Wolli Creek and Marillana Creek during October 2008 (dry season) and May 2009 (wet). There was no separation between system, indicating that at a broad scale the macroinvertebrate assemblages of Marillana Creek were similar to those from Weeli Wolli Creek in October 2008 and May 2009. The consistent seasonal trend, however, was still evident, with a significant separation between seasons being found. Overall, macroinvertebrate assemblages were also significantly separate amongst reaches, but some reaches were barely separable and recorded low R-values. The greatest separation was between WW-Two and both Marillana Creek reaches. The greatest similarity in macroinvertebrate assemblages was between both Marillana reaches. These reaches were also similar to the most downstream Weeli Wolli reach, WW-Four

## 4.5 Fish

The main fish findings were:

- Three of the eleven freshwater fish species known from the Fortescue River were recorded from Marillana Creek during October 2008 and May 2009; the spangled perch *Leiopotherapon unicolor*, Hyrtl's tandan (eel-tailed catfish) *Neosiluris hyrtlii*, and western rainbowfish *Melanotaenia australis*. These were the only species collected from Marillana Creek during previous regional surveys by the authors and are the only species known from Weeli Wolli Creek system
- A total of 1008 freshwater fish were collected during October 2008 and 1149 during May 2009. Western rainbowfish were the most abundant species collected from both reaches during both seasons. A greater abundance of fish was recorded from the downstream reach (Reach Two).
- Western rainbowfish of all age-classes were present in the population, from juveniles and sub-adults to large adults, suggesting successful breeding and recruitment. A greater proportion of new recruits (< 30 mm SL) were collected from both reaches during May 2009 following wet season rains. The majority of new recruits were recorded from the upper reach
- The greatest number of smaller Hyrtl's catfish (<70 mm SL) was recorded from the lower reach (MAR-Two) during the dry season. Few catfish were collected from MAR-One in either season, but those that were would be considered sub-adults to adults. Catfish of all age-classes were recorded from MAR-Two, including few juveniles, sub-adults, adults, and a number of larger sized adults
- No juvenile spangled perch (< 50 mm) were caught along Marillana Creek during the current study. This perhaps reflects the secretive nature of this species and its ability to quickly evade capture by hiding in snags and other cover. Further sampling of the creek should locate juveniles should they be present. Adults (> 70 mm) were collected from both reaches during both seasons, but no larger individuals were captured at the maximum size range (between 200 mm and 310 mm). The greatest number of spangled perch were recorded during the wet season at MAR-Two, and these were mostly adults, with only a few sub-adults recorded.

# 5 RECOMMENDATIONS

Recommendations for future monitoring include:

1. Continue monitoring in the same manner as documented here to detect any changes that may occur to the ecology of Marillana Creek as a result of increased discharge of dewatering water, and possible adverse conditions which may impact lower Weeli Wolli Creek
2. Future sampling should also include habitat assessments which can be compared with those taken along Weeli Wolli Creek
3. Establish Regional sites in Fortescue Marshes to ensure any cumulative impacts that may occur in the future do not adversely affect the marshes during times of connection
4. Deploy dissolved oxygen loggers for a period of 24 hours in pools with an abundance of algae to determine the extent of overnight DO depletion.

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# APPENDICES

# Appendix 1. Site photographs

For photographs of Weeli Wolli sites see WRM (2010).

## MARILLANA CREEK

## REACH ONE

**DRY 08** **WET 09**

**MAR1-1**

**MAR1-2**

**DRY 08** **WET 09**

**MAR1-3**

**MAR1-4**

**MAR1-5**

**DRY 08** **WET 09**

**MAR1-6**

**REACH TWO**

**DRY 08** **WET 09**

**MAR2-1**

**MAR2-2**

**DRY 08** **WET 09**

**MAR2-3**

**MAR2-4**

**MAR2-5**

**DRY 08**
**MAR2-6**

**WET 09**

# Appendix 2. ANZECC/ARMCANZ (2000) trigger values for the protection of aquatic systems in tropical northern Australia

**Table A2-1.** Default trigger values for some physical and chemical stressors for tropical Australia for slightly disturbed ecosystems (TP = total phosphorus; FRP = filterable reactive phosphorus; TN = total nitrogen; NOx = total nitrates/nitrites; NH4+ = ammonium). Data derived from trigger values supplied by Australian states and territories, for the Northern Territory and regions north of Carnarvon in the west and Rockhampton in the east (ANZECC/ARMCANZ 2000).

| | TP ($\mu g\ L^{-1}$) | FRP ($\mu g\ L^{-1}$) | TN ($\mu g\ L^{-1}$) | NOx ($\mu g\ L^{-1}$) | $NH_4^+$ ($\mu g\ L^{-1}$) | DO % saturation[f] | pH |
|---|---|---|---|---|---|---|---|
| **Aquatic Ecosystem** | | | | | | | |
| Upland River[e] | 10 | 5 | 150 | 30 | 6 | 90-120 | 6.0-7.5 |
| Lowland River[e] | 10 | 4 | 200-300[h] | 10[b] | 10 | 85-120 | 6.0-8.0 |
| Lakes & Reservoirs | 10 | 5 | 350[c] | 10[b] | 10 | 90-120 | 6.0-8.0 |
| Wetlands[3] | 10-50[g] | 5-25[g] | 350-1200[g] | 10 | 10 | 90[b]-120[b] | 6.0-8.0 |

b = Northern Territory values are 5µgL$^{-1}$ for $NO_x$, and <80 (lower limit) and >110% saturation (upper limit) for DO;
c = this value represents turbid lakes only. Clear lakes have much lower values;
e = no data available for tropical WA estuaries or rivers. A precautionary approach should be adopted when applying default trigger values to these systems;
f = dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability;
g = higher values are indicative of tropical WA river pools;
h = lower values from rivers draining rainforest catchments.

**Table A2-2.** Default trigger values for salinity and turbidity for the protection of aquatic ecosystems, applicable to tropical systems in Australia (ANZECC/ARMCANZ 2000).

| *Aquatic Ecosystem* | | *Comments* |
|---|---|---|
| ***Salinity*** | ***(µs/cm)*** | |
| **Aquatic Ecosystem** | | |
| Upland & lowland rivers | 20-250 | Conductivity in upland streams will vary depending on catchment geology. The fist flush may result in temporarily high values |
| Lakes, reservoirs & wetlands | 90-900 | Higher conductivities will occur during summer when water levels are reduced due to evaporation |
| ***Turbidity*** | ***(NTU)*** | |
| **Aquatic Ecosystem** | | |
| Upland & lowland rivers | 2-15 | Can depend on degree of catchment modification and seasonal rainfall runoff |
| Lakes, reservoirs & wetlands | 2-200 | Most deep lakes have low turbidity. However, shallow lakes have higher turbidity naturally due to wind-induced re-suspension of sediments. Wetlands vary greatly in turbidity depending on the general condition of the catchment, recent flow events and the water level in the wetland. |

# Appendix 3. Water quality data from October 2008 and May 2009.

For Weeli Wolli water quality data see WRM (2009).

**Table A3-1.** Water quality data from Marillana Creek, October 2008 (dry). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines.

| Reach | Site | pH | Temp (ºC) | EC (µS/cm) | DO (%) | DO (mg/L) |
|---|---|---|---|---|---|---|
| One | MAR1-1 | 7.76 | 25.1 | 983 | 56 | 4.4 |
| | MAR1-2 | 7.67 | 26.4 | 983 | 71 | 5.5 |
| | MAR1-3 | 7.98 | 25.3 | 1000 | 84 | 6.8 |
| | MAR1-4 | 7.83 | 25.7 | 1020 | 77 | 6.2 |
| | MAR1-5 | 7.98 | 26.2 | 1027 | 63 | 5.3 |
| | MAR1-6 | 7.66 | 27.8 | 1040 | 157 | 11.6 |
| Two | MAR2-1 | 8.06 | 30.6 | 927 | 147 | 10.7 |
| | MAR2-2 | 7.93 | 28.4 | 926 | 112 | 8.5 |
| | MAR2-3 | 8.26 | 29.3 | 907 | 165 | 12.4 |
| | MAR2-4 | 8.34 | 29.5 | 905 | 180 | 13.1 |
| | MAR2-5 | 7.75 | 25.9 | 942 | 79 | 6.3 |
| | MAR2-6 | 8.34 | 27.5 | 943 | 94 | 8.2 |

**Table A3-2.** Water quality data from Marillana Creek, May 2009 (wet). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines.

| Reach | Site | pH | Temp (ºC) | EC (µS/cm) | DO (%) | DO (mg/L) |
|---|---|---|---|---|---|---|
| One | MAR1-1 | 7.89 | 25.3 | 939 | 87 | 7.3 |
| | MAR1-2 | 7.86 | 23.8 | 985 | 105 | 9.2 |
| | MAR1-3 | 7.56 | 23.1 | 1000 | 44 | 3.9 |
| | MAR1-4 | 7.9 | 23 | 996 | 82 | 7.4 |
| | MAR1-5 | 8.01 | 22.3 | 1000 | 107 | 9.9 |
| | MAR1-6 | 7.89 | 23.9 | 1010 | 103 | 9.2 |
| Two | MAR2-1 | 8.06 | 24.8 | 987 | 122 | 10.7 |
| | MAR2-2 | 8.00 | 23.8 | 987 | 88 | 7.9 |
| | MAR2-3 | 8.60 | 19.8 | 963 | 133 | 11.5 |
| | MAR2-4 | 7.79 | 23.7 | 943 | 80 | 7.2 |
| | MAR2-5 | 7.70 | 24.8 | 939 | 60 | 5.1 |
| | MAR2-6 | 7.87 | 20.9 | 939 | 80 | 7.4 |

**Table A3-3.** Nutrient data from Marillana Creek, October 2008 (dry). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | N_NO3 | N_NH3 | Total N | Total P |
|---|---|---|---|---|---|
| One | MAR1-1 | 0.12 | 0.01 | 0.22 | 0.005 |
| | MAR1-2 | 0.03 | 0.005 | 0.1 | 0.005 |
| | MAR1-3 | 0.01 | 0.005 | 0.27 | 0.01 |
| | MAR1-4 | 0.01 | 0.005 | 0.07 | 0.005 |
| | MAR1-5 | 0.01 | 0.005 | 0.05 | 0.005 |
| | MAR1-6 | 0.01 | 0.005 | 0.09 | 0.005 |
| Two | MAR2-1 | 1.3 | 0.005 | 1.8 | 0.005 |
| | MAR2-2 | 0.84 | 0.005 | 1.2 | 0.005 |
| | MAR2-3 | 0.08 | 0.005 | 0.17 | 0.005 |
| | MAR2-4 | 0.03 | 0.005 | 0.1 | 0.005 |
| | MAR2-5 | 0.15 | 0.005 | 0.24 | 0.005 |
| | MAR2-6 | 0.04 | 0.03 | 0.16 | 0.005 |

**Table A3-4.** Nutrient data from Marillana Creek, May 2009 (wet). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | N_NO3 | N_NH3 | Total N | Total P |
|---|---|---|---|---|---|
| One | MAR1-1 | 0.42 | 0.005 | 0.68 | 0.04 |
| | MAR1-2 | 0.17 | 0.01 | 0.35 | 0.02 |
| | MAR1-3 | 0.02 | 0.005 | 0.15 | 0.02 |
| | MAR1-4 | 0.07 | 0.005 | 0.16 | 0.03 |
| | MAR1-5 | 0.01 | 0.01 | 0.07 | 0.02 |
| | MAR1-6 | 0.01 | 0.01 | 0.18 | 0.02 |
| Two | MAR2-1 | 1 | 0.005 | 1.4 | 0.04 |
| | MAR2-2 | 0.61 | 0.005 | 1.00 | 0.02 |
| | MAR2-3 | 0.37 | 0.005 | 0.74 | 0.02 |
| | MAR2-4 | 0.45 | 0.005 | 0.59 | 0.02 |
| | MAR2-5 | 0.12 | 0.005 | 0.24 | 0.02 |
| | MAR2-6 | 0.08 | 0.005 | 0.22 | 0.02 |

**Table A3-5.** Ionic composition data collected from Marillana Creek in October 2008 (dry). All values are mg/L.

| Reach | Site | Na | K | Ca | Mg | Cl | CO3 | HCO3 | SO4_S | Alkalinity | Hardness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 92.1 | 7.9 | 50 | 46.9 | 138 | 0.5 | 323 | 63.2 | 265 | 320 |
| | MAR1-2 | 92 | 7.7 | 49.3 | 46.4 | 143 | 0.5 | 311 | 62.8 | 255 | 310 |
| | MAR1-3 | 93.9 | 7.8 | 50.8 | 47.2 | 145 | 0.5 | 342 | 64.2 | 280 | 320 |
| | MAR1-4 | 102 | 7.6 | 52.8 | 49.6 | 153 | 0.5 | 329 | 67.3 | 270 | 340 |
| | MAR1-5 | 99.1 | 7.9 | 51.7 | 49.5 | 162 | 0.5 | 336 | 66.9 | 275 | 330 |
| | MAR1-6 | 98.2 | 7.5 | 52.7 | 49.3 | 144 | 0.5 | 342 | 68.5 | 280 | 330 |
| Two | MAR2-1 | 67.6 | 8.2 | 54.9 | 54.7 | 102 | 0.5 | 384 | 54.9 | 315 | 360 |
| | MAR2-2 | 76.7 | 8.2 | 50.6 | 53.8 | 99 | 0.5 | 366 | 57.6 | 300 | 350 |
| | MAR2-3 | 79 | 7.5 | 49.1 | 47.6 | 107 | 0.5 | 366 | 54.5 | 300 | 320 |
| | MAR2-4 | 86.4 | 7.9 | 46.8 | 50 | 113 | 0.5 | 366 | 56.9 | 300 | 320 |
| | MAR2-5 | 82.7 | 7.5 | 52.1 | 50.1 | 120 | 0.5 | 354 | 57.2 | 290 | 340 |
| | MAR2-6 | 83.7 | 7.5 | 51.4 | 50.6 | 125 | 0.5 | 342 | 58 | 280 | 340 |

**Table A3-6.** Ionic composition data collected from Marillana Creek in May 2009 (wet). All values are mg/L.

| Reach | Site | Na | K | Ca | Mg | Cl | CO3 | HCO3 | SO4_S | Alkalinity | Hardness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 82.7 | 7.3 | 45.6 | 45.3 | 111 | 0.5 | 311 | 53.7 | 255 | 300 |
| | MAR1-2 | 83.4 | 7.3 | 45.8 | 44.9 | 122 | 0.5 | 317 | 54.1 | 260 | 300 |
| | MAR1-3 | 86.3 | 7.3 | 48.1 | 45.5 | 129 | 0.5 | 323 | 56.1 | 265 | 310 |
| | MAR1-4 | 83.3 | 7.1 | 47.9 | 44.7 | 129 | 0.5 | 323 | 53 | 265 | 300 |
| | MAR1-5 | 86.1 | 7.1 | 47.7 | 45.5 | 124 | 0.5 | 323 | 56.5 | 265 | 310 |
| | MAR1-6 | 85.9 | 7.1 | 46.9 | 44.8 | 114 | 0.5 | 317 | 56.4 | 260 | 300 |
| Two | MAR2-1 | 67.9 | 7.7 | 52 | 51.2 | 100 | 0.5 | 366 | 51.7 | 300 | 340 |
| | MAR2-2 | 69.9 | 7.3 | 48.5 | 52.2 | 102 | 0.5 | 366 | 60.8 | 300 | 340 |
| | MAR2-3 | 72.3 | 7.4 | 48.3 | 50.5 | 99 | 0.5 | 305 | 51.6 | 280 | 330 |
| | MAR2-4 | 73.2 | 7.2 | 48.7 | 51.3 | 100 | 0.5 | 342 | 51.8 | 280 | 330 |
| | MAR2-5 | 73.1 | 7.3 | 50 | 48.5 | 104 | 0.5 | 336 | 51.5 | 275 | 320 |
| | MAR2-6 | 73.6 | 7.4 | 49.9 | 48.2 | 105 | 0.5 | 329 | 51.7 | 270 | 320 |

**Table A3-7.** Metals data collected from Marillana Creek in October 2008. Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | Al | As | B | Ba | Cd | Co | Cr | Cu | Fe | Mn | Mo | Ni | Pb | Se | U | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 0.0025 | 0.0005 | 0.36 | 0.036 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0025 | 0.0025 |
| | MAR1-2 | 0.0025 | 0.0005 | 0.34 | 0.035 | 0.0002 | 0.0025 | 0.0005 | 0.001 | 0.027 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0025 | 0.0025 |
| | MAR1-3 | 0.0025 | 0.0005 | 0.36 | 0.034 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0025 | 0.0025 |
| | MAR1-4 | 0.0025 | 0.0005 | 0.36 | 0.036 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0014 | 0.0025 | 0.0025 |
| | MAR1-5 | 0.0025 | 0.0005 | 0.35 | 0.033 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0012 | 0.0025 | 0.0025 |
| | MAR1-6 | 0.0025 | 0.0005 | 0.35 | 0.035 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.024 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.0025 | 0.0025 |
| Two | MAR2-1 | 0.0025 | 0.0005 | 0.31 | 0.013 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0025 | 0.0025 |
| | MAR2-2 | 0.0025 | 0.0005 | 0.35 | 0.027 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.0025 | 0.0025 |
| | MAR2-3 | 0.0025 | 0.0005 | 0.32 | 0.028 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0018 | 0.0025 | 0.0025 |
| | MAR2-4 | 0.0025 | 0.0005 | 0.34 | 0.024 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0015 | 0.005 | 0.0025 |
| | MAR2-5 | 0.0025 | 0.0005 | 0.3 | 0.035 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0021 | 0.0025 | 0.0025 |
| | MAR2-6 | 0.0025 | 0.0005 | 0.3 | 0.033 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.01 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0023 | 0.0025 | 0.0025 |

**Table A3-8.** Metals data collected from Weeli Wolli Creek, May 2009. Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | Al | As | B | Ba | Cd | Co | Cr | Cu | Fe | Mn | Mo | Ni | Pb | Se | U | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 0.028 | 0.0005 | 0.32 | 0.051 | 0.00005 | 0.0025 | 0.0008 | 0.0007 | 0.014 | 0.004 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0042 | 0.006 |
| | MAR1-2 | 0.0025 | 0.0005 | 0.3 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.00005 | 0.055 | 0.007 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0038 | 0.006 |
| | MAR1-3 | 0.0025 | 0.0005 | 0.29 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.0002 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0042 | 0.004 |
| | MAR1-4 | 0.0025 | 0.0005 | 0.29 | 0.051 | 0.00005 | 0.0025 | 0.0005 | 0.0003 | 0.018 | 0.005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0035 | 0.004 |
| | MAR1-5 | 0.0025 | 0.0005 | 0.3 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.0002 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0042 | 0.003 |
| | MAR1-6 | 0.026 | 0.0005 | 0.28 | 0.049 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0012 | 0.0044 | 0.006 |
| Two | MAR2-1 | 0.0025 | 0.0005 | 0.27 | 0.032 | 0.00005 | 0.0025 | 0.0005 | 0.00005 | 0.015 | 0.005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0016 | 0.004 |
| | MAR2-2 | 0.007 | 0.0005 | 0.31 | 0.042 | 0.00005 | 0.0025 | 0.0005 | 0.0001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0012 | 0.0046 | 0.004 |
| | MAR2-3 | 0.0025 | 0.0005 | 0.25 | 0.047 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0014 | 0.004 | 0.005 |
| | MAR2-4 | 0.0025 | 0.0005 | 0.25 | 0.048 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0015 | 0.0043 | 0.005 |
| | MAR2-5 | 0.0025 | 0.0005 | 0.25 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.003 | 0.004 |
| | MAR2-6 | 0.022 | 0.0005 | 0.26 | 0.055 | 0.00005 | 0.0025 | 0.0009 | 0.0007 | 0.02 | 0.02 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.0025 | 0.008 |

# Appendix 4. Microinvertebrate data from October 2008 and May 2009.

**Table A4-1.** Dry season, October 2008.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **PROTISTA** | | | | | | | | | | | | | | |
| **Ciliophora** | | *Didinium* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| | | *Euplotes* sp. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Rhizopoda** | | | | | | | | | | | | | | |
| | **Arcellidae** | *Arcella discoides* | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 |
| | | *Arcella* sp. [med., transp., domed] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Arcella* sp. [sm., brn] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Centropyxidae** | *Centropyxis aculeata* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 |
| | | *Centropyxis ecornis* | 2 | 3 | 2 | 2 | 3 | 2 | 1 | 1 | 2 | 2 | 2 | 1 |
| | | *Centropyxis* sp [med.] | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | | *Centropyxis* sp [sm, elongate] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | *Centropyxis* sp [tiny] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | **Cyclopyxidae** | *Cyclopyxis* sp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Difflugiidae** | *Difflugia elegans* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | | *Difflugia gramen* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Euglyphidae** | *Euglypha* sp. | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Lesquereusiidae** | *Lesquereusia spiralis* | 2 | 2 | 1 | 0 | 2 | 2 | 0 | 0 | 1 | 2 | 1 | 2 |
| | | *Netzelia tuberculata* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **ROTIFERA** | | | | | | | | | | | | | | |
| **Bdelloidea** | | | | | | | | | | | | | | |
| | | indet. bdelloid [v. sm.] | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Monogononta** | | | | | | | | | | | | | | |
| | **Atrochidae** | *Cupelopagis vorax* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Epiphanidae** | *Microcodides* cf. *chlaena* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Euchlanidae** | *Euchlanis* sp. | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | *Tripleuchlanis plicata* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| | **Lecanidae** | *Lecane bulla* | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| | | *Lecane curvicornis* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* cf. *elsa* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Lecane ludwigii* | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane luna* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* (*M.*) a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| | | *Lecane* (*M.*) b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | **Lepadellidae** | *Colurella* sp. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | *Lepadella* sp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Mytillinidae** | *Mytilinia ventralis* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Notommatidae** | *Eosphora anthadis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | | *Notommata copeus* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Notommata* sp. | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **COPEPODA** | | | | | | | | | | | | | | |
| **Cyclopoida** | | | | | | | | | | | | | | |
| | | *?Tropocyclops* sp. | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | ?*Microcyclops* [late copepodite only] | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | cyclopoid copepodites | 0 | 0 | 0 | 2 | 2 | 1 | 2 | 2 | 3 | 2 | 1 | 1 |
| | | cyclopoid nauplii | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 2 | 2 | 1 | 1 | 0 |
| | | | | | | | | | | | | | | |
| **CLADOCERA** | | | | | | | | | | | | | | |
| | **Chydoridae** | *Armatalona macrocopa* | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 2 |
| | | *Alona rigidicaudis* | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Alona* cf. *verrucosa* | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Ephemeroporus barroisi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **OSTRACODA** | | | | | | | | | | | | | | |
| | | *Diacypris* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | *Limnocythere* sp. | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 |
| | | juv. ostracods, indet. | 0 | 2 | 1 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 1 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **9** | **8** | **8** | **9** | **11** | **5** | **10** | **8** | **19** | **16** | **7** | **6** |

**Table A4-2.** Wet season, May 2009.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **PROTISTA** | | | | | | | | | | | | | | |
| **Rhizopoda** | | | | | | | | | | | | | | |
| | **Arcellidae** | *Arcella discoides* | 2 | 1 | 2 | 3 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 |
| | **Centropyxidae** | *Centropyxis aculeata* | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| | | *Centropyxis ecornis* | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Centropyxis* sp [med.] | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Centropyxis* sp [tiny] | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Difflugiidae** | *Difflugia* [sm, ovoid] | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Euglyphidae** | *Euglypha* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Lesquereusiidae** | *Lesquereusia modesta* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lesquereusia spiralis* | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Netzelia tuberculata* | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Trinematidae** | *Trinema* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **ROTIFERA** | | | | | | | | | | | | | | |
| **Bdelloidea** | | indet. bdelloid [sm.] | 0 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | indet. bdelloid [tiny] | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Monogononta** | | | | | | | | | | | | | | |
| | **Brachionidae** | *Keratella tropica* | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Dicranophoridae** | *Dicranophorus sp.* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Epiphanidae** | *Microcodides* cf. *chlaena* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Euchlanidae** | *Euchlanis incisa* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Euchlanis* sp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tripleuchlanis plicata* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Lecanidae** | *Lecane batillifer* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane bulla* | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane lunaris* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* cf. *thalera* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* (*M.*) a | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* (*M.*) b | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Lepadellidae** | *Colurella* sp. | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Notommatidae** | *Cephalodella* cf. *forficula* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Notommata copeus* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Trichocercidae** | *Trichocerca* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Trichotriidae** | *Macrochaetus* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **COPEPODA** | | | | | | | | | | | | | | |
| **Cyclopoida** | | | | | | | | | | | | | | |
| | | *?Tropocyclops* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Thermocyclops decipiens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | cyclopoid copepodites | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| | | cyclopoid nauplii | 0 | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **CLADOCERA** | | | | | | | | | | | | | | |
| | **Chydoridae** | *Alona rigidicaudis* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | *Alona* cf. *verrucosa* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Chydorus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Karualona karua* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Daphniidae** | *Ceriodaphnia cornuta* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **OSTRACODA** | | | | | | | | | | | | | | |
| | | *Limnocythere* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | juv. ostracods, indet. | 0 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **4** | **6** | **20** | **18** | **1** | **0** | **6** | **2** | **1** | **2** | **1** | **3** |

# Appendix 5. Hyporheic data from October 2008 and May 2009.

**Table A5-1.** Dry season, October 2008.

| | | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Species* | *CAT* | *MAR1-1dry* | *MAR1-2dry* | *MAR1-3dry* | *MAR1-4dry* | *MAR1-5dry* | *MAR1-6dry* | *MAR2-1dry* | *MAR2-2dry* | *MAR2-3dry* | *MAR2-4dry* | *MAR2-5dry* | *MAR2-6dry* |
| **ANNELIDA** | | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | **P** | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| **CRUSTACEA** | | | | | | | | | | | | | | | |
| **Amphipoda** | | | | | | | | | | | | | | | |
| **Crangonyctoid** | **Paramelitidae** | *?Chydaekata* sp. | **S** | 0 | 4 | 0 | 0 | 0 | 0 | 6 | 4 | 0 | 5 | 24 | 4 |
| | | | | | | | | | | | | | | | |
| **Copepoda** | | | | | | | | | | | | | | | |
| **Cyclopoida** | **Cyclopodidae** | *Microcyclops varicans* | **X** | 0 | 6 | 0 | 0 | 3 | 8 | 0 | 0 | 3 | 2 | 0 | 0 |
| | | *Diacyclops* sp. [copepodites] | **P** | | | | 3 | | | | | | | | |
| | | Cyclopodidae: copepodites/males | **X** | 0 | 10 | 1 | 9 | 7 | 15 | 0 | 1 | 3 | 5 | 0 | 2 |
| | | | | | | | | | | | | | | | |
| **ARACHNIDA** | | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | **U** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | | |
| **COLLEMBOLLA** | | Collembolla spp. | **X** | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| **INSECTA** | | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Baetidae** | *Baetidae Genus 1 WA sp.1* | **O** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | | | | | | | | | | | | | | | |
| **COLEOPTERA** | **Hydrophilidae** | Hydrophilidae spp. | **U** | 0 | 6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 |
| | **Scirtidae** | *Scirtidae* sp. (L) | **X** | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 14 | 0 |
| | | | | | | | | | | | | | | | |
| **DIPTERA** | | Diptera instar spp. | **X** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| | **Chironomidae** | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Chironominae | *Paratendipes "K1"* | **X** | 0 | 36 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Cryptochironomus griseidorsum* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Polypedilum sp.* | **X** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tanytarsus sp.* | **X** | 0 | 6 | 4 | 0 | 0 | 6 | 0 | 0 | 0 | 1 | 0 | 0 |
| | Orthocladiinae | Unknow n genus (WW08) | **X** | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Tanypodinae | *Paramerina sp.* | **X** | 0 | 22 | 1 | 1 | 0 | 9 | 0 | 0 | 0 | 4 | 3 | 6 |
| | | *Procladius sp.* | **X** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | **Ceratopogonidae** | Ceratopogoniinae spp. | **X** | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 0 |
| | | Ceratopogoniinae spp. (P) | **X** | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | Dasyheilenae | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| | | | | | | | | | | | | | | | |
| **LEPIDOPTERA** | **Pyralidae** | Nymphulinae spp. | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 |
| | | | | | | | | | | | | | | | |
| | | **TAXA RICHNESS** | | **0** | **13** | **4** | **3** | **3** | **5** | **3** | **3** | **2** | **13** | **6** | **7** |

**Table A5-2.** Wet season, May 2009.

| | | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class/Order | Family | Species | CAT | MAR1-1wet | MAR1-2wet | MAR1-3wet | MAR1-4wet | MAR1-5wet | MAR1-6wet | MAR2-1wet | MAR2-2wet | MAR2-3wet | MAR2-4wet | MAR2-5wet | MAR2-6wet |
| **CNIDARIA** | | | | | | | | | | | | | | | |
| **HYDROZOA** | **Hydridae** | *Hydra* sp. | **X** | 0 | 2 | 0 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| **NEMATODA** | | Nematoda spp. | **U** | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ANNELIDA** | | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | **P** | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **GASTROPODA** | | | | | | | | | | | | | | | |
| | **Lymnaeidae** | *Austropeplea lessoni* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **CRUSTACEA** | | | | | | | | | | | | | | | |
| **AMPHIPODA** | | | | | | | | | | | | | | | |
| **Crangonyctoid** | **Paramelitidae** | *?Chydaekata* sp. | **S** | 1 | 2 | 3 | 2 | 3 | 2 | 4 | 3 | 4 | 3 | 3 | 0 |
| **COPEPODA** | | | | | | | | | | | | | | | |
| **Cyclopoida** | **Cyclopodidae** | Cyclopidae: copepodites/males | **U** | 0 | 4 | 9 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| | | *Ectocyclops phaleratus* | **X** | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Microcyclops varicans* | **X** | 0 | 4 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| **ARACHNIDA** | | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | **U** | 0 | 2 | 2 | 0 | 2 | 1 | 2 | 2 | 2 | 0 | 2 | 0 |
| | | Oribatida spp. | **U** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| **COLLEMBELA** | | Collembolla spp. | **X** | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | **Entomobryoidea** | Entomobryoidea spp. | **X** | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 |
| | | Poduroidea spp. | **X** | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **INSECTA** | | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Baetidae** | *Genus 1 WA sp. 1* | **O** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 1 |
| | **Caenidae** | *Tasmanacoenis arcuata* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 3 |
| **COLEOPTERA** | **Dytiscidae** | Dytiscidae spp. (L) | **O** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Limbodessus occidentalis* | **O** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Platynectes decempunctatus* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Elmidae** | *Austrolimnius sp. (L)* | **U** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Hydraenidae** | *Hydraena sp.* | **X** | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | **Hydrophilidae** | Hydrophilidae spp. (L) | **U** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | *Enochrus sp. (L)* | **X** | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 2 | 2 | 0 |
| | | *Enochrus mastersii* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Helochares sp. (L)* | **X** | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 1 | 0 | 2 | 0 |
| | | *Laccobius sp. (L)* | **X** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class/Order | Family | Species | CAT | MAR1-1wet | MAR1-2wet | MAR1-3wet | MAR1-4wet | MAR1-5wet | MAR1-6wet | MAR2-1wet | MAR2-2wet | MAR2-3wet | MAR2-4wet | MAR2-5wet | MAR2-6wet |
| | | *Paranacaena sp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Sternolophus sp. (L)* | X | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Hygrobidae** | *Hygrobia spp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | **Scirtidae** | *Scirtidae sp. (L)* | X | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 2 | 4 |
| | | | | | | | | | | | | | | | |
| **HEMIPTERA** | **Hebridae** | *Hebrus axillaris* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | | |
| **ODONATA** | | | | | | | | | | | | | | | |
| **Anisoptera** | | Anisoptera sp. (imm) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| **Zygoptera** | | Zygoptera sp. (imm) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | | | | | | | | | | | | | | |
| **DIPTERA** | **Chironomidae** | | | | | | | | | | | | | | |
| | Chironominae | *Paratendipes "K1"* | X | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | | *Cryptochironomus griseidorsum* | X | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tanytarsus sp.* | X | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | WWTS5 | X | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 |
| | Orthocladiinae | *Rheocricotopus sp.* | X | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Cricotopus albitarsis* | X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Thienemanniella sp.* | X | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Corynonoeura sp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | Unknown genus (WW08) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| | Tanypodinae | *Paramerina sp.* | X | 6 | 64 | 1 | 0 | 36 | 0 | 26 | 6 | 32 | 1 | 34 | 15 |
| | | *Thienemannimyia sp.* | X | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Nilotanypus sp.* | X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | | *Larsia ?albiceps* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Ceratopogonidae** | Ceratopogonidae (P) | X | 0 | 0 | 2 | 0 | 1 | 2 | 2 | 0 | 2 | 0 | 2 | 0 |
| | | Ceratopogoninae sp. | X | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 3 | 2 | 3 | 2 |
| | | Dasyheleinae sp. | X | 2 | 3 | 3 | 2 | 1 | 2 | 2 | 0 | 2 | 2 | 3 | 2 |
| | | Forcipomyiinae sp. | X | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Dolichopodidae** | Dolichopodidae spp. | X | 2 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | **Ephydridae** | Ephydridae spp. | X | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Simuliidae** | Simuliidae spp. | X | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Syrphidae** | Syrphidae spp. | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Thaumaleidae** | Thaumaleidae spp. | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | **Tipulidae** | Tipulidae spp. | X | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| **TRICHOPTERA** | **Hydropsychidae** | *Cheumatopsyche sp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | **Lepidoptera** | Lepidoptera spp. (imm) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| | **Philpotomidae** | *Chimarra uranka* | X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | | | | | | | | | | | | | | |
| | | **Taxa richness** | | **16** | **15** | **19** | **6** | **15** | **13** | **20** | **7** | **20** | **8** | **17** | **22** |

# Appendix 6. Macoinvertebrate data from October 2008 and May 2009.

**Table A6-1.** October 2008.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **CNIDARIA** | | | | | | | | | | | | | | |
| **Hydrozoa** | | *Hydra* sp. | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 |
| **ANNELIDA** | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | 3 | 0 | 2 | 0 | 1 | 4 | 0 | 0 | 3 | 3 | 2 | 3 |
| **MOLLUSCA** | | | | | | | | | | | | | | |
| **GASTROPODA** | **Ancylidae** | *Ferissa petterdi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Lymnaeidae** | *Austropeplea lessoni* | 0 | 2 | 0 | 3 | 3 | 4 | 1 | 2 | 3 | 2 | 2 | 2 |
| | **Planorbidae** | *Gyraulus hesperus* | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 2 | 2 | 2 | 0 | 2 |
| **ARACHNIDA** | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | 3 | 0 | 0 | 4 | 2 | 0 | 2 | 4 | 3 | 3 | 4 | 3 |
| **ORIBATIDA** | | Oribatida spp. | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| **INSECTA** | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Caenidae** | Caenidae spp. (imm.) | 0 | 0 | 0 | 3 | 0 | 2 | 2 | 0 | 0 | 3 | 0 | 0 |
| | | *Tasmanocoenis arcuata* | 4 | 2 | 3 | 3 | 2 | 2 | 2 | 0 | 3 | 4 | 2 | 3 |
| | **Baetidae** | Baetidae spp. (imm.) | 0 | 0 | 0 | 4 | 3 | 2 | 2 | 0 | 0 | 0 | 4 | 0 |
| | | *Baetidae Genus 1 WA sp.1* | 4 | 1 | 3 | 4 | 2 | 0 | 4 | 4 | 3 | 4 | 4 | 4 |
| | | *Cloeon* sp. | 0 | 0 | 0 | 0 | 4 | 3 | 0 | 0 | 0 | 4 | 0 | 0 |
| **ODONATA** | | | | | | | | | | | | | | |
| **Anisoptera** | | Anisoptera spp.(imm) | 2 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 2 | 2 | 0 |
| | **Libellulidae** | Libellulidae spp. (imm.) | 1 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 2 |
| | | *Diplacodes haematodes* | 2 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 0 | 2 |
| | | *Nannophlebia injabandi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | | *Orthetrum caledonicum* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | *Zyxomma elgneri* | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| **HEMIPTERA** | **Belostomatidae** | *Diplonychus eques* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Corixidae** | Corixidae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Gerridae** | Gerridae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Limnogonus fossarum gilguy* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | *Rhagadotarsus anomolus* | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Hebridae** | Hebridae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 0 |
| | | *Hebrus axillaris* | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| | **Nepidae** | *Laccotrephes tristis* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Naucoridae** | *Naucoris subopacus* | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| | **Notonectidae** | *Anisops* sp. (F) | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Pleidae** | *Paraplea brunni* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Velidae** | Veliidae spp.(imm.) | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | *Microvelia australiensis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **COLEOPTERA** | **Dytiscidae** | *Platynectes* sp. (L) | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | *Platynectes decempunctatus var decemp.* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 0 |
| | | *Tiporus tambreyi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Elmidae** | *Austrolimnius* sp. (A) | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Austrolimnius* sp. (L) | 0 | 0 | 0 | 3 | 0 | 1 | 1 | 2 | 3 | 0 | 2 | 1 |
| | **Gyrinidae** | *Aulonogyrus strigosus* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Aulonogyrus/Macrogyrus* sp. (L) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | | *Dineatus australis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | **Hydraenidae** | *Hydraena sp.* | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Hydrophilidae** | *Berosus* sp. (L) | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 3 | 0 | 0 |
| | | *Berosus dallasae* | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Coelostoma sp.* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 |
| | | *Helochares* sp. (L) | 2 | 2 | 1 | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | 2 |
| | | *Helochares tatei* | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 0 | 1 |
| | | *Laccobius bili* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Paracymus pygmaeus* | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Sternolophus* sp. (L) | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Hydrochidae** | *Hydrochus* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 2 |
| | **Scirtidae** | Scirtidae spp. (L) | 2 | 2 | 0 | 3 | 0 | 1 | 0 | 1 | 2 | 0 | 2 | 1 |
| **DIPTERA** | **Chironomidae** | Chironomidae spp. (P) | 2 | 2 | 3 | 4 | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 3 |
| | | *Paramerina sp.* | 2 | 1 | 0 | 3 | 3 | 0 | 0 | 0 | 2 | 2 | 3 | 3 |
| | | *Thienemannimyia sp.* | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 2 | 3 | 3 | 2 | 3 |
| | | *Nilotanypus sp.* | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 1 |
| | | *Larsia ?albiceps* | 2 | 2 | 2 | 2 | 3 | 0 | 2 | 2 | 3 | 1 | 3 | 3 |
| | | *Procladius sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Ablabesmyia hilli* | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 1 |
| | | *Rheocricotopus sp.* | 3 | 2 | 2 | 3 | 0 | 0 | 3 | 2 | 1 | 2 | 3 | 1 |
| | | *nr. Parametriocnemus* | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Cricotopus albitarsis* | 2 | 2 | 3 | 0 | 0 | 0 | 3 | 3 | 2 | 3 | 4 | 3 |
| | | *Thienemanniella sp.* | 3 | 1 | 1 | 3 | 2 | 0 | 3 | 3 | 2 | 2 | 4 | 2 |
| | | *Corynonoeura sp.* | 2 | 1 | 3 | 4 | 3 | 0 | 2 | 0 | 0 | 1 | 3 | 3 |
| | | *Paratendipes "K1"* | 0 | 3 | 1 | 3 | 2 | 0 | 2 | 1 | 0 | 1 | 0 | 0 |
| | | *Chironomus sp.* | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | *Cryptochironomus griseidorsum* | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 0 | 1 | 0 | 2 | 2 |
| | | *Polypedilum nubifer* | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Dicrotendipes sp1* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| | | *Dicrotendipes sp2* | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 3 | 0 |
| | | *Cladopelma curtivala* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| | | *Polypedilum watsoni* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | | *Paracladopelma sp "M1"* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | *Polypedilum sp.* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 |
| | | WWC17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

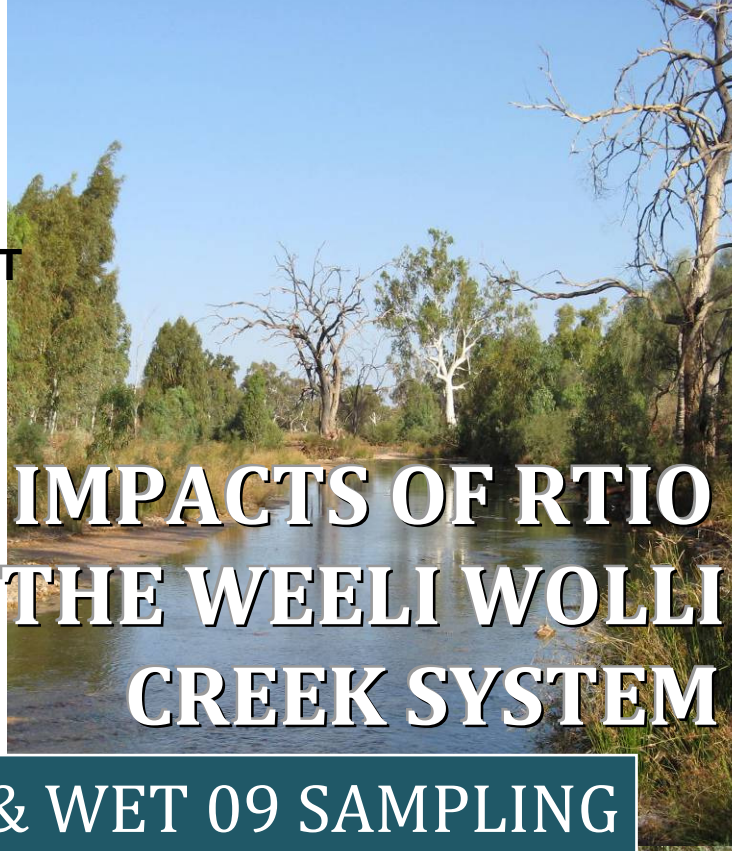
| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| | | *Tanytarsus sp.* | 1 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 3 |
| | | *Paratanytarsus sp.* | 0 | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 0 |
| | | *Cladotanytarsus sp.* | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | WWTS5 | 1 | 2 | 2 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 |
| | **Ceratopogonidae** | Ceratopogoniinae spp. | 2 | 2 | 3 | 3 | 4 | 2 | 2 | 1 | 2 | 2 | 3 | 3 |
| | | Dasyheilenae spp. | 3 | 2 | 0 | 3 | 4 | 2 | 0 | 4 | 3 | 4 | 2 | 0 |
| | | Forcypomiinae spp. | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 2 | 0 |
| | | Ceratopogonidae spp. (P) | 0 | 2 | 2 | 3 | 1 | 2 | 0 | 2 | 2 | 2 | 2 | 2 |
| | **Culicidae** | *Anopheles* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | Culicidae spp. (P) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Dolichopidae** | Dolichopodidae spp. | 3 | 0 | 2 | 3 | 2 | 0 | 2 | 2 | 2 | 2 | 2 | 2 |
| | **Ephydridae** | Ephydridae spp. | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 1 | 1 |
| | **Simuliidae** | Simulidae spp (P) | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 0 | 2 |
| | | Simulidae spp. | 3 | 3 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 | 2 | 2 |
| | **Stratiomyidae** | Stratiomyidae spp. | 0 | 2 | 0 | 0 | 0 | 2 | 1 | 0 | 3 | 0 | 2 | 1 |
| | **Tabanidae** | Tabanidae spp. | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 1 | 0 |
| | **Tipulidae** | Tipulidae spp. | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TRICHOPTERA** | | Trichoptera spp. (P) | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 1 |
| | **Ecnomidae** | *Ecnomus* sp. | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 2 |
| | **Hydropsychidae** | *Cheumatopsyche wellsae (spAV11)* | 4 | 3 | 2 | 4 | 2 | 1 | 4 | 4 | 4 | 4 | 5 | 4 |
| | **Hydroptilidae** | *Hellyethira* sp | 0 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 3 | 1 |
| | **Orthotrichidae** | *Orthotrichia spp.* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Leptoceridae** | Oecetis spp. | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| | | *Triaenodes spp.* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Triplectides australis* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Triplectides ciskus seductus* | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 1 |
| | **Philopotamidae** | Philopotamidae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | *Chimmara* sp. | 4 | 3 | 1 | 3 | 0 | 0 | 4 | 3 | 3 | 3 | 2 | 3 |
| **LEPIDOPTERA** | **Pyralidae** | *Nymphulinae cf sp. 3* | 2 | 3 | 3 | 3 | 3 | 0 | 2 | 3 | 2 | 3 | 0 | 2 |
| | | *Nymphulinae cf sp. 37* | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 3 | 0 | 0 |
| | | Nymphulinae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 3 | 0 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **35** | **40** | **36** | **46** | **33** | **34** | **40** | **31** | **47** | **47** | **52** | **52** |

**Table A6-2.** May 2009.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **ANNELIDA** | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 1 | 2 | 0 |
| | | | | | | | | | | | | | | |
| **MOLLUSCA** | | | | | | | | | | | | | | |
| **GASTROPODA** | **Planorbidae** | *Gyraulus hesperus* | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 0 | 0 | 0 |
| | **Ancylidae** | *Ferrissia petterdi* | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **CRUSTACEA** | | | | | | | | | | | | | | |
| **AMPHIPODA** | **Paramelitidae** | *?Chydaekata* sp. | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **ARACHNIDA** | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 2 | 2 | 3 | 4 | 4 |
| **ORIBATIDA** | | Oribatidae spp. | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **INSECTA** | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Baetidae** | Baetidae spp (dam) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | *Genus 1 WA sp. 1* | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 5 | 5 | 5 | 4 | 4 |
| | **Caenidae** | *Tasmanacoensis arcutata* | 2 | 4 | 4 | 2 | 2 | 3 | 1 | 0 | 2 | 3 | 0 | 4 |
| **ODONATA** | | | | | | | | | | | | | | |
| **Anisoptera** | | Anisoptera spp. (imm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Aeshnidae** | Aeshnidae spp. (imm) | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Gomphidae** | *Austrogomphus gordoni* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Libellulidae** | *Diplacodes haematodes* | 0 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Nannophlebia injabandi* | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 |
| **Zygoptera** | **Coenagrionidae** | Coenagrionidae spp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **HEMIPTERA** | **Gerridae** | *Limnogonus fossarum gilguy* | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 1 |
| | **Mesoveliidae** | *Mesoveliidae spp. (imm)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Naucoridae** | *Naucoris subopacus* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **COLEOPTERA** | **Dytiscidae** | *Platynectes decempunctatus var decem.* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Platynectes* sp. (L) | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tiporus centralis* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Elmidae** | *Austrolimnius* sp (A) | 0 | 0 | 2 | 3 | 3 | 2 | 1 | 1 | 0 | 2 | 0 | 1 |
| | | *Austrolimnius* sp. (L) | 0 | 0 | 1 | 3 | 4 | 3 | 2 | 2 | 0 | 2 | 2 | 0 |
| | **Gyrinidae** | *Aulonogyrus strigosus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Dineutus australis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | **Hydrophilidae** | Hydrophilidae spp. (L) | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 0 | 1 |
| | | *Berosus dallasae* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | *Helochares tatei* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Helochares* sp. (L) | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| | **Scirtidae** | Scirtidae spp. (L) | 2 | 0 | 0 | 2 | 0 | 1 | 0 | 3 | 3 | 2 | 3 | 3 |
| **DIPTERA** | **Ceratopogonidae** | Ceratopogoniinae spp. | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 3 | 2 | 2 |
| | | Dasyheleinae spp. | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Forcipomyiinae spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MAR1-1 | MAR1-2 | MAR1-3 | MAR1-4 | MAR1-5 | MAR1-6 | MAR2-1 | MAR2-2 | MAR2-3 | MAR2-4 | MAR2-5 | MAR2-6 |
| | **Chironomidae** | Chironomidae spp. (P) | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 0 | 0 | 0 |
| | | *Paramerina sp.* | 0 | 2 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 2 |
| | | *Thienemannimyia sp.* | 1 | 3 | 1 | 2 | 2 | 1 | 0 | 1 | 2 | 3 | 2 | 3 |
| | | *Nilotanypus sp.* | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 0 | 2 | 1 | 2 |
| | | *Larsia ?albiceps* | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 0 | 3 |
| | | *Procladius sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | *Ablabesmyia hilli* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Rheocricotopus sp.* | 3 | 3 | 0 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 |
| | | *Cricotopus albitarsis* | 3 | 2 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 3 |
| | | *Thienemanniella sp.* | 3 | 2 | 0 | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
| | | *Corynonoeura sp.* | 1 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | *Paracladopelma "K2"* | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Paratendipes "K1"* | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| | | *Cryptochironomus griseidorsum* | 0 | 2 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| | | *Dicrotendipes sp1* | 2 | 2 | 3 | 3 | 3 | 2 | 0 | 0 | 1 | 0 | 2 | 2 |
| | | *Dicrotendipes sp2* | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 2 | 2 |
| | | *Tanytarsus sp.* | 2 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 1 |
| | | *Cladotanytarsus sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | WWTS5 | 2 | 2 | 0 | 2 | 0 | 0 | 2 | 1 | 2 | 2 | 2 | 2 |
| | **Dolichopodidae** | Dolichopodidae spp. | 0 | 3 | 0 | 2 | 2 | 3 | 2 | 0 | 2 | 1 | 0 | 0 |
| | **Simulidae** | Simulidae spp. | 3 | 4 | 1 | 3 | 3 | 4 | 3 | 3 | 4 | 3 | 2 | 2 |
| | | Simuliidae sp (P) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 |
| | **Syrphidae** | Syrphidae spp. | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Tabanidae** | Tabanidae spp. | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 |
| | **Tanyderidae** | Tanyderidae spp. | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TRICHOPTERA** | **Ecnomidae** | *Ecnomus sp.* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Hydroptilidae** | Hydroptilidae sp (imm) | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Hellyethira sp.* | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | **Hydropsychidae** | *Cheumatopsyche wellsae* | 4 | 4 | 1 | 4 | 4 | 0 | 5 | 5 | 0 | 4 | 4 | 4 |
| | **Leptoceridae** | *Oecetis sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | *Triplectides ciuskus seductus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Philopotamidae** | *Chimarra* sp. | 3 | 4 | 0 | 3 | 3 | 0 | 4 | 3 | 0 | 3 | 3 | 3 |
| **LEPIDOPTERA** | **Nymphulinae** | *Nymphulinae sp. 3* | 3 | 4 | 3 | 4 | 4 | 4 | 0 | 3 | 3 | 3 | 3 | 4 |
| | | *Nymphulinae sp. 18* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 2 |
| | | *Nymphulinae sp. 37* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **23** | **26** | **32** | **30** | **29** | **26** | **27** | **23** | **30** | **26** | **25** | **33** |

RIO TINTO
HAMERSLEY HOPE MANAGEMENT SERVICES



# CUMULATIVE IMPACTS OF RTIO MINING ON THE WEELI WOLLI CREEK SYSTEM

## DRY 08 & WET 09 SAMPLING
## FINAL REPORT

*Wetland Research & Management*

July 2010

## Study Team

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## Recommended Reference Format

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## Disclaimer



This document has been printed on 'Reflex Green Recycled Paper'.

Frontispiece (top to bottom): Marillana Creek at MAR2-5; MAR2-3; and, riffle at MAR1-3 (all photos taken by WRM personnel).

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## TABLES



## FIGURES

## PLATES

# 1 INTRODUCTION

## 1.1 Background

The Rio Tinto Iron Ore (RTIO) mine at Yandi is located in the East Pilbara region of Western Australia. A number of temporary creeklines traverse the mine area, including Marillana, Yandicoogina, Phil's and Weeli Wolli creeks (Figures 1 & 2). The mine has been operating since 1996, and as part of mine operations de-watering of the Yandi JSE and Central pits has been necessary since 1998, with excess water discharged directly into Marillana Creek. Since late 2007, excess water has also been discharged into Weeli Wolli Creek (from discharge outlet D06; see Figure 2). For the period 1998-2009, average annual discharge into Marillana Creek from all outlets combined was 0.61 GL/year (Figure 3). Peak average discharge into Marillana Creek was 1.29 GL/year in 2009. Average annual discharge into Weeli Wolli Creek between 2008 and 2009 was 0.15 GL/year (Figure 3). Projected average discharge into Marillana Creek and Weeli Wolli Creek is anticipated to be 1.06 GL/year and 0.92 GL/year, respectively (Figure 3). Upstream of RTIO Yandi on Marillana Creek, the BHP-BIO Yandi mine (operating since 1994) also dewaters their developing pit, with discharge occurring into the upstream section of Marillana creek. It is likely that discharge from BHP-BIO will increase over the next few years as an increase in their abstraction rate to a peak of 15GL/year has been approved, with excess water likely being discharged into Marillana Creek. Downstream of these mining operations, Marillana Creek flows into Weeli Wolli Creek (see Figures 1 & 2), into which RTIO's Hope Downs 1 (HD1) operation also discharges their dewatering water. Discharge from HD1 is predominantly via a single gabion structure adjacent to the main creek, however a system of spur lines deliver water as seepage flows to important trees and pools upstream of the gabion, in the area of the historic spring and permanent pools. Approximately 10% of dewatering discharge is released via the system of spur lines, with the remainder released from the gabion. The total volume discharged from HD1 into Weeli Wolli Creek varies between years, but was approx. 25.55 GL/year during 2008/09.

Discharge from Yandi (RTIO & BHPBIO) operations pose potential impacts to the aquatic ecosystem of Marillana Creek, and also to the lower Weeli Wolli Creek system downstream of the confluence with Marillana; this section of Weeli Wolli Creek is also impacted by discharge water from HD1, adding to the cumulative impact on this section of the creekline. An added issue is the proposed listing of the Fortescue Marshes as a Ramsar Wetland of International Importance. Weeli Wolli flows to the north, where it drains into the Fortescue River via the Fortescue Marsh. The Marsh is approximately 20 km downstream from the Marillana - Weeli Wolli Creek confluence. Historically the two systems are only connected during flooding associated with intense cyclonic events. With additional discharge from BHP-BIO's Yandi, RTIO's Yandi and RTIO's HD1 operations, surface flows along Weeli Wolli will continue to increase, and the concern from the regulators is ensuring that permanent flows do not reach the Marsh. Prior to dewatering discharge at HD1, the spring resulted in perennial surface flow for approximately 2 km along the upper section of Weeli Wolli Creek. Since the commencement of discharge from HD1, surface flows in Weeli Wolli Creek now extend approximately 20 km downstream of historic perennial flow, and currently extend past Yandi operations, beyond the confluence with Marillana Creek, downstream of Gray's Crossing.

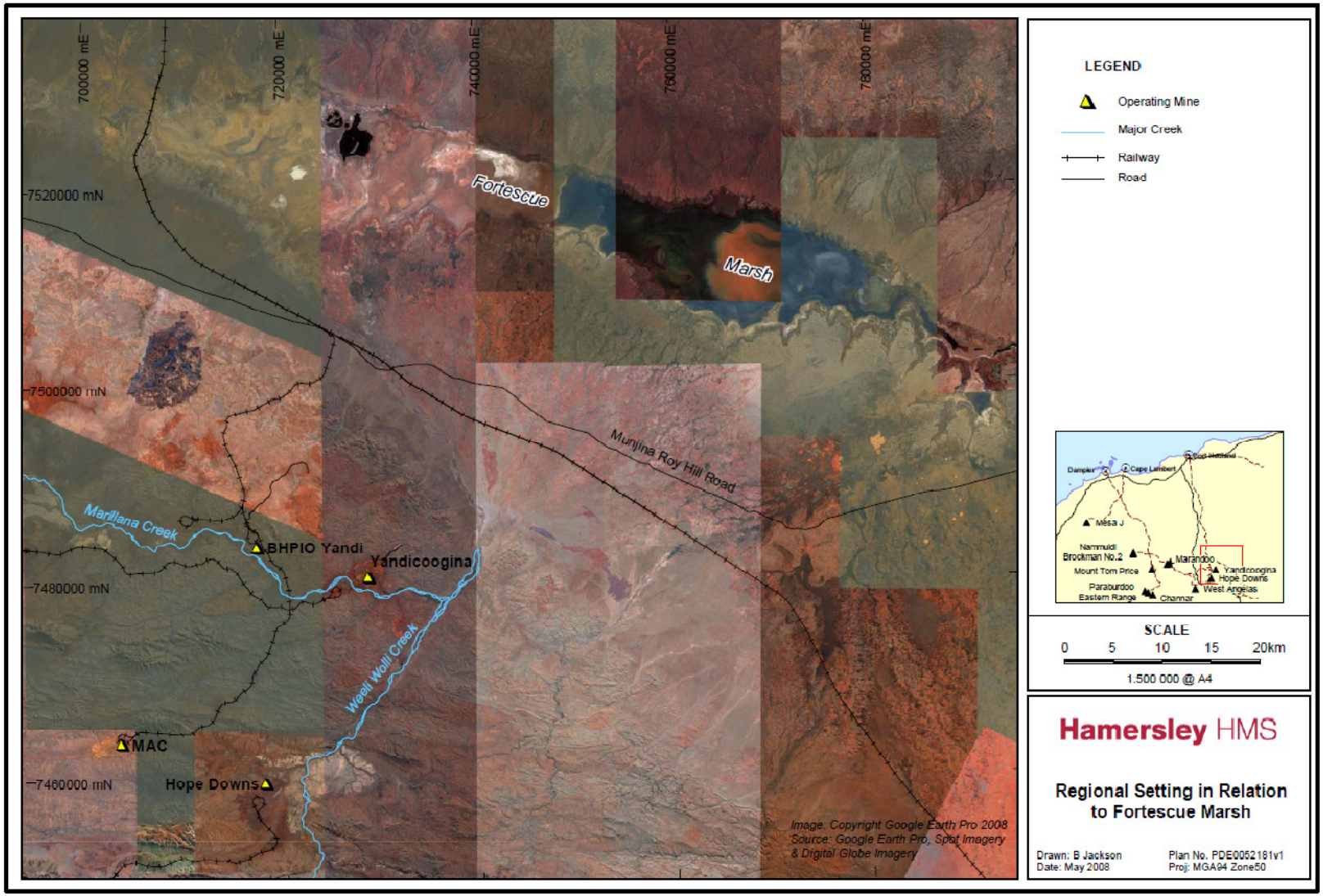



**Figure 1.** Map showing the location of Marillana Creek and Weeli Wolli Creek with respect to the Fortescue Marshes in the Pilbara Region of Western Australia.

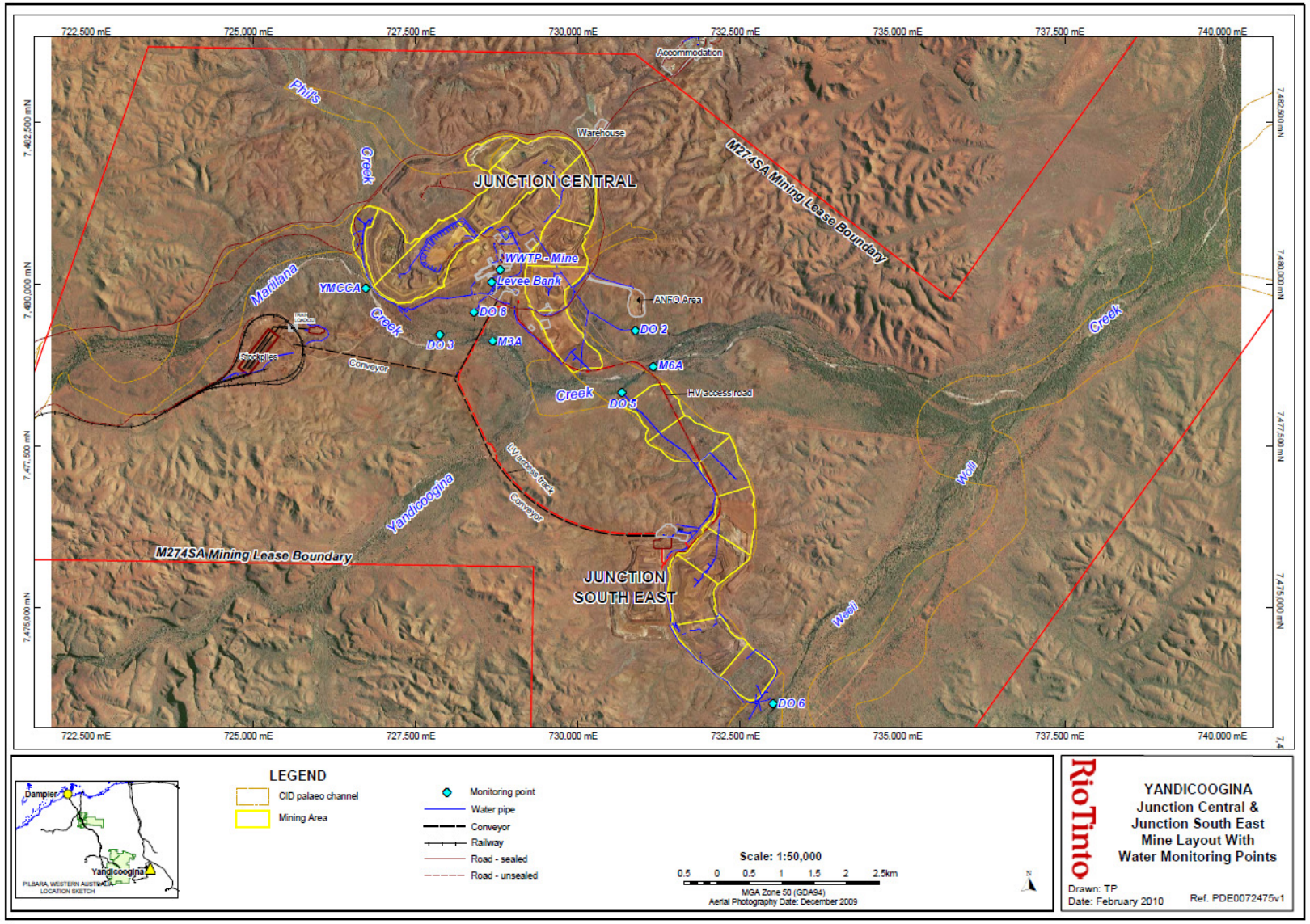



**Figure 2.** Map showing the location of all discharge outlets (D01-D09) across the Yandi mine lease.

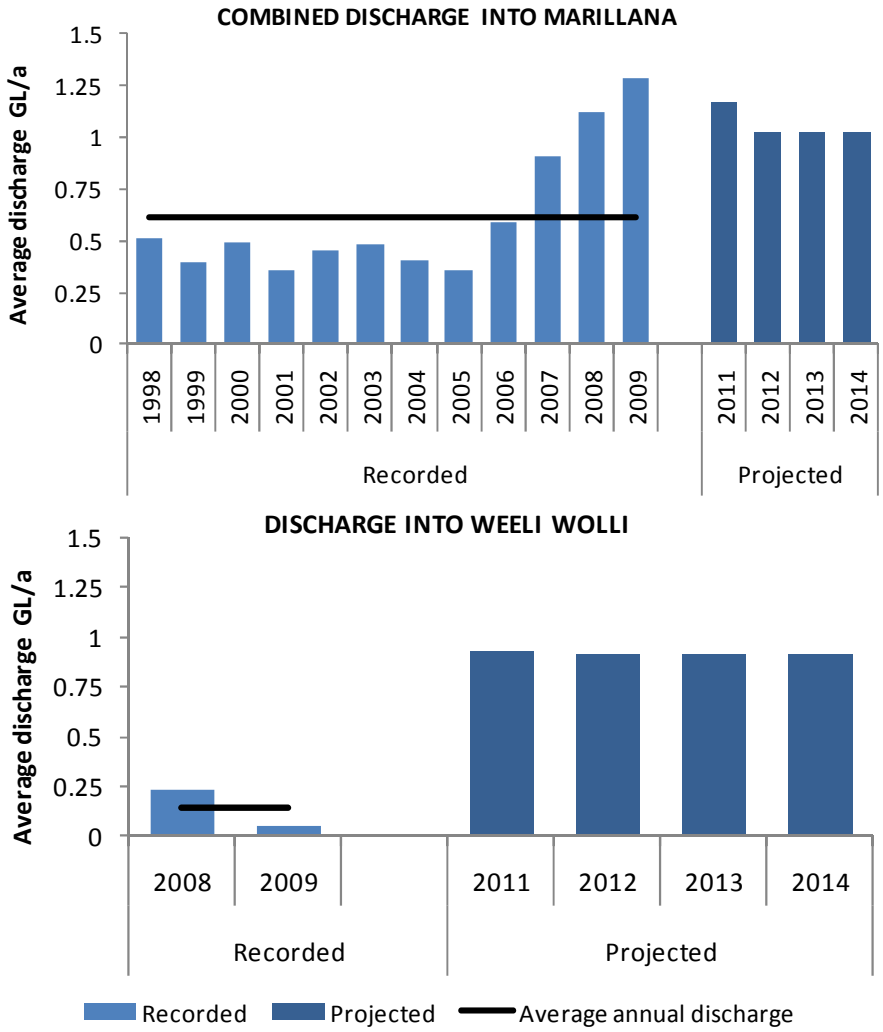



**Figure 3.** Current and projected average discharge (GL/year) into Marillana Creek for all outlets combined (top), and into Weeli Wolli Creek (bottom). Information provided by RTIO.

The specific and cumulative effects of these operations need to be assessed. Therefore, RTIO commissioned *Wetland Research and Management* to undertake a study of the aquatic biota of Marillana Creek. The purpose of this was to a.) assess specific effects of RTIO's (and BHPIO's) Yandi operations on Marillana Creek, and b.) provide data that supports the HD1 Living Water Survey, to assess Cumulative Impacts on the Weeli Wolli system. To this end, Marillana Creek was broken into two reaches of differing discharge regimes to document current ecological condition. The two study reaches were; 1.) downstream of BHP-BIO's discharge but upstream of RTIO's Yandi discharge, and 2.) downstream of RTIO's Yandi discharge as far as surface flows reach (approx. 0.5 km upstream of the confluence with Weeli Wolli).

Similarly, the Living Water Survey aimed to characterise Weeli Wolli Creek in four reaches of differing flow regime to document current ecological condition. The four study reaches were; (1.) the spring where permanent pools were located, 2.) within the reach of historic permanent flow downstream of the spring, 3.) within the area of creek which was highly ephemeral and dry for much of the year but is now perennial as far as the confluence with

Marillana Creek due to discharge[1], and 4.) the now perennial reach below the confluence with Marillana Creek[2], which varies in length depending on season and dewatering discharge.

This report presents the findings from two rounds of sampling at both Marillana and Weeli Wolli creeks (October 2008 & May 2009; see WRM 2009a).

## 1.2 Study objectives

The aim of this study was to document current ecological condition of Marillana Creek and Weeli Wolli Creek with respect to water quality and aquatic biota assemblages (microinvertebrates, macroinvertebrates, hyporheic fauna[3] and fish) to establish baseline conditions, assess current effects of RTIO's Yandi mine, and provide data to feed into a Cumulative Impacts study of the Weeli Wolli system.

[1] Discharge from RTIO's Yandi at outlet D06 is into Reach Three on Weeli Wolli Creek.

[2] As this reach is downstream of the confluence with Marillana Creek, it is also influenced by discharge from RTIO and BHP-BIO's Yandi mines.

[3] Aquatic invertebrate fauna which reside in the area below the streambed where water percolates through spaces between the rocks and cobbles.

# 2 METHODS

## 2.1 Study area

Marillana Creek and Weeli Wolli Creek are located approximately 75 km north-west of Newman, in the Pilbara Region of Western Australia. The main drainage system in the area is the Fortescue River, which arises near Newman, flows north and then northwest into the Fortescue Marsh (see Figure 1).

Marillana Creek drains eastward before joining Weeli Wolli Creek. Streamflow is seasonal, with flows usually occurring in response to heavy rainfall events. On average, Marillana Creek historically flows for 30 to 60 days a year. Annual streamflow in the area around Yandi can range from negligible to tens of millions of cubic metres.

Weeli Wolli Creek is approximately 70 km in length, and has a catchment area of 4100 $km^2$. A dense network of ephemeral tributary streamlines is associated with the system. Weeli Wolli flows to the north, where it drains into the Fortescue River via the Fortescue Marsh. The creek is fed by Weeli Wolli Spring which arises as a result of groundwater flow being "dammed" by the Brockman Formation, which forces groundwater to the surface, appearing as the perennial spring.

Weeli Wolli Spring is considered to be of high ecological, social and cultural value (EPA 2001, Kendrick 2001, Gardiner 2003, van Leeuwen 2009). It has high environmental significance in the Pilbara region because it is a permanent water body. Due to the aridity of the region, such systems are rare. Halse *et al.* (2002) suggested that such systems provide an important "source of animals for colonisation of newly flooded pools and maintenance of populations of invertebrate species at the regional level". The creek is also of significance to indigenous people as it holds mythological and ceremonial importance (EPA 2001), and has social value in the form of local tourism (van Leeuwen 2009). In 2009 the spring was nominated for listing as a Threatened Ecological Community at the State level, on the basis of floristic communities as well as the diverse aquatic invertebrate and significant stygofauna communities (van Leeuwen 2009).

## 2.2 Sites and sampling design

Marillana Creek was broken into two main reaches, reflecting differences in mining operations and discharge:

- Reach One – downstream of BHP-BIO's Yandi discharge and upstream of RTIO's Yandi discharge,
- Reach Two - downstream of RTIO's Yandi discharge as far as flows reach (just upstream of the confluence with Weeli Wolli) (Figure 4).

Weeli Wolli Creek was also stratified into separate reaches of differing historic flow regime. Four reaches along Weeli Wolli Creek were sampled, including:

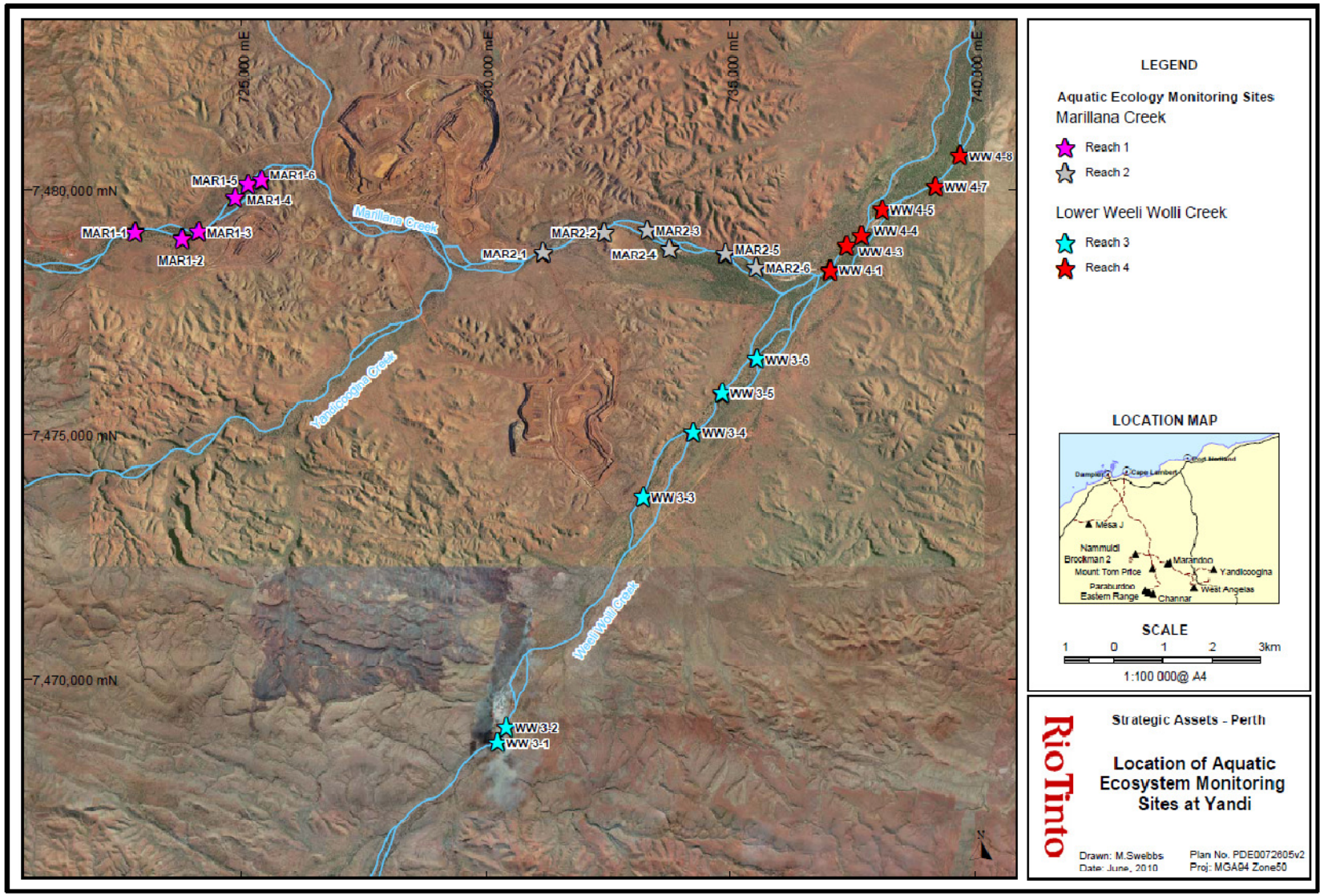



**Figure 4.** Location of the reaches and sampling sites along Marillana Creek and lower Weeli Wolli Creek.

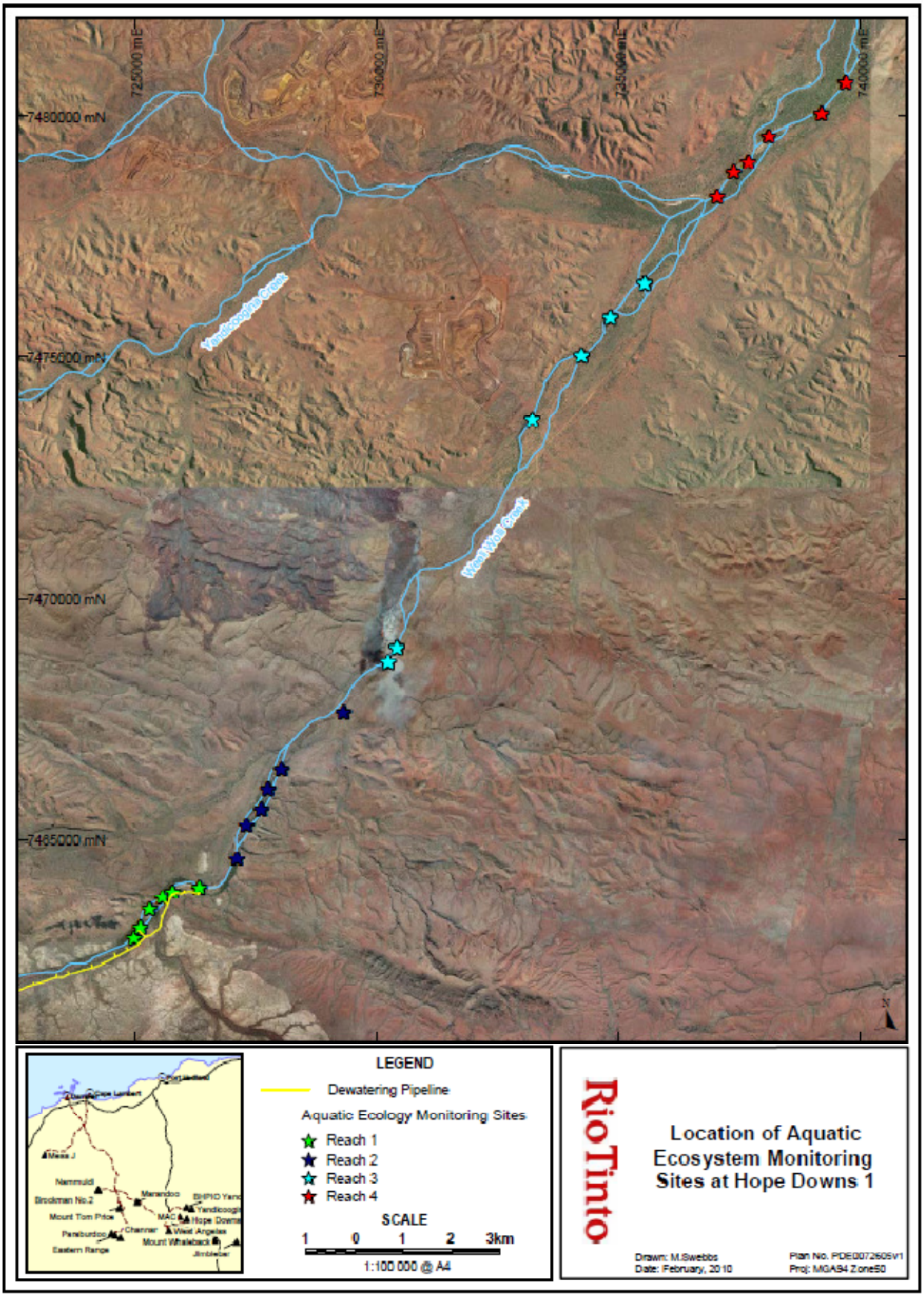



**Figure 5.** Location of the reaches and sampling sites along Weeli Wolli Creek.

- Reach One – in the area of Weeli Wolli Spring where permanent pools historically were located,
- Reach Two - within the historic reach of continuous permanent flow downstream of the spring,
- Reach Three - downstream of this point to the junction with Marillana Creek, where the creek historically was highly ephemeral and dry for much of the year, and
- Reach Four - the now permanent reach below the Marillana Creek confluence towards Fortescue Marshes (WRM 2009a; see Figures 4 and 5).

Six replicate samples were taken within each reach to characterise the fauna and conditions along each reach, and to provide adequate statistical power for analyses (Tables 1 and 2). Replicates were located to provide a geographical spread within each reach, but positions were influenced by access (Figures 4 and 5).

Site photographs are provided in Appendix 1.

**Table 1.** GPS location (UTM WGS84) of sites sampled along Marillana Creek.

| *Reach* | *Historic flows* | *Site* | *GPS Location* | |
|---|---|---|---|---|
| | | | *Easting* | *Northing* |
| 1 | Upstream of RTIO's Yandi discharge | MAR1-1 | 50 722832 | 7479165 |
| | | MAR1-2 | 50 723796 | 7479028 |
| | | MAR1-3 | 50 724135 | 7479167 |
| | | MAR1-4 | 50 724876 | 7479864 |
| | | MAR1-5 | 50 725143 | 7480136 |
| | | MAR1-6 | 50 725416 | 7480219 |
| 2 | Downstream of RTIO's Yandi discharge | MAR2-1 | 50 731178 | 7478739 |
| | | MAR2-2 | 50 732424 | 7479151 |
| | | MAR2-3 | 50 733306 | 7479198 |
| | | MAR2-4 | 50 733764 | 7478806 |
| | | MAR2-5 | 50 734906 | 7478710 |
| | | MAR2-6 | 50 735531 | 7478436 |

## 2.3 Water quality

At each site a number of water quality variables were recorded *in situ* using portable WTW field meters, including pH, electrical conductivity (µS/cm), dissolved oxygen (% and mg/L), and water temperature (°C). Water depth was measured using a graduated pole. Undisturbed water samples were taken for laboratory analyses of ionic composition, nutrients and metals. Samples collected for nutrients and metals were filtered through 0.45 µm Millipore nitrocellulose filters. All water samples were kept cool in an esky while in the field, and frozen as soon as possible for subsequent transport to the laboratory. All laboratory analyses were conducted by the Natural Resources Chemistry Laboratory, Chemistry Centre, WA (a NATA accredited laboratory). Water quality variables measured are summarised in Table 3.

**Table 2.** GPS location (UTM WGS84) of sites sampled along Weeli Wolli Creek.

| *Reach* | *Historic flows* | *Site* | *GPS Location* | |
|---|---|---|---|---|
| | | | *Easting* | *Northing* |
| 1 | springs and permanent pools | WW1-1 | 50 724996 | 7463013 |
| | | WW1-2 | 50 725118 | 7463229 |
| | | WW1-3 | 50 725314 | 7463617 |
| | | WW1-4 | 50 725578 | 7463854 |
| | | WW1-5 | 50 725784 | 7463974 |
| | | WW1-6 | 50 726338 | 7464051 |
| 2 | permanent flows | WW2-1 | 50 727121 | 7464649 |
| | | WW2-2 | 50 727314 | 7465349 |
| | | WW2-3 | 50 727622 | 7465670 |
| | | WW2-4 | 50 727760 | 7466098 |
| | | WW2-5 | 50 728036 | 7466500 |
| | | WW2-6 | 50 729320 | 7467676 |
| 3 | highly ephemeral flows, where the creek was dry for much of the year | WW3-1 | 50 730243 | 7468720 |
| | | WW3-2 | 50 730424 | 7469027 |
| | | WW3-3 | 50 733220 | 7473739 |
| | | WW3-4 | 50 734243 | 7475063 |
| | | WW3-5 | 50 734838 | 7475862 |
| | | WW3-6 | 50 735545 | 7476564 |
| 4 | Highly ephemeral flows, where the creek was dry for much of the year (but has been influenced by discharge from BHP's Yandi mine) | WW4-1 | 50 737041 | 7478376 |
| | | WW4-3 | 50 737381 | 7478874 |
| | | WW4-4 | 50 737684 | 7479082 |
| | | WW4-5 | 50 738105 | 7479616 |
| | | WW4-7 | 50 739194 | 7480091 |
| | | WW4-8 | 50 739700 | 7480735 |

Water quality data were compared against ANZECC/ARMCANZ (2000) water quality guidelines. ANZECC/ARMCANZ (2000) provides trigger values for a range of water quality parameters for the protection of aquatic ecosystems. These trigger values may be adopted in the absence of adequate site-specific data. ANZECC/ARMCANZ (2000) recommends different levels of species protection applied to different levels of ecosystem condition. The 99% value is applied to high conservation/ecological value ecosystems, the 95% value to slightly to moderately disturbed ecosystems and the 90% or 80% values to highly disturbed ecosystems. In the ANZECC/ARMCANZ (2000) water quality management framework, the decision about the ecosystem condition is typically a joint one between stakeholders. Based on the observed condition of creeks in the vicinity of Weeli Wolli Creek, it is suggested that either the 99% or possibly the 95% values are applied. When applying trigger values (TVs), ANZECC/ARMCANZ (2000) state the following:

> "*Trigger values are concentrations that, if exceeded, would indicate a potential environmental problem, and so 'trigger' a management response, e.g. further investigation and subsequent refinement of the guidelines according to local conditions*." (Section 2.1.4); and
>
> "*Exceedances of the trigger values are an 'early warning' mechanism to alert managers of a potential problem. They are not intended to be an instrument to assess 'compliance' and should not be used in this capacity*." (Section 7.4.4).

**Table 3.** All water quality parameters measured.

| *Parameter* | *Units* | *Parameter* | *Units* |
|---|---|---|---|
| pH | pH units | Aluminium (Al) | mg/L |
| Electrical conductivity | µS/cm | Arsenic (As) | mg/L |
| Dissolved oxygen | % saturation | Boron (B) | mg/L |
| Dissolved oxygen | mg/L | Barium (Ba) | mg/L |
| Water temp | ℃ | Cadmium (Cd) | mg/L |
| Average water depth | m | Cobalt (Co) | mg/L |
| Maximum water depth | m | Chromium (Cr) | mg/L |
| Sodium (Na) | mg/L | Copper (Cu) | mg/L |
| Potassium (K) | mg/L | Iron (Fe) | mg/L |
| Calcium (Ca) | mg/L | Manganese (Mn) | mg/L |
| Magnesium (Mg) | mg/L | Molybdenum (Mo) | mg/L |
| Chloride (Cl) | mg/L | Nickel (Ni) | mg/L |
| $CO_3$ | mg/L | Lead (Pb) | mg/L |
| $HCO_3$ | mg/L | Selenium (Se) | mg/L |
| $SO_4$ | mg/L | Uranium (U) | mg/L |
| Alkalinity | mg/L | Vanadium (V) | mg/L |
| Hardness | mg/L | Zinc (Zn) | mg/L |
| Nitrate ($NO_3$) | mg/L | | |
| Ammonium ($NH_3$) | mg/L | | |
| Total Nitrogen (total N) | mg/L | | |
| Total Phosphorus (total P) | mg/L | | |

Hence, TVs should not be used in a 'pass-fail' approach to water quality management. Their main purpose is to inform managers and regulators that changes in water quality are occurring and may need to be investigated. In the case of baseline data collection, the guidelines may be used to establish background levels relative to TVs, and show where certain elements may be naturally elevated (i.e. due to geological features). This allows future discrimination of mine effects from natural enrichment. Where background levels are elevated, then it is desirable to establish site-specific TVs.

The guidelines recommend, that where an appropriate default TV does not exist, or the default TV is consistently lower than natural background concentrations, natural background data should be used to derive the TV. In these instances, the 80$^{th}$ percentile (and 20$^{th}$ percentile in the case of variables that require an upper and lower guidelines, e.g. pH) of a baseline dataset should be used. This value is then compared to the median value of the subject water (i.e. the dewatering water) (for further details see Sections 3.3.2.4 and 7.4.4 of ANZECC/ARMCANZ 2000). It is also recommended that TV are based on at least two years of monthly monitoring data.

## 2.4 Microinvertebrates

Microinvertebrate samples were collected from each site by gentle sweeping over an approximate 15 m distance with a 53 µm mesh pond net. Care was taken not to disturb the benthos (bottom sediments). Samples were preserved in 70% ethanol and sent to Dr Russ Shiel of Adelaide University for processing. Dr Shiel is a world authority on microfauna, with extensive experience in fauna survey and impact assessment across Australasia.

Microinvertebrate samples were processed by identifying the first 200-300 individuals encountered in an agitated sample decanted into a 125 $mm^2$ gridded plastic tray, with the tray then scanned for additional missed taxa also taken to species, and recorded as 'present'. Specimens were identified to the lowest taxon possible, i.e. species or morphotypes. Where specific names could not be assigned, vouchers were established. These vouchers are held by Dr Shiel at Adelaide University, Adelaide, Australia.

## 2.5 Hyporheic fauna

At each site, hyporheic sampling was conducted by digging a hole approximately 20 cm deep and 40 cm diameter in alluvial gravels in dry streambed adjacent to the waters edge. The hole was allowed to infiltrate with water, and then the water column was swept with a modified 53 µm mesh plankton net immediately after the hole had filled, and again after approx. 30 minutes, after other sampling had been conducted.

Samples were preserved in 70% ethanol and returned to the laboratory for processing. Any hyporheic fauna present was removed from samples by sorting under a low power dissecting microscope. Specimens were sent to appropriate taxonomic experts for identification and confirmation of their status as hyporheic fauna.

Chironomidae (non-biting midges) were sent to Dr Don Edward (The University of Western Australia), Amphipoda to Dr Terrie Finston (The University of Western Australia) for genetic analysis, Copepoda and Ostracoda to Dr Russ Shiel (Adelaide University).

All taxa recorded from hyporheic samples were classified using Boulton's (2001) categories;

- stygobite – obligate groundwater species, with special adaptations to survive such conditions
- permanent hyporheos stygophiles - epigean[4] species which can occur in both surface- and groundwaters, but is a permanent inhabitant of the hyporheos
- occasional hyporheos stygophiles – use the hyporheic zone seasonally or during early life history stages
- stygoxene (species that appear rarely and apparently at random in groundwater habitats, there by accident or seeking refuge during spates or drought; not specialised for groundwater habitat).

4 Epigean – living or occurring on or near the surface of the ground.

## 2.6 Macroinvertebrates

Macroinvertebrate sampling was conducted with a 250 µm mesh FBA pond net to selectively collect the macroinvertebrate fauna. In order to allow comparisons to be made between sites and systems, a standardised sampling approach was adopted, whereby riffle habitats were selectively sampled at each site. This standardises for habitat and avoids issues with greater diversity due to greater habitat diversity on any reach. Each sample was washed through a 250 µm sieve to remove fine sediment, leaf litter and other debris (Plate 1). Samples were then preserved in 70% ethanol.

**Plate 1.** Using the 250 µm sieve at MAR2-4 to remove fine sediment, leaf litter and other debris.

In the laboratory, macroinvertebrates were removed from samples by sorting under a low power dissecting microscope. Collected specimens were then identified to the lowest possible level (genus or species level) and enumerated to $\log_{10}$ scale abundance classes (*i.e.* 1 = 1 - 10 individuals, 2 = 11 - 100 individuals, 3 = 101-1000 individuals, 4 = >1000). In-house expertise was used to identify invertebrate taxa using available published keys and through reference to the established voucher collections held by WRM. External specialist taxonomic expertise was sub-contracted to assist with Chironomidae (non-biting midges) (Dr Don Edward, The University of Western Australia).

## 2.7 Fish

Fish fauna were sampled using a variety of methods in order to effectively collect as many individuals as possible in each reach. Fish sampling methods included electrofishing, seine nets, gill nets and dip nets.

Electrofishing was conducted with a Smith-Root Model 12-B battery powered backpack electrofisher (Plate 2). Electrofishing is an extremely useful and efficient sampling tool in rivers with clear, low salinity, slow flow water. All meso-habitats within a 40 metre reach were shocked with the intention of recovering as many species/ individuals as possible. Shocking was not continuous, but targeted areas of optimum habitat, whereby the operator would shock, move to a new habitat before shocking again, and so prevent fish being driven along in front of the electrical field.

Smaller species and juveniles were sampled by beach seine (10 m net, with a 2 m drop and 6 mm mesh) deployed in shallow areas where there was little vegetation or large woody debris. Generally, two seines were conducted at each site to maximise the number of individuals caught.

**Plate 2.** Electrofishing at MAR2-1.

**Principles of electrofishing**: a DC voltage is passed from a negative electrode (cathode) to a positive electrode (anode) whilst the electrodes are immersed in the water. If a fish is caught in the electrical field generated, a process referred to as 'Galvanotaxis' occurs. This is the involuntary movement of the fish towards the anode, until it reaches an electrical field strong enough to stun it ('galvanoarcosis'). The Smith-Root electrofisher uses a pulsed DC current, which is more effective than a flat DC signal because the body of the fish flexes with each pulse, accentuating the involuntary swimming action towards the anode. Once the current is switched-off, or the fish removed from the electrical field, the fish quickly recovers. Some damage to fish may occur if they are caught in a high electrical field close to the anode for an extended period. The operator of the electrofisher carries the anode (in the form of a modified pond net) whilst trailing the cathode (a stainless steel cable approximately 3.5 m long, referred to as a 'rat tail'). The Smith-Root backpack electrofisher has an effective range of approximately 3 m. Galvanotaxis can be used to 'pull' fish and crayfish out from under debris, logs, boulders and bank undercuts.

Gillnetting involved setting 10 m light-weight fine mesh gill nets with a 2 m drop (of varying stretched mesh net size 13mm and 19 mm) at each site. Nets were left for the duration of sampling at that particular site.

All fish were identified in the field, measured and then released alive. Fish nomenclature followed that of Allen *et al.* (2002). Measuring the fish captured provided information on the size structure, breeding and recruitment of the fish population.

## 2.8 Data analysis

### 2.8.1 Univariate analysis

Univariate statistics were performed using SPSS software (Version 17.0 for Windows). Independent samples were used as replicates and two-way analysis of variance (ANOVA) was applied to test for significant differences in species richness (of microinvertebrates and macroinvertebrates) between reaches, systems and/or seasons. Two-way ANOVA was also undertaken on some physico-chemical parameters, including water temperature, total nitrogen concentration, magnesium, sulphate, etc.

A Levene's test was used in the first instance to test for equality of variances. Tukeys post-hoc tests were utilised in the case of significant differences to locate reach differences.

### 2.8.2 Multivariate analysis

Multivariate analyses were performed using the PRIMER package v 6 (Plymouth Routines in Multivariate Ecological Research; Clarke and Gorley 2006) to investigate differences in aquatic fauna assemblages (macroinvertebrates and microinvertebrates) across reaches, seasons and sampling events, and relationships with physico-chemical characteristics from each site. The PRIMER package, developed for multivariate analysis of marine fauna

samples, has been applied extensively to analysis of freshwater invertebrate data. Analyses applied to the data included some or all of the following:

1. Describing pattern amongst the fauna assemblage data (macroinvertebrates and microinvertebrates) using ordination techniques based on Bray-Curtis similarity matrices (Bray and Curtis 1957). The clustering technique uses a hierarchical agglomerative method where samples of similar assemblages are grouped and the groups themselves form clusters at lower levels of similarity. A group average linkage was used to derive the resultant dendrogram. Ordination of data was by Multi-Dimensional Scaling (MDS) (Clarke and Warwick 2001). Ordinations were depicted as two-dimensional plots based on the site by site similarity matrices. For environmental data, the Euclidean Distance Measure was used to create resemblances, and the data was first transformed (where necessary) and normalised.
2. Cluster analysis to produce SIMPROF results which were overlain on the ordination where necessary.
3. For any groups found in (1) or selected *a priori* (*i.e.* reach and season), Two-way Crossed Analysis of Similarity (ANOSIM) – effectively an analogue of the univariate two-way ANOVA – was conducted to determine if reaches and sampling events were significantly different from one another. The ANOSIM test statistic reflects the observed differences *between* groups (*e.g.* between reaches) with the differences amongst replicates *within* the groups. The test is based upon rank similarities between samples in the underlying Bray-Curtis similarity matrix. The analysis presents the significance of the overall test (Significance level of sample statistic), and significance of each pairwise comparison (Significance level %), with degree of separation between groups (R-statistic), 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. A significance level <5% = significant effect/difference.
4. The SIMPER routine was used to examine which taxa were contributing to the differences of any groups that were found to be different according to the ANOSIM procedure or otherwise found to be separated in cluster or ordination analyses.
5. The relationship between the environmental and biotic data was assessed in two ways:
    - The BIOENV routine was used to calculate the minimum suite of parameters that explain the greatest percent of variation (i.e. the parameters which most strongly influence the species ordination)
    - For visualisation, the numeric value of key environmental data (as determined by BIOENV) were superimposed onto MDS ordinations, as circles of differing sizes – so-called 'bubble plots'.
6. Differences in multivariate dispersions among groups (i.e. seasons) was investigated using PERMDISP (Anderson 2006) in PERMANOVA (Anderson 2005). PERMDISP can be undertaken on the basis of any distance measure (i.e. Euclidean Distance) or similarity (i.e. Bray-Curtis) measure of choice. The test can be considered in two steps, 1) calculation of the distances from observations to their centroids, and 2) comparison of the average of these distances among groups, using ANOVA (Anderson 2006). A p-value is obtained using permutation of the observations. The approach is a multivariate analogue to Levene's Test (Levene 1960).

# 3 RESULTS AND DISCUSSION

## 3.1 Water quality

As mentioned previously, water quality data were compared against ANZECC/ARMCANZ (2000) water quality guidelines. The default trigger values for physical and chemical stressors applicable to tropical northern Australia are provided in Appendix 2.

### 3.1.1 Physico-chemistry

**Dissolved oxygen (DO)**

Dissolved oxygen levels in the current study ranged from 56% (MAR1-1) to 180% (MAR2-4) during October 2008, and 44% (MAR1-3) to 133% (MAR2-3) in May 2009 (Appendix 3). During the dry season of Oct-08, all but two sites (MAR2-2 & MAR2-6) recorded DO levels outside the recommended ANZECC/ARMCANZ (2000) guidelines for the protection of lowland river systems in the tropical north of Australia (Appendices 2 and 3). Low DO can impact the aquatic ecosystem through a slowing in growth rates of aquatic fauna, reproductive difficulties, stress, increased susceptibility to disease, and in some cases increased mortality. Low DO also promotes the accelerated release of nutrients and heavy metals from sediments, which can have a toxic effect on aquatic flora and fauna. In most cases, the 'low' DO levels (<85%) recorded during the current study were unlikely to be low enough to have an ecological impact. DO concentrations less the ~20% typically represent environmental conditions of 'stress' to resident aquatic fauna, particularly fish with high metabolic demand for oxygen. DO values as low as this were not recorded during the current study. However, oxygen needs of aquatic biota differ between species and between life history stages. The 'high' DO values recorded during the current study may be cause for concern. Super-saturation (DO>100%) occurs when net photosynthesis exceeds total oxygen consumption and is common in areas of high macrophyte and algal growth. Such sites would experience oxygen stress overnight, as respiration by plants, algae, bacteria and other aquatic fauna deplete DO. Super-saturated DO can also lead to fish bubble disease. One site in particular, MAR2-4 in October 2008, recorded exceptionally high DO levels (180%). Super-saturation can occur in systems with good light penetration and nutrient inputs which lead to excessive algal and macrophyte growth.

**pH**

Most river systems in Western Australia (including those in the Pilbara *e.g* Robe, Harding and lower Fortescue at Millstream) have a natural pH range circum-neutral. In the absence of baseline data, ANZECC/ARMCANZ (2000) guidelines recommend average pH should be between 6 and 8 in lowland rivers of tropical northern Australia. Generally, the pH values recorded during the current study were within these guidelines and were circum-neutral to slightly basic. During the dry season, pH ranged from 7.7 (MAR1-6) to 8.3 (MAR2-4 & MAR2-6), and during the wet from 7.6 (MAR1-3) to 8.6 (MAR2-3). The slightly basic pH recorded from Marillana Creek is not likely to cause adverse impacts to aquatic biota. WRM (2009b) reported similarly basic pH from Marillana Creek previously, while Johnson and Wright (2003), Streamtec (2004), and WRM (2009a, b, 2010) recorded slightly basic pH from other systems in the East Pilbara, including Weeli Wolli Creek, Coondiner Creek, Kalgan Creek and the Fortescue River (WRM 2009b).

**Electrical conductivity (Ec)**

All sites were fresh as classified by the DoE (2003)[5] (Appendix 3). Conductivity ranged from 905 µS/cm (MAR2-4) to 1040 µS/cm (MAR1-6) during the dry season of 2008, and from 939 µS/cm (MAR1-1, MAR2-5 & MAR2-6) to 1010 µS/cm (MAR1-6) in the wet season (Appendix 3). Whilst all conductivity values were above ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems, all sites were considered fresh and their conductivity is likely to be of little ecological consequence. There is a general acceptance that when conductivity is less than 1500 µS/cm, freshwater ecosystems experience little ecological stress (Hart *et al.* 1991, Horrigan *et al.* 2005).

**Ions**

Alkalinity refers to the capacity of water to neutralise acid and is an expression of buffering capacity. It essentially relates to the amount of bases[6] in water which buffer against sudden changes in pH (McDonald and Wood 1993, Riethmuller *et al.* 2001, Lawson 2002). Bases are able to buffer water by absorbing hydrogen ions when the water is acid and releasing them when the water becomes basic (Lawson 2002). Therefore, alkalinity is important for aquatic fauna as it can protect against rapid pH changes (Riethmuller *et al.* 2001). Alkalinity of less than 20 mg/L is considered low; waters would be poorly buffered and the removal of carbon dioxide during photosynthesis would result in rapidly rising pH (Sawyer and McCarty 1978, Romaire 1985, Lawson 2002). If alkalinity is naturally low (< 20 mg/L) there can be no greater than a 25% reduction in alkalinity. In the current study, alkalinity was high at all sites along the length of Marillana Creek (Appendix 3). Alkalinity ranged from 255 mg/L at MAR1-2 to 315 mg/L at MAR2-1 during the dry, and 255 mg/L (MAR1-1) to 300 mg/L (MAR2-1 & MAR2-2) in the wet (Appendix 3). This suggests that the buffering capacity of waters along Marillana Creek is high.

The ionic composition of waters is determined by rain-borne salts (*i.e.* wind-blown dusts) and geology (*e.g*. weathering of soils) of the catchment (DeDeckker and Williams 1986). However, the composition over the warmer months, particularly in shallow reaches, will be altered by evapo-concentration and precipitation of less soluble salts, such as calcium carbonate and magnesium sulphate (Hart and McKelvie 1986). The ionic composition of inland waters in Australia is known to vary widely, but the proportions of calcium, magnesium and bicarbonate are often enriched compared to seawater (DeDeckker and Williams 1986).

The composition of major ions along Marillana Creek was typically dominated by sodium and hydrogen bicarbonate ($Na^+ > Ca^{2+} > Mg^{2+} > K^+$: $HCO_3^- > Cl^- > SO_4^{2-} > CO_3^-$). This did not change between seasons. The dominance of major ions at Marillana Creek was the same as that reported from Weeli Wolli Creek downstream of the confluence with Marillana Creek (i.e. WW Reach Four; WRM 2009a, 2010).

[5] Fresh defined as < 1500 µS/cm, Brackish = 1500 – 4500 µS/cm, Saline = 4500 – 50,000 µS/cm, Hypersaline > 50,000 µS/cm (DoE 2003). Classifications were presented as TDS (mg/L) in DoE (2003) so a conversion factor of 0.68 was used to convert to conductivity µS/cm as recommended by ANZECC/ARMCANZ (2000).

[6] Bases are ions which release hydroxyl ions (OH-) when dissolved in water. Generally these bases are principally bicarbonate and carbonate ions (Lawson 2002).

**Nutrients**

Total nitrogen levels along Marillana Creek varied between reach and season, ranging from 0.05 mg/L at MAR1-5 in the dry, to 1.8 mg/L at MAR2-1 also in the dry season (Figure 6 and Appendix 3). The ANZECC/ ARMCANZ (2000) trigger value[7] was exceeded at two sites in the dry season (MAR2-1 & MAR2-2), and six sites in the wet (MAR1-1, MAR1-2, MAR2-1, MAR2-2, MAR2-3 & MAR2-4) (Figure 6 and Appendix 3). Total phosphorus ranged from 0.005 mg/L (at all sites except MAR1-3) in the dry, to 0.04 mg/L (MAR1-1 & MAR2-1) during the wet season (Figure 6 and Appendix 3). The ANZECC/ARMCANZ (2000) trigger value[8] was exceeded at all sites during the wet season (Figure 6 and Appendix 3).

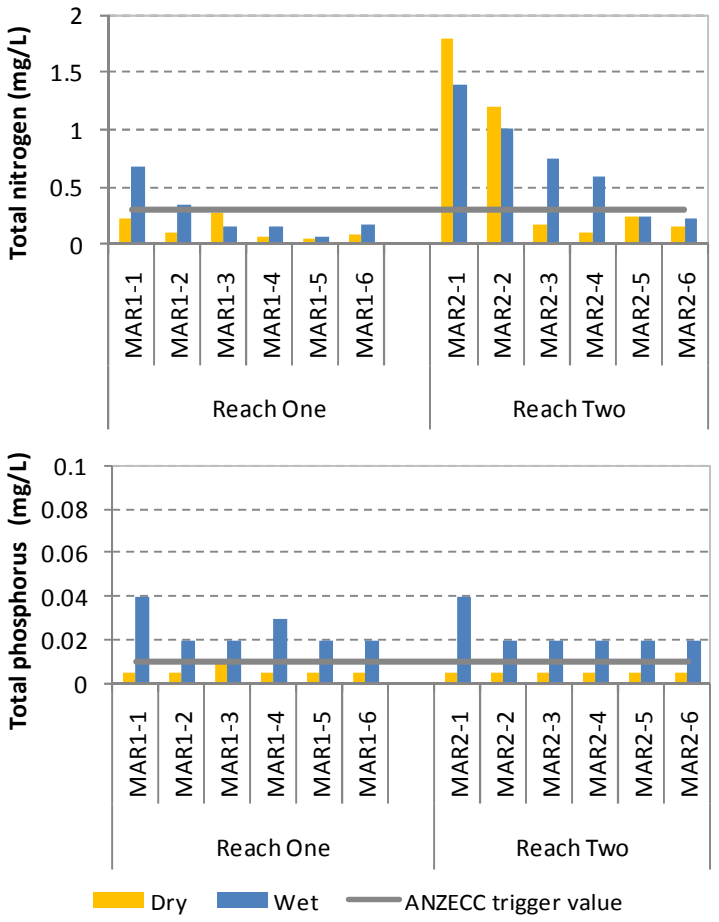



**Figure 6.** Nutrient levels (mg/L) recorded from Marillana Creek during the wet (Oct-08) and dry season (May-09), showing total nitrogen (top) and total phosphorus (bottom). The ANZECC/ARMCANZ (2000) trigger value is indicated by the grey line.

Total nitrogen levels recorded from Marillana Creek were significantly different between reach (Two-way ANOVA; df = 1, p= 0.01) but not season (Two-way ANOVA; df = 1, p = 0.13; Table 4). Significantly higher total nitrogen levels were recorded from Reach Two when compared to Reach One (Figure 7 and Table 4). The cause of the elevated total nitrogen levels from the downstream Marillana reach is unknown, but may be coming from any number of potential sources, including current pastoral activities and cattle stocking, past cattle use and leaching from soils, and/or some influence from Yandi operations such as elevated total nitrogen in groundwater discharge water, contamination of groundwater from ammonium nitrate storage or septic systems, and/or elevated total nitrogen in mine process water discharged into the creek. Although elevated nitrogen levels are not uncommon in creeks of this area due to pastoral activities and cattle stocking, the significantly higher levels recorded from Marillana Reach Two do suggest another source may be present, as cattle were seen along the length of Marillana Creek

[7] The ANZECC/ARMCANZ (2000) guidelines recommend that total nitrogen should not exceed 0.3 mg/L in tropical northern Australian lowland rivers.

[8] The ANZECC/ARMCANZ (2000) guidelines recommend that total phosphorus should not exceed 0.01 mg/L in tropical northern Australian lowland rivers.

during sampling. Elevated total nitrogen and total phosphorus levels have been recorded from mine process water which is discharged from the levee bank discharge point upstream of Marillana Reach Two (Table 5 & see Figure 3 for the location of the discharge point). However, potential sources for the increased total nitrogen from MAR-Two need to be investigated further before any conclusions can be drawn.

**Table 4.** Two-way ANOVA of nutrient data by reach and season.

| *Type* | *Source* | *df* | *F-value* | *p-value* |
|---|---|---|---|---|
| **Log total nitrogen** | **Reach** | 1 | 8.95 | 0.007 |
| | **Season** | 1 | 2.54 | 0.127 |
| | **Reach*Season** | 1 | 0.01 | 0.904 |
| | **Total** | 23 | | |
| **Log total phosphorus** | **Reach** | 1 | 0.81 | 0.379 |
| | **Season** | 1 | 210.60 | 0.000 |
| | **Reach*Season** | 1 | 0.05 | 0.816 |
| | **Total** | 23 | | |

**Table 5.** Total nitrogen (mg/L) and total phosphorus (mg/L) concentrations in mine process water recorded from the levee bank discharge point at RTIOs Yandi. Data provided by RTIO Yandi. Shading indicates the value exceeds ANZECC/ARMCANZ (2000) guidelines.

| *Year* | *Sample date* | *Total N (mg/L)* | *Total P (mg/L)* |
|---|---|---|---|
| **2009** | 27/01/2009 | 1.7 | 1.7 |
| | 25/02/2009 | 2.9 | 1.6 |
| | 24/03/2009 | 15 | 9.2 |
| | 15/04/2009 | 20 | 5 |
| | 26/05/2009 | 17 | 20 |
| | 17/06/2009 | 26 | 13 |
| | 28/07/2009 | 19 | 23 |
| | 27/08/2009 | 57 | 0.83 |
| | 16/09/2009 | 6.9 | 10 |
| | 28/10/2009 | 12 | 8.9 |
| | 30/11/2009 | 3.1 | 7.3 |
| **2010** | 19/01/2010 | 2.5 | 5.9 |
| | 15/02/2010 | 3.1 | 7.4 |

Total phosphorus levels of Marillana Creek were significantly different between season (Two-way ANOVA; df = 1, p= 0.00), but not reach (Two-way ANOVA; df = 1, p = 0.38; Table 4). In this case, significantly greater phosphorus levels were recorded during the wet season (Figure 7 and Table 4).

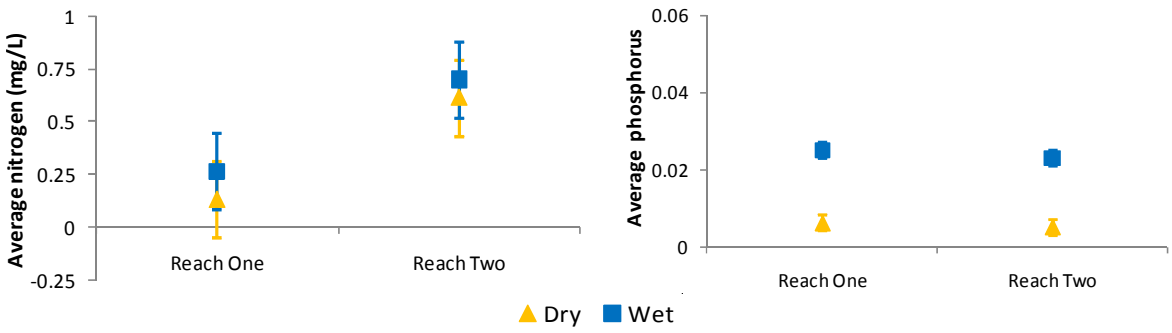



**Figure 7.** Average nutrient concentration (±se) per reach and season, showing average total nitrogen (left) and average total phosphorus (right).

### 3.1.2 Patterns in water quality data

Patterns were evident within the water quality ordination, with samples forming groups according to reach and season (Figure 8). Water quality was found to be significantly different between reach (Two-way crossed ANOSIM; sample statistic = 0.63; significance of sample statistic p = 0.0001) and season (Two-way crossed ANOSIM; sample statistic = 0.73; significance of sample statistic p = 0.0001). Samples within each grouping, however, seemed to be highly variable (Figure 8). Dry season samples from Marillana Reach One formed the tightest group in the ordination (Figure 8), suggesting that samples within this group were most similar to each other, than any other group.

Water quality variables influencing the separation of samples amongst seasons were total phosphorus and zinc, with total phosphorus being higher in the wet season and zinc being lower in the wet season (Figure 9). The concentration of total nitrogen influenced the separation of samples amongst reaches, and was higher from Reach Two (Figure 9).

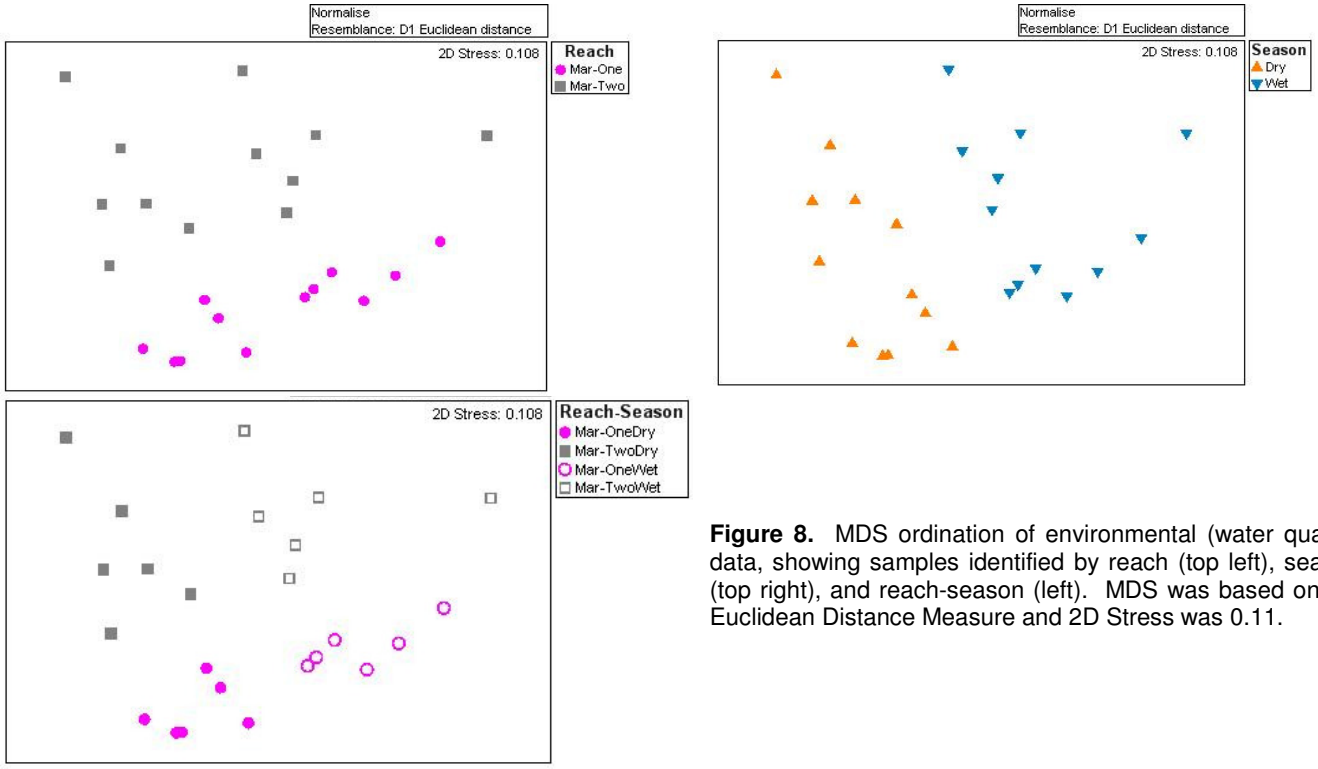



**Figure 8.** MDS ordination of environmental (water quality) data, showing samples identified by reach (top left), season (top right), and reach-season (left). MDS was based on the Euclidean Distance Measure and 2D Stress was 0.11.

### 3.1.3 Comparisons with Weeli Wolli water quality data

Using all water quality data collected from Weeli Wolli and Marillana Creek in October 2008 and May 2009, patterns were evident in ordination space (Figure 10). Water quality was significantly separate between systems (i.e. Weeli Wolli compared with Marillana Creek; One-way ANOSIM; sample statistic = 0.57, significance of sample statistic p = 0.0001).

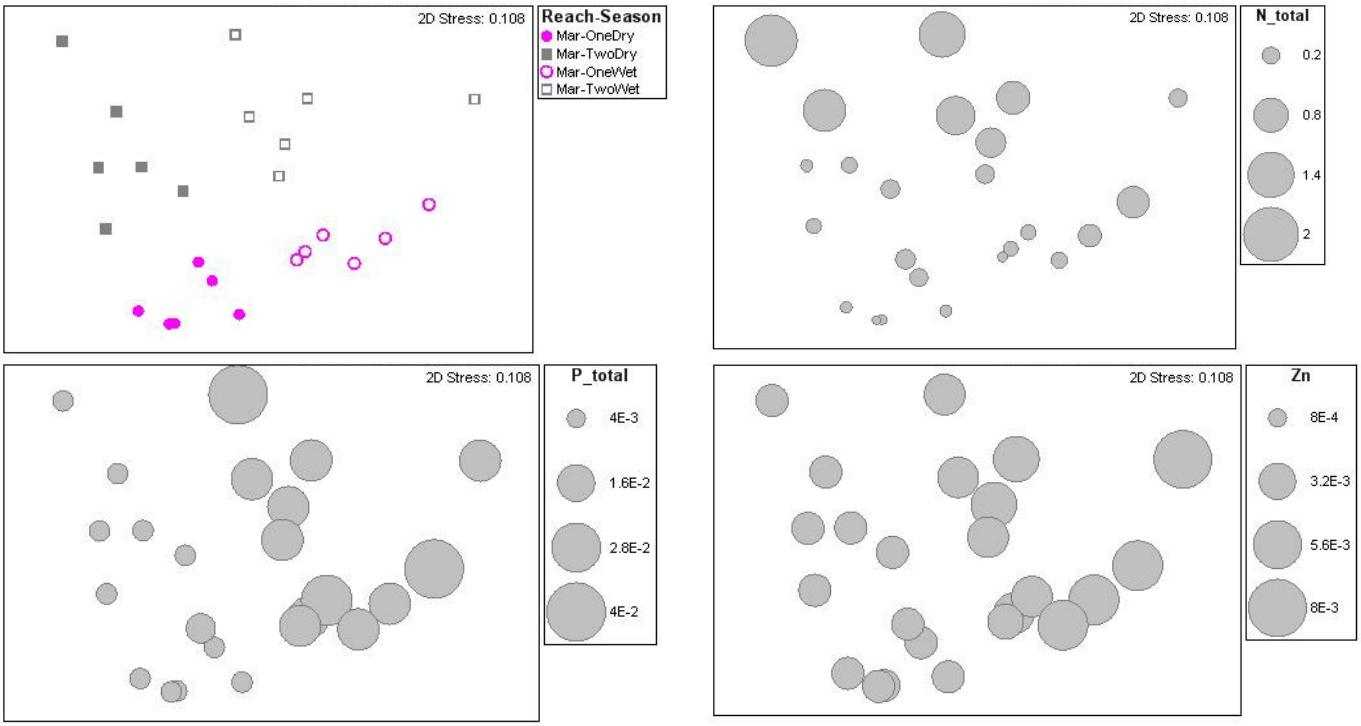



**Figure 9.** Bubble plots showing water quality parameters which contributed to the separation between reaches (top right; total nitrogen), and seasons (bottom; total phosphorus and zinc).

In addition, water quality was significantly different amongst season (Two-way crossed ANOSIM; sample statistic = 0.74, significance of sample statistic p = 0.0001) and reach (Figure 10 & Table 6; Two-way crossed ANOSIM; sample statistic = 0.79, significance of sample statistic p = 0.0001). All reaches were in fact significantly separate from one another, but a longitudinal pattern was also evident, with samples from Weeli Wolli Reach One being most similar to Reach Two (R=0.69) and least similar to Weeli Wolli Reach Four (R=0.92); and samples from Weeli Wolli Reach Four being most similar to Marillana Reach Two (R=0.68), and least similar to Marillana Reach One (R=0.91; Table 6). The two most similar reaches were those along Marillana Creek; MAR One and MAR Two (R=0.42; Table 6).

**Table 6.** Pair-wise ANOSIM results of water quality amongst reach, showing R-values (sample statistic)[9], * = groups significantly different.

| | *WW One* | *WW Two* | *WW Three* | *WW Four* | *MAR One* |
|---|---|---|---|---|---|
| **WW One** | | | | | |
| **WW Two** | 0.69* | | | | |
| **WW Three** | 0.87* | 0.37* | | | |
| **WW Four** | 0.92* | 0.97* | 0.86* | | |
| **MAR One** | 0.99* | 1.00* | 0.99* | 0.91* | |
| **MAR Two** | 0.83* | 0.87* | 0.78* | 0.68* | 0.42* |

[9] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barley separable.

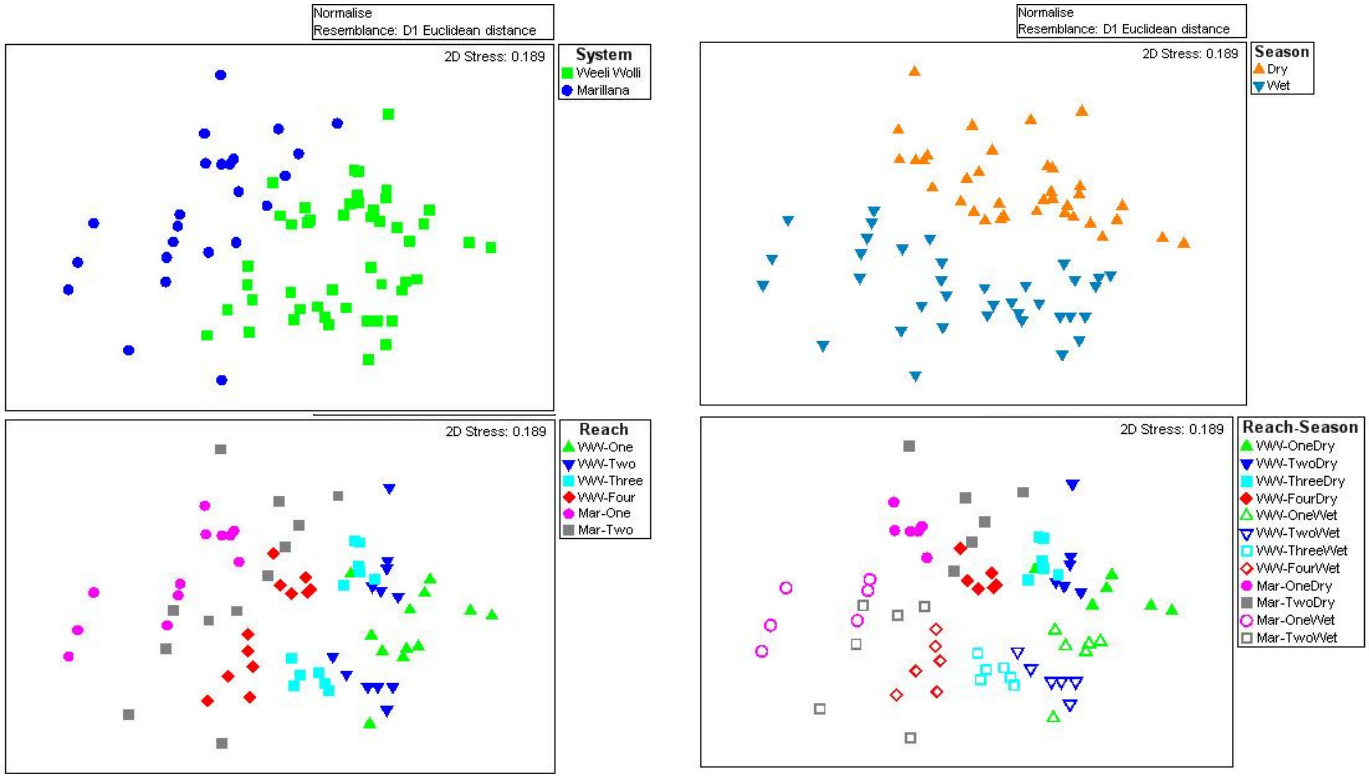



**Figure 10.** MDS ordination of environmental (water quality) data from Weeli Wolli Creek and Marillana Creek, showing samples identified by system (top left), season (top right), reach (bottom left), and reach-season (bottom right). MDS was based on the Euclidean Distance Measure and 2D Stress was 0.19.

In order to see more clearly the separations amongst reaches, individual ordinations were undertaken for each season and significant SIMPROF clusters overlain on the MDS (Figures 11 & 12). The dry season plot clearly shows Marillana Creek samples from both reaches grouped with Weeli Wolli Reach Four samples (Figure 11). This suggests that during the dry season, the water quality of Marillana Creek was similar to that recorded from the downstream Weeli Wolli reach (WW Reach Four). It appears that water quality of the downstream reach of Weeli Wolli Creek is influenced by Marillana Creek.

Weeli Wolli Reaches Two and Three formed their own group, and Weeli Wolli Reach One also formed a distinct group (Figure 11). One site from Marillana Creek, MAR2-6, separated from other Marillana and WW-Four sites based on its higher concentration of ammonia (NH3; Figure 11) Other water quality variables influencing the ordination were barium[10], which was highest from Marillana Creek and WW-Four, and sodium, which was lower from WW-One (Figure 11).

[10] No trigger value exists within the ANZECC/ARMCANZ (2000) guidelines for barium, so it is not known whether the higher values reported from Marillana Creek and Weeli Wolli Reach Four are of ecological concern.

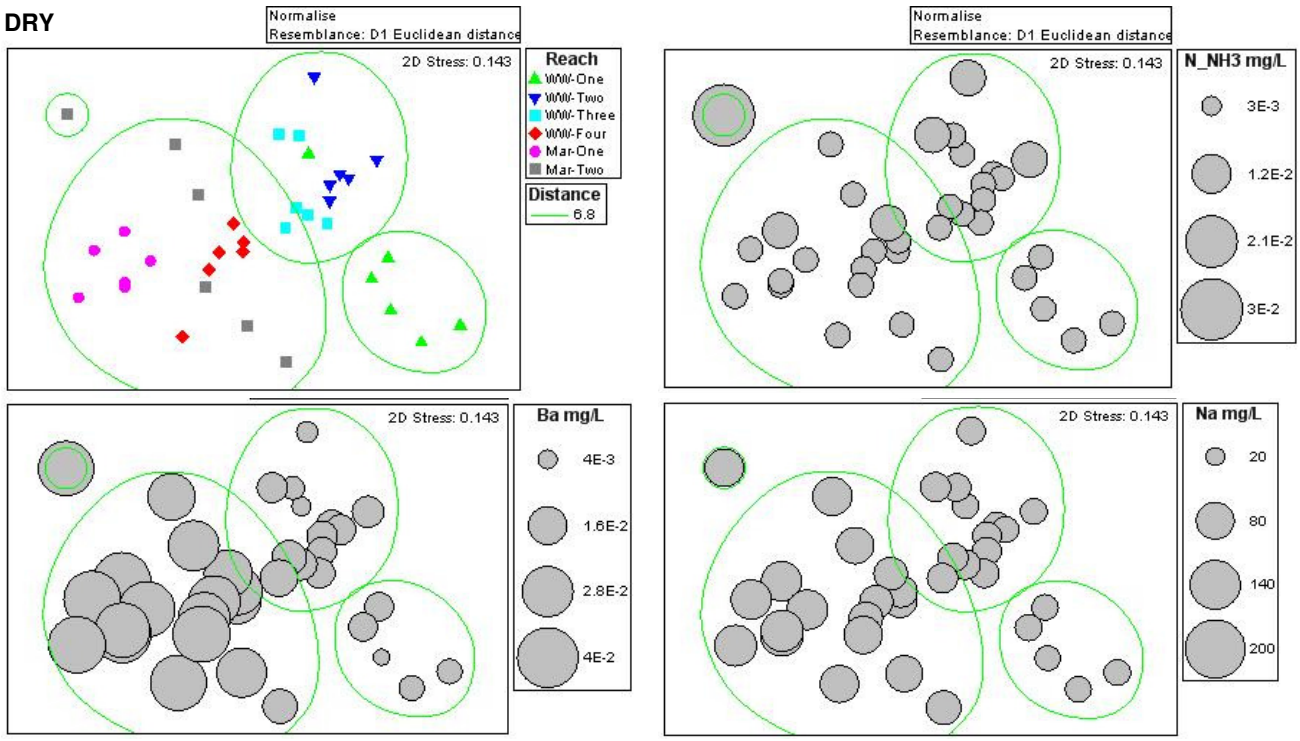



**Figure 11.** Dry season MDS ordination of environmental (water quality) data from Weeli Wolli Creek and Marillana Creek (top left). Samples are identified by reach and are grouped within significant SIMPROF clusters at a Euclidean Distance of 6.8. The MDS was based on the Euclidean Distance Measure and 2D Stress was 0.14.

This pattern was slightly different in the wet season, with WW-Four forming its own distinct group, separate from Marillana Creek sites (Figure 12). Once again, WW-One formed its own group, and WW-Two and WW-Three formed another separate group. In this case, all sites within Marillana Creek were found to have similar water quality, with the exception of MAR2-1 (Figure 12).

Water quality variables found to contribute to the patterns in the ordination included total nitrogen, barium, copper, and manganese (Figure 12). The concentration of total nitrogen was highest from MAR2-1, and influenced the separation of this site from all others, including other Marillana Creek sites (Figure 12). As was recorded during the dry season, Barium was again higher from Marillana Creek and WW-Four sites. Higher copper concentrations were recorded from Weeli Wolli Reach One, and higher manganese from WW-Two and WW-Three (Figure 12). However, the concentrations of both these dissolved metals were still below ANZECC/ARMCANZ (2000) guidelines for the protection of 99% of species, and are therefore not of ecological concern.

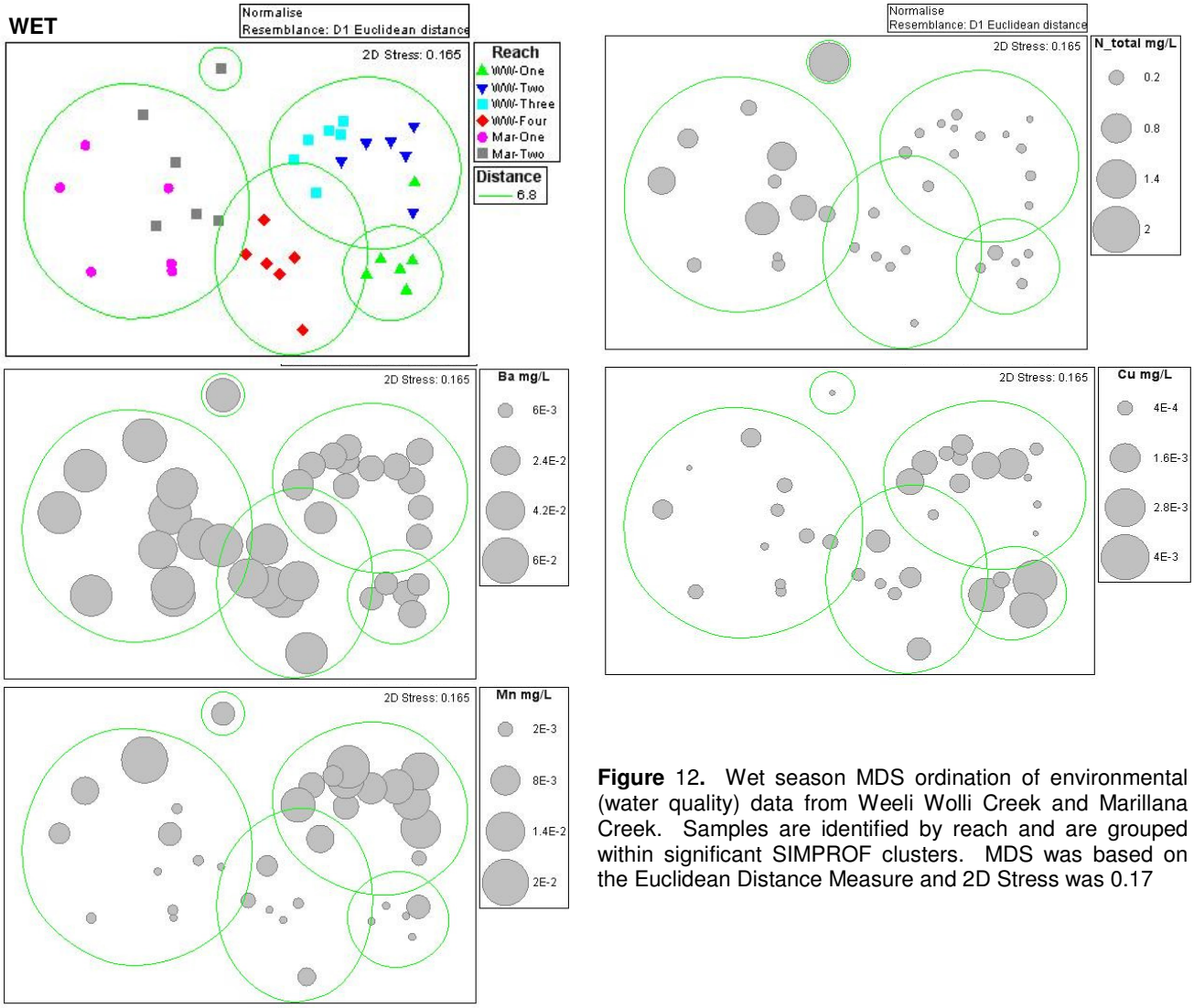



**Figure** 12**.** Wet season MDS ordination of environmental (water quality) data from Weeli Wolli Creek and Marillana Creek. Samples are identified by reach and are grouped within significant SIMPROF clusters. MDS was based on the Euclidean Distance Measure and 2D Stress was 0.17

## 3.2 Microinvertebrates

### 3.2.1 Taxonomic composition and species richness

A total of 59 taxa of microinvertebrates were recorded from Marillana Creek during the current study, with 45 being recorded in October 2008, and 41 taxa in May 2009 (Appendix 4). The microinvertebrate fauna comprised Protista (Ciliophora & Rhizopoda), Rotifera (Bdelloidea & Monogonata), Cladocera (water fleas), Copepoda (Cyclopoida) and Ostracoda (seed shrimp).

The microinvertebrate fauna were typical of tropical systems reported elsewhere (e.g. Koste and Shiel 1983, Tait *et al.* 1984, Smirnov and De Meester 1996, Segers *et al*. 2004). For example, Brachionidae within the Rotifera were poorly represented. This family tends to dominate temperate rotifer plankton, but is overshadowed by Lecanidae in tropical waters, as was the case here. Within the Cladocera fauna, daphniids tend to predominate in temperate waters, with low representation in the tropics. No daphniids were recorded from Marillana Creek during the current study, however, one species has been recorded from Flat Rocks upstream of the Yandi mine on Marillana Creek during the Regional Survey (Jess Delaney, WRM, unpub. data). In tropical systems throughout the world, daphniids tend to be replaced by sidids, moinids, and in the case of heavily vegetated or shallow waters, by chydorids, as seen here (see Appendix 4).

Microinvertebrate taxa richness varied greatly between reach and season (Figure 11). During the dry season of October 2008, the greatest number of microinvertebrate taxa was recorded from MAR2-3 (19 taxa), and the least from MAR1-6 (5 taxa). During the wet, the greatest number of taxa was recorded from MAR1-3 (20 taxa). No microinvertebrate taxa were collected from MAR1-6 during the wet season (Figure 13 and Appendix 4). More microinvertebrate taxa were recorded during the dry season (Figures 13 and 14).

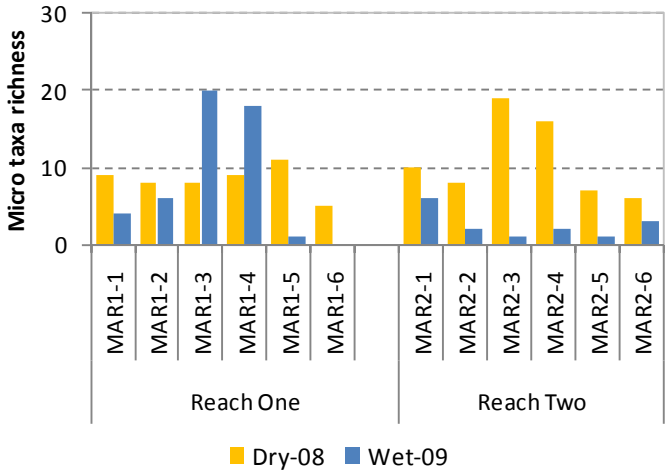



**Figure 13**. Microinvertebrate taxa richness recorded from each site along Marillana Creek during both seasons.

Using microinvertebrate data from Weeli Wolli Creek in the analysis, there was no significant difference in the average number of taxa between reach (Two-way ANOVA; df = 5, p= 0.14; Figure 14 and Table 7). There was, however, a significant difference in microinvertebrate taxa richness between season (Two-way ANOVA; df = 1, p= 0.02; Table 7), with a greater number of taxa being recorded during the dry (Figure 14). There was no interaction between reach and season (Table 7). Microinvertebrate taxa richness was highly variable within reach and within season as seen by the large standard error bars, particularly during the dry season (see Figure 14).

**Table 7.** Two-way ANOVA results for macroinvertebrate taxa richness by reach and season (including Weeli Wolli data), showing degrees of freedom, f-value and p-value.

| *Source* | *df* | *F* | p |
|---|---|---|---|
| **Reach** | 5 | 1.76 | 0.14 |
| **Season** | 1 | 6.31 | 0.02 |
| **Reach*Season** | 5 | 1.76 | 0.13 |
| **Total** | 69 | | |

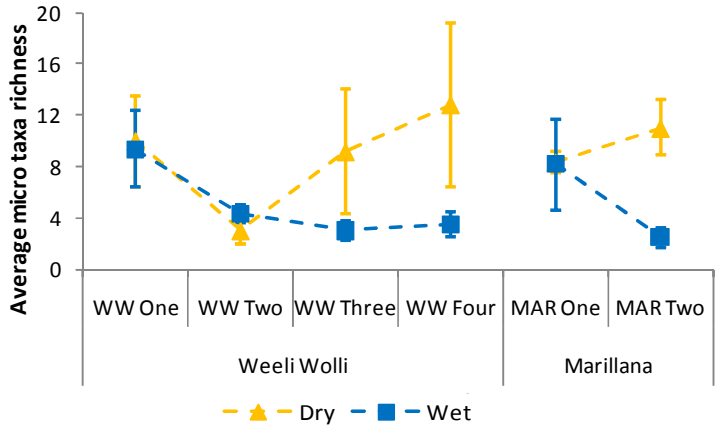
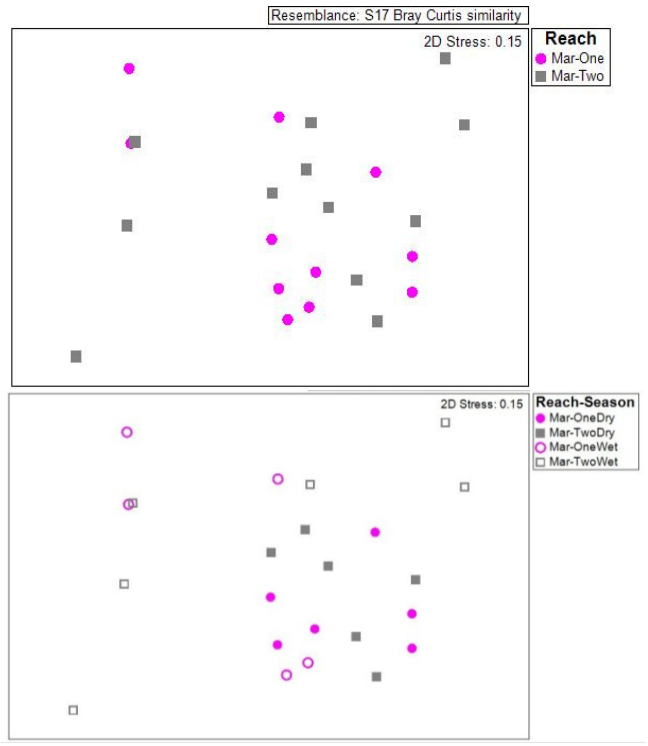



**Figure 14.** Average microinvertebrate taxa richness (±se) from all reaches (including those along Weeli Wolli Creek) showing data for both the dry (October 2008) and wet season (May 2009).

### 3.2.2 Patterns in microinvertebrate assemblage structure

No microinvertebrates were recorded from MAR1-6 during the wet season and this had an over-riding effect on the microinvertebrate abundance ordination for Marillana Creek. This site was therefore removed from further multivariate analysis.

No patterns were evident within the microinvertebrate abundance ordination (Figure 15). There was no significant difference in the microinvertebrate assemblages between reach (Two-way crossed ANOSIM; sample statistic = 0.025; significance of sample statistic p = 0.361). While there did appear to be some separation of samples between season (Figure 15), groups were found to be barely separable (Two-way crossed ANOSIM; sample statistic = 0.34; significance of sample statistic p = 0.0004). However, dry season samples did appear to be less variable than wet season samples (Figure 15). The variability within each season, as measured by the deviation of samples from their centroid (i.e. centre of each sampling group in ordination space), was significantly lower during the dry season (PERMDISP; f = 13.52, df1 = 1, df2 = 21; p = 0.003; Figure 16).



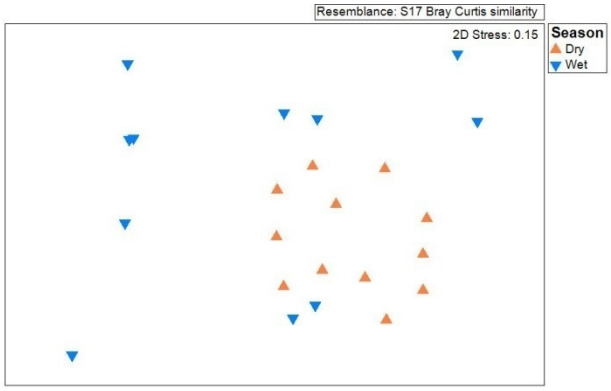




**Figure 15.** MDS ordination of microinvertebrate $\log_{10}$ abundance data with MAR1-6 removed from analyses, showing samples identified by reach (top left), season (top right), and reach-season (left). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.15.

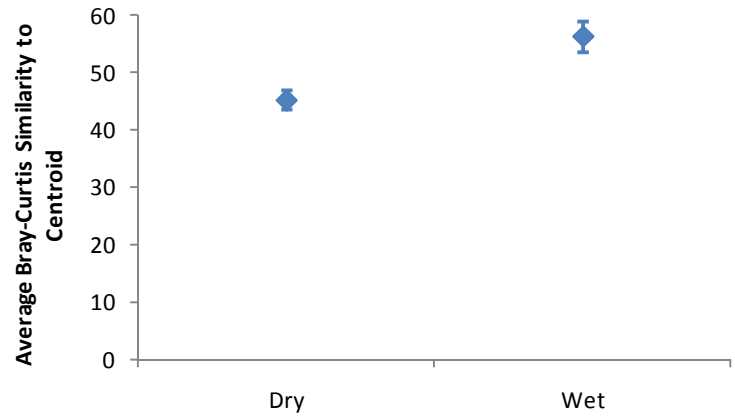



**Figure 16.** Average Bray-Curtis similarities to centroids (±se) for each season, using Marillana Creek microinvertebrate abundance data.

### 3.2.3 Comparison of microinvertebrate assemblages with Weeli Wolli Creek

The multivariate ordination incorporating all microinvertebrate abundance data recorded from Weeli Wolli and Marillana creeks during October 2008 and May 2009, showed no clear patterns (Figure 17). There was no significant separation between system (One-way ANOSIM; sample statistic = -0.07; significance level of sample statistic p = 0.969; Figure 17), indicating that the microinvertebrate assemblages of Marillana Creek were generally similar to those from Weeli Wolli Creek in October 2008 and May 2009. Season groups were also found to be barely separable (Two-way Crossed ANOSIM; sample statistic = 0.25; significance level of sample statistic p = 0.0001; Figure 17). Overall, differences in microinvertebrate assemblages between reach were also barely separable (Two-way

Crossed ANOSIM; sample statistic = 0.18; significance level of sample statistic p = 0.0001). The greatest similarity (i.e. lowest R-value and no significant difference) was between Marillana reaches One and Two (Table 8). The greatest separation of microinvertebrate assemblages was between Weeli Wolli Reach One and Marillana Reach Two (Table 8).

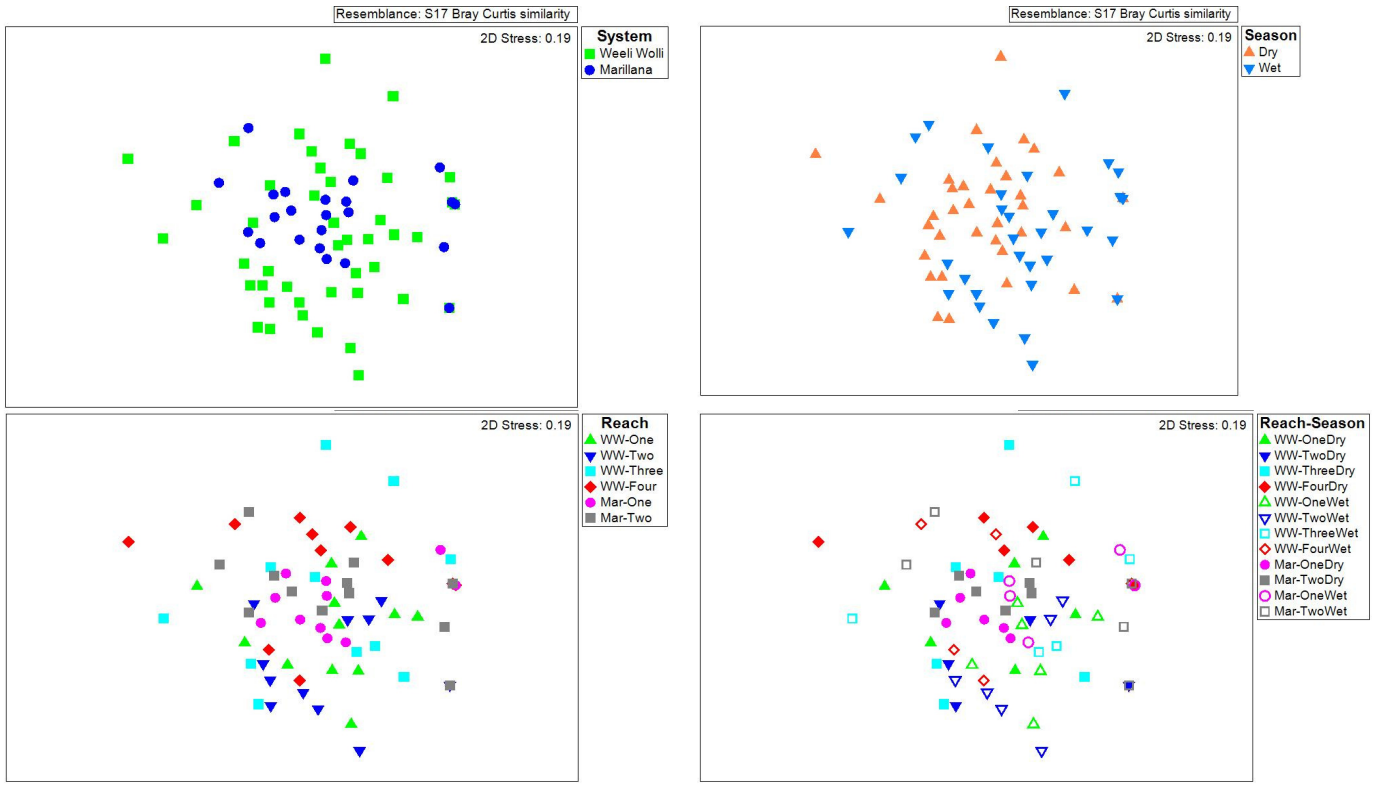



**Figure 17.** MDS ordination of microinvertebrate log10 abundance data from Weeli Wolli Creek and Marillana Creek, showing samples identified by system (top left), season (top right), reach (bottom left), and reach-season (bottom right). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.19.

**Table 8.** Pair-wise ANOSIM results of microinvertebrate $log_{10}$ abundance data amongst reach, showing R-values (sample statistic)[11], * = groups significantly different.

| | *WW One* | *WW Two* | *WW Three* | *WW Four* | *MAR One* |
|---|---|---|---|---|---|
| **WW One** | | | | | |
| **WW Two** | 0.16 | | | | |
| **WW Three** | 0.20* | 0.14 | | | |
| **WW Four** | 0.22* | 0.19* | 0.15* | | |
| **MAR One** | 0.23* | 0.23* | 0.07 | 0.20* | |
| **MAR Two** | 0.37* | 0.32* | 0.11 | 0.18* | 0.02 |

[11] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barley separable.

## 3.3 Hyporheic fauna

### 3.3.1 Taxonomic composition and species richness

A total of 22 taxa were recorded from hyporheic samples collected along Marillana Creek in October 2008, and 58 taxa were recorded in May 2009 (Appendix 5). Of the taxa recorded in the dry season of October 2008, the vast majority were classified as stygoxene (72%) and do not have specialised adaptations for groundwater habitats. However, 5% of the taxa were classified as occasional hyporheos stygophiles, 5% were stygobites[12], and 9% were possible hyporheic taxa. There were no taxa classified as permanent hyporheic stygophiles, and 9% were unknown due to insufficient taxonomy and/or information (Figure 18). Of the taxa recorded during the wet season, most were stygoxene taxa (81%), with 9% being considered hyporheos fauna[13] (5% occasional hyporheos stygophiles, 2% stygobites, and 2% possible hyporheic taxa) (Figure 18). Classifications followed those by Boulton (2001), however, this type of analysis should be treated with some caution as results are likely affected by available information on life history, taxonomic resolution, and interpretation of classification categories.

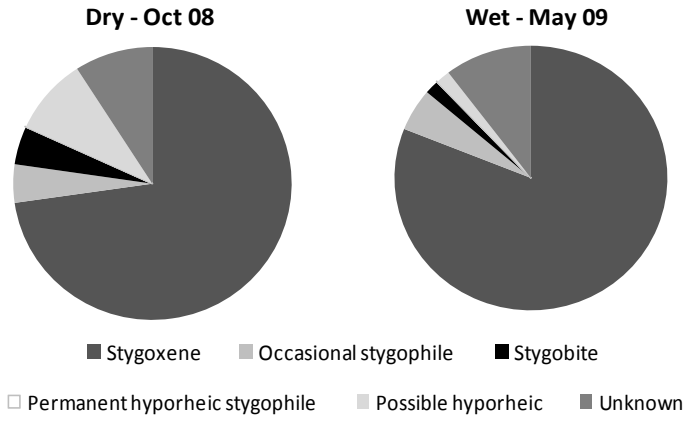



**Figure 18.** Proportion of species from each hyporheic classification category, showing data collected in Oct-08 (left) and May-09 (right).

The results from this study are similar to those reported previously in the Pilbara (Halse *et al.* 2002, WRM 2009a, WRM 2010), in that <20% of taxa collected in hyporheic habitats were entirely dependent on groundwater for their persistence as a species. Halse *et al*. (2002) suggested that it is not surprising that the hyporheos is dominated by species with some affinity for surface water, because the hyporheos is an "ecotone between productive, species-rich surface water systems and nutrient-poor groundwater systems with lower number of species per sampling unit".

Hyporheos fauna were recorded from both reaches of Marillana Creek during both seasons (Figure 19). The greatest number of occurrences of hyporheos taxa was recorded from Reach Two in the wet season of May 2009, and the least from Reach One during the dry of October 2008 (Figure 19).

[12] A stygobite is an aquatic animal that is restricted to groundwater and/or hyporheic environments (i.e. stygofauna). They have adaptations to survive such conditions, including elongated appendages and antennas, no eyes, and a lack of pigmentation. There are likely to be a greater percentage of stygobites at Weeli Wolli than reported here because genetic studies have so far determined that at least four species of stygal amphipod occur along Weeli Wolli and Marillana creeks.

[13] Hyporheos fauna – animals restricted to hyporheic environments.

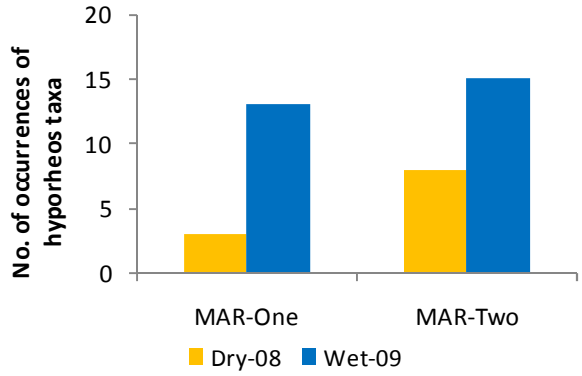



**Figure 19.** Number of occurrences of taxa considered hyporheos recorded from each reach along Marillana Creek during the dry 2008 and May 2009.

### 3.3.2 Hyporheos taxa

Species considered to be restricted to the hyporheos were the stygobitic amphipod ?*Chydaekata* sp., possible hyporheos species Oligochaeta spp. and *Diacyclops* sp. (copepodites), and the occasional stygophiles Baetidae Genus 1 WA sp.1 (mayfly larvae), *Limbodessus occidentalis* and Dytiscidae spp. larvae (Appendix 5).

The stygobitic amphipods collected from hyporheic samples were recorded as ?*Chydaekata* sp. because preliminary results from genetic analysis suggest that at least two species of stygal amphipod occur at Marillana Creek, including *Chydaekata* sp. and species D-Mar (Dr Terrie Finston, UWA, pers. comm.). The *Chydaekata* sp. seem to be the most abundant species along the creek, and are currently known from multiple bores in Marillana and Weeli Wolli creeks. Other species of *Chydaekata*, whose distributions are restricted to distinct tributaries, are known from Ethel Creek, Spearhole Creek, Tuccamunna Creek, and Roy Hill (Finston *et al.* 2007). Species D is currently undescribed, but it has been recorded previously from Marillana Creek and Weeli Wolli Creek (Dr Terrie Finston, UWA, pers. comm.; our WW WRM report 2010). No morphological data exist for Species D so genetic analysis is currently the only means of distinguishing this species. Stygal amphipods were recorded from both reaches along Marillana Creek during the current study (see Appendix 5) and were also abundant along all reaches of Weeli Wolli Creek (WRM 2010).

Of the copepod species collected from hyporheic samples, at least one was considered a possible hyporheic species, the Cyclopodidae *Diacyclops* sp. (copepodites). These copepodites were too small (juvenile) to identify accurately, but may have been *Diacyclops humphreysi* which was recently recorded from hyporheic samples of Weeli Wolli Creek (WRM 2010). This species is relatively common and widespread throughout Western Australia (Karanovic 2006). In the Pilbara, it has been recorded from the Marandoo[14] area (Biota 2008), Barrow Island (Biota 2005), the coastal side of the North-West Coastal Highway between the Fortescue River and Dampier (Bennelongia 2007), Cape Preston

[14] *D. humphreysi* was recorded from bores within the Marandoo area by Biota (2008). This species was also recorded from the Marandoo area during the DEC Pilbara Biological Survey from Warp2 (May 2004) and Tom Price North (July 2003) (Biota 2008).

(Bennelongia 2008) and the Pardoo area, approximately 70 km east of Port Hedland (Coffey 2009). Given the likelihood of the *Diacyclops* sp. (copepodites) collected during the current study being juvenile *D. humphreysi*, they were considered possible hyporheic taxa. *Diacyclops* sp. (copepodites) were recorded from MAR1-4 during the dry season (see Appendix 5).

Other taxa considered possible hyporheics were the Oligochaeta spp. In the past, Oligochaeta from hyporheic samples taken from Weeli Wolli Creek were formally identified by Dr Adrian Pinder (DEC), with at least five species considered to be occasional stygophiles (WRM 2009a). Oligochaetes were not able to be definitively identified, but were considered possible hyporheic species given the presence of occasional stygophiles from the adjacent Weeli Wolli Creek.

The occasional stygophile Baetidae Genus 1 WA sp.1 was collected from benthos (surface water macroinvertebrate samples) and hyporheos during the current study. This species is known to be common in surface waters and hyporheic habitats of Weeli Wolli Creek (Halse *et al*. 2002, WRM 2009a, WRM 2010). It occurs widely across north-western Australia (Suter 1997). Baetidae Genus 1 WA sp.1 were collected from hyporheic samples from sites MAR2-1, MAR-2-5 and MAR2-6 (see Appendix 5).

The dytiscid beetle *Limbodessus occidentalis*[15] recorded from MAR-One (1-3) during the wet season is also an occasional hyporheos stygophile. This species is known from both epigean and stygal habitats. It has been recorded from calcrete aquifers while sampling bores at Moorarie and Killara North, but is most commonly recorded from the edge of pools in sandy riverbeds and interstitially to at least two meters from the water's edge in an upstream direction (Watts and Humphreys 2004). This species has been previously recorded from interstitial samples taken from Weeli Wolli in September 2003 during surveys conducted by the DEC (Adrian Pinder, DEC, unpub. data) and more recently during the Living Water Study undertaken by the authors (WRM 2009a).

[15] Previously known as *Boongurrus occidentalis* sp. nov. (Watts and Humphreys 2004). The genus *Boongurrus* has since been synomised with *Limbodessus* (Balke and Ribera 2004).

## 3.4 Macroinvertebrates

### 3.4.1 Taxonomic composition and species richness

A total of 115 taxa of macroinvertebrates were recorded from the 12 riffle habitat sites along Marillana Creek during October 2008 and May 2009 (Table 9 and Appendix 6). Of these, 104 were recorded in October (dry) and 68 were recorded in May (wet) (Table 9 and Appendix 6). The macroinvertebrate fauna included Cnidaria (freshwater hydra), Mollusca (freshwater snails), Oligochaeta (aquatic segmented worms), Crustacea (side swimmers), Acarina (water mites), Ephemeroptera (mayfly larvae), Odonata (dragonfly and damselfly larvae), Hemiptera (true aquatic bugs), Coleoptera (aquatic beetles), Diptera (two-winged fly larvae), Trichoptera (caddisfly larvae), and Lepidoptera (aquatic moth larvae).

**Table 9.** Composition of macroinvertebrates recorded from Marillana Creek in October 08 (dry season) and May 09 (wet).

| *Macroinvertebrates* | *No. of taxa* | |
|---|---|---|
| | Oct-08 | May-09 |
| Cnidaria (freshwater hydra) | 1 | 0 |
| Mollusca (snails & bivalves) | 3 | 2 |
| Oligochaeta (aquatic worms) | 1+ | 1+ |
| Crustacea (side swimmers) | 0 | 1+ |
| Acarina (water mites) | 2+ | 2+ |
| Ephemeroptera (mayflies) | 5 | 3 |
| Odonata (dragonflies & damselflies) | 6 | 6 |
| Hemiptera (true bugs) | 13 | 3 |
| Coleoptera (aquatic beetles) | 19 | 12 |
| Diptera (two-winged flies) | 40 | 28 |
| Trichoptera (caddis-flies) | 11 | 7 |
| Lepidoptera (moths) | 3 | 3 |
| **Total number of taxa** | **104** | **68** |

The taxonomic listing includes records of larval and pupal stages for groups such as Diptera and Coleoptera. Current taxonomy is not sufficiently developed to allow identification of larval and pupal stages of all members of these groups to species level. In many instances, it is likely that these stages are the same species as the larval/adult stages recorded from the same location. However, because this could not be definitively determined, they were treated as separate taxa. In any case, different life stages often have different functional roles in the ecosystem and therefore it makes sense to treat them as separate taxa.

Taxa richness varied between reach and season. During the dry season of October 2008, the greatest number of macroinvertebrate taxa was recorded from MAR2-5 and MAR2-6 (55 taxa), and the least from MAR2-2 (32 taxa). During the wet, the greatest number of taxa was again collected from MAR2-6 (33 taxa), and the least from MAR1-1 (23 taxa) (Figure 20 and Appendix 6). More macroinvertebrate taxa were recorded during the dry season (Figures 20 and 21).

Using macroinvertebrate data from Weeli Wolli Creek in the analysis, there was a significant difference in the average number of macroinvertebrate taxa between reach (Two-way ANOVA; df = 5, p= 0.002) and season (Two-way ANOVA; df = 1, p= 0.000; see Table 10 and Figure 21). There was also a significant interaction between the wet and dry seasons for WW Reach Two, and between seasons for Marillana Reach Two (Figure 21). Significantly lower taxa richness was recorded from WW Reach Two[16] compared with all other reaches on Weeli Wolli and Marillana Creek (Table 10 and Figure 21). Across all reaches in Weeli Wolli and Marillana Creek, macroinvertebrate taxa richness was significantly greater in the dry season (Table 10 and Figure 21).

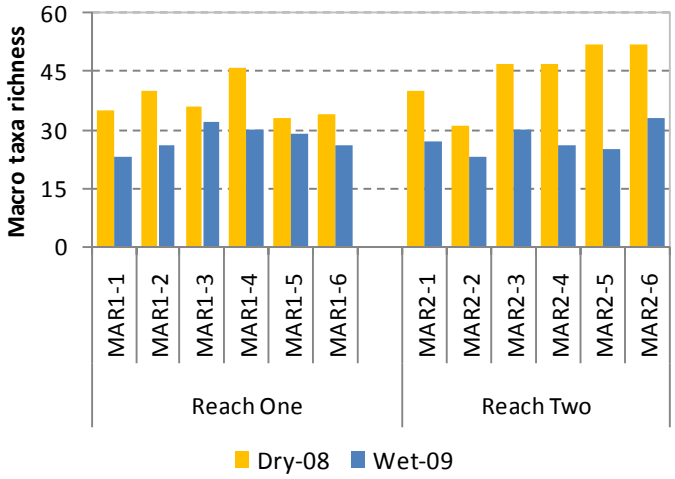



**Figure 20**. Macroinvertebrate taxa richness recorded from each site along Marillana Creek during both seasons.

**Table 10.** Two-way ANOVA results for macroinvertebrate taxa richness by reach and season (including Weeli Wolli data), showing degrees of freedom, f-value and p-value. Tukeys post-hoc results are presented in ascending order of mean taxa richness, with groups of no difference in means joined by a black line.

| *Source* | *df* | *F* | p | Tukeys post-hoc | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | WW 2 | MAR 1 | WW 3 | MAR 2 | WW 4 | WW 1 |
| **Reach** | 5 | 4.27 | 0.002 | | | | | | |
| **Season** | 1 | 31.05 | 0.000 | | | | | | |
| **Reach*Season** | 5 | 2.38 | 0.049 | | | | | | |
| **Total** | 71 | | | | | | | | |

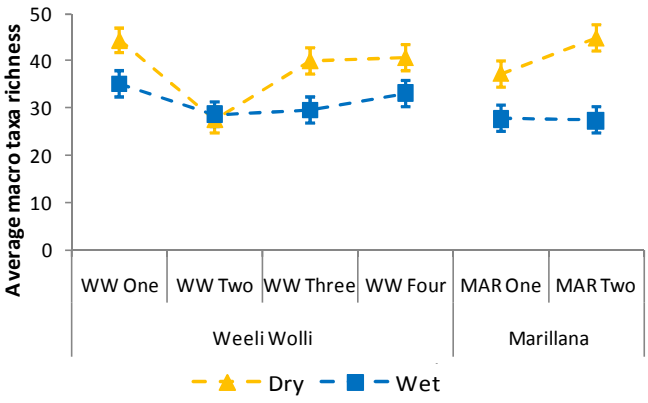



**Figure 21.** Average macroinvertebrate taxa richness (±se) from all reaches (including those along Weeli Wolli Creek) showing data for both the dry (October 2008) and wet season (May 2009).

[16] Weeli Wolli Reach Two is the reach immediately below the gabion and is likely impacted by greatly increased flows which will likely adversely affect species preferring low flows/low velocity

### 3.4.2 Conservation significance of macroinvertebrates

While the majority of taxa collected during October 2008 and May 2009 were common, ubiquitous species with distributions extending across Northern Australia (4%), Australasia (23%), and the world (cosmopolitan species; 5%), a number of taxa were endemic to Western Australia (1%) or, more specifically, the Pilbara region of Western Australia (3%). Taxa endemic to Western Australia included the mayfly Baetidae Genus 1 WA sp1 and the dragonfly *Austrogomphus gordoni*. Taxa with distributions restricted to the Pilbara region of Western Australia included the stygal amphipod *Chydaekata* sp., the dragonfly *Nannophlebia injabandi*, and the hydrophilid beetle *Laccobius billi*. Over 64% of macroinvertebrate taxa were classified as indeterminate, due to insufficient taxonomy/knowledge.

Indeterminate taxa made up the greatest proportion of taxa from each reach during each season (Figure 22). This was generally followed by Australasian taxa, with distributions across Australia and the south-east Asian region, and then cosmopolitan or Northern Australian species (Figure 22). A greater proportion of taxa endemic to the Pilbara were recorded from Marillana Creek during the wet season (Figure 22). No Western Australian endemic taxa were recorded from either reach during the dry season.

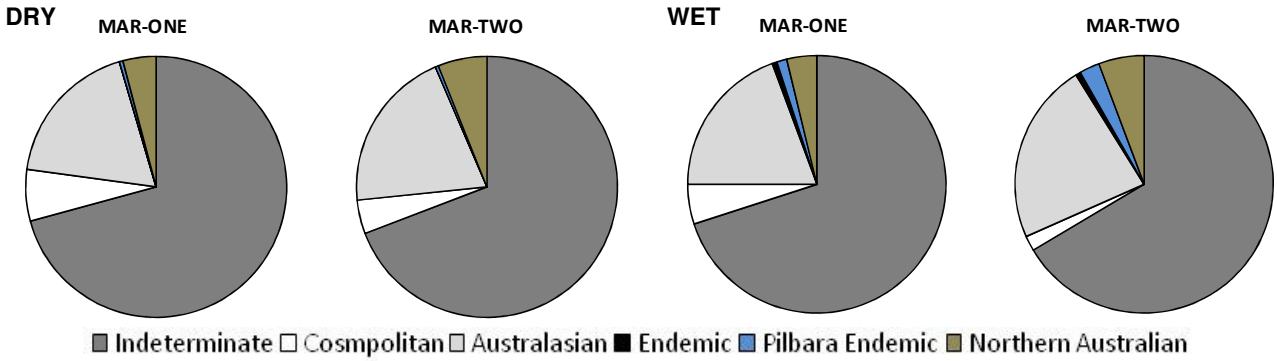



**Figure 22.** Proportions of species from each conservation category recorded from both reaches during the October 2008 dry season (left) and the May 2009 wet season (right).

### 3.4.3 Patterns in macroinvertebrate assemblage structure

The macroinvertebrate abundance ordination showed some clear patterns (Figure 23). In a similar manner to the water quality data, there was a distinct seasonal effect, with samples taken during the dry season separating from those taken during the wet (Figure 23). This was found to be significant (Two-way crossed ANOSIM; sample statistic = 0.54; significance of sample statistic p = 0.0001). While there did appear to be some separation of samples based on reach, there was also some overlap (Figure 23). Further analysis revealed that while macroinvertebrate assemblages were significantly separate between reach, the groups were barely separable[17] (Two-way crossed ANOSIM; sample statistic = 0.11; significance of sample statistic p = 0.0001). This is likely due to the large variability evident

[17] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barely separable.

within reaches, as well as similarities between reaches, represented as overlap in ordination space (Figure 23).

Water quality variables found to be contributing to patterns within the macroinvertebrate ordination of Marillana Creek were dissolved oxygen, chloride, sodium, log total phosphorus and sulphate (BIOENV; Rho =0.56, significance of sample statistic p = 0.01). Sodium concentrations were lower from Reach Two during the wet, sulphate was higher during the dry season, and log total phosphorus was higher during the wet (Figure 24).

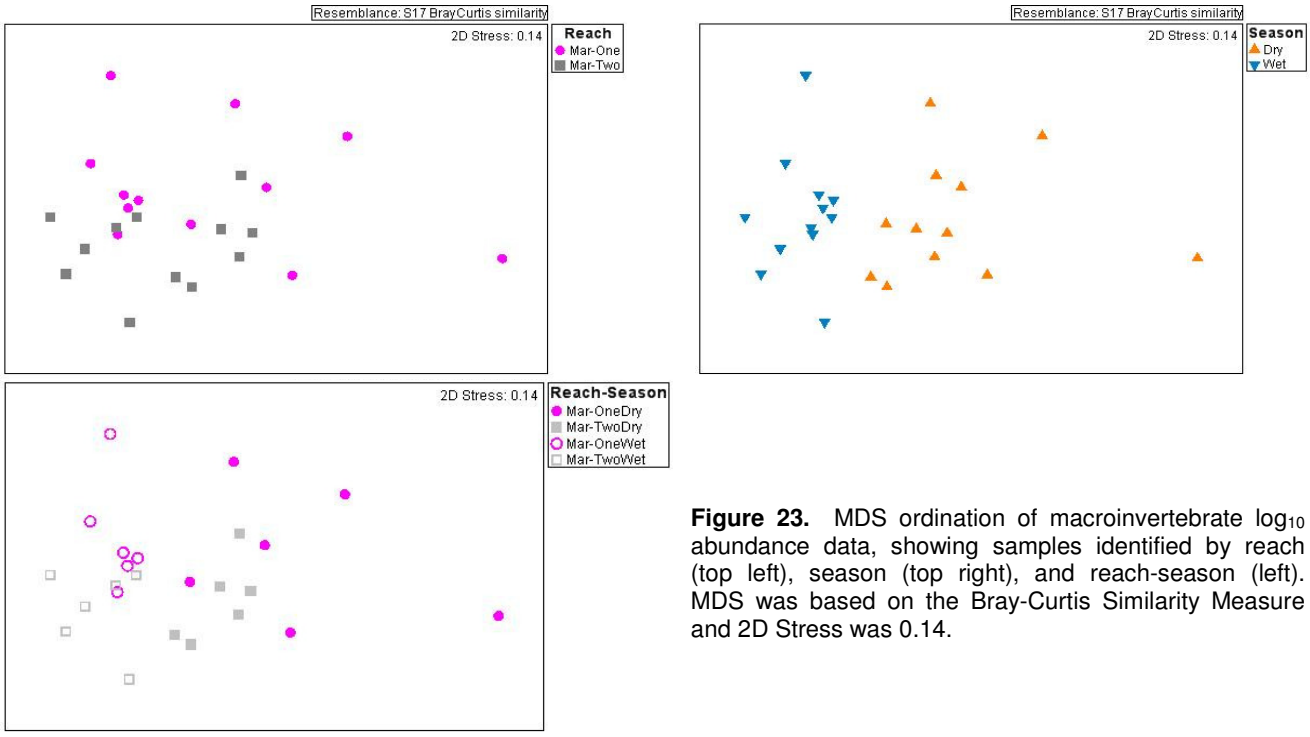



**Figure 23.** MDS ordination of macroinvertebrate $log_{10}$ abundance data, showing samples identified by reach (top left), season (top right), and reach-season (left). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.14.

### 3.4.4 Comparison of macroinvertebrate assemblages with Weeli Wolli Creek

Analyses were also completed using all macroinvertebrate $log_{10}$ abundance data recorded from Weeli Wolli Creek and Marillana Creek during October 2008 (dry season) and May 2009 (wet). Groupings within the macroinvertebrate ordination incorporating all data were less clear than within the water quality ordination (Figures 8 & 25). Firstly, there was no separation between systems (One-way ANOSIM; sample statistic = 0.01, significance of sample statistic p = 0.38), suggesting that on a broad scale the macroinvertebrate assemblages of Marillana Creek were similar to those from Weeli Wolli Creek in October 2008 and May 2009 (Figure 25). The consistent seasonal trend, however, was evident within the macroinvertebrate assemblages of Weeli Wolli and Marillana creeks, with a significant separation between seasons being found (Figure 25; Two-way crossed ANOSIM; sample statistic = 0.46, significance of sample statistic p = 0.0001). Overall, macroinvertebrate assemblages were also significantly separate amongst reaches, but some reaches were barely separable and recorded low R-values (Figure 25 & Table 11; Two-way crossed ANOSIM; sample statistic = 0.29, significance of sample statistic p = 0.0001). The greatest separation was between WW-Two and both Marillana Creek reaches (MAR-One, R=0.52; and MAR-Two, R=0.49; Table 11). There was considerable overlap in the

macroinvertebrate assemblages between a number of reaches, suggesting these reaches had similar faunal assemblages (Figure 25). The greatest similarity (i.e. lowest R-value) was between both Marillana reaches (R=0.11; Table 11). These reaches were also similar to the downstream Weeli Wolli reach, WW-Four (Table 11).

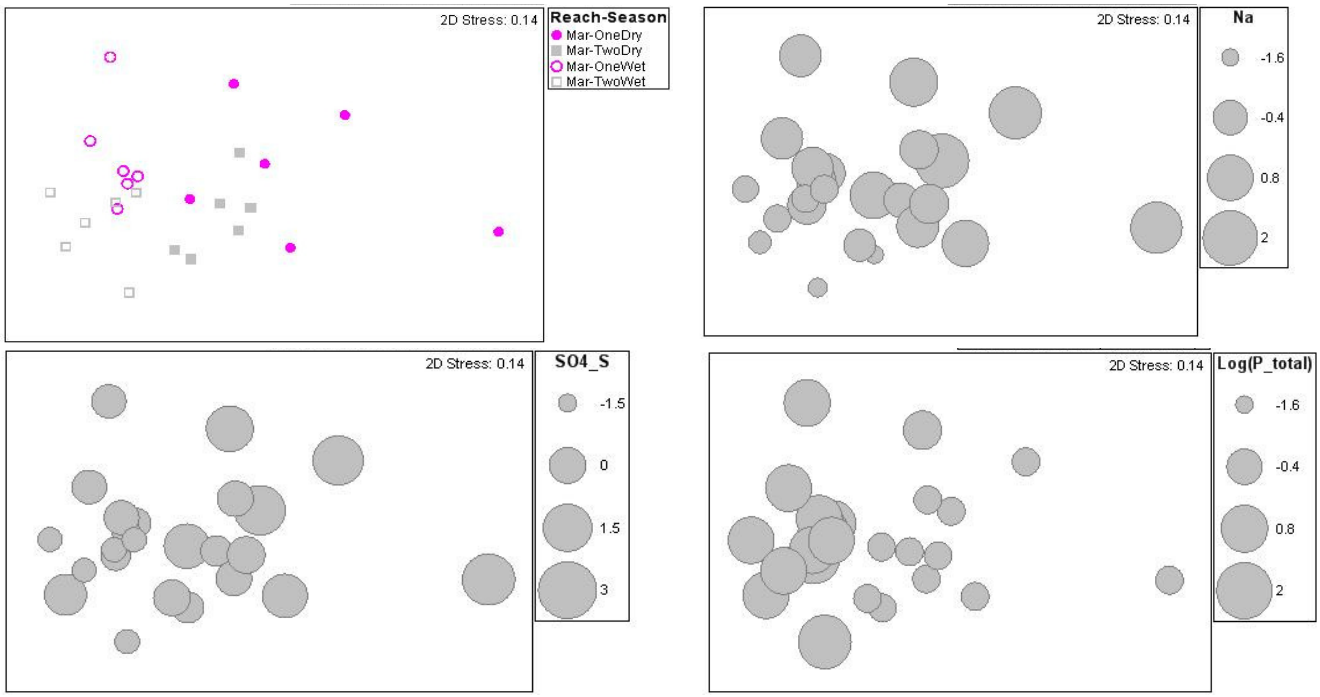



**Figure 24.** Bubble plots of water quality variables influencing the macroinvertebrate ordination, including sodium, sulphate and log total phosphorus.

**Table 11.** Pair-wise ANOSIM results of macroinvertebrate $log_{10}$ abundance data amongst reach, showing R-values (sample statistic)[18], * = groups significantly different.

| | *WW One* | *WW Two* | *WW Three* | *WW Four* | *MAR One* |
|---|---|---|---|---|---|
| **WW One** | | | | | |
| **WW Two** | 0.40* | | | | |
| **WW Three** | 0.47* | 0.21* | | | |
| **WW Four** | 0.24* | 0.38* | 0.18* | | |
| **MAR One** | 0.26* | 0.52* | 0..34* | 0.15* | |
| **MAR Two** | 0.41* | 0.49* | 0.31* | 0.14* | 0.11* |

[18] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barley separable.

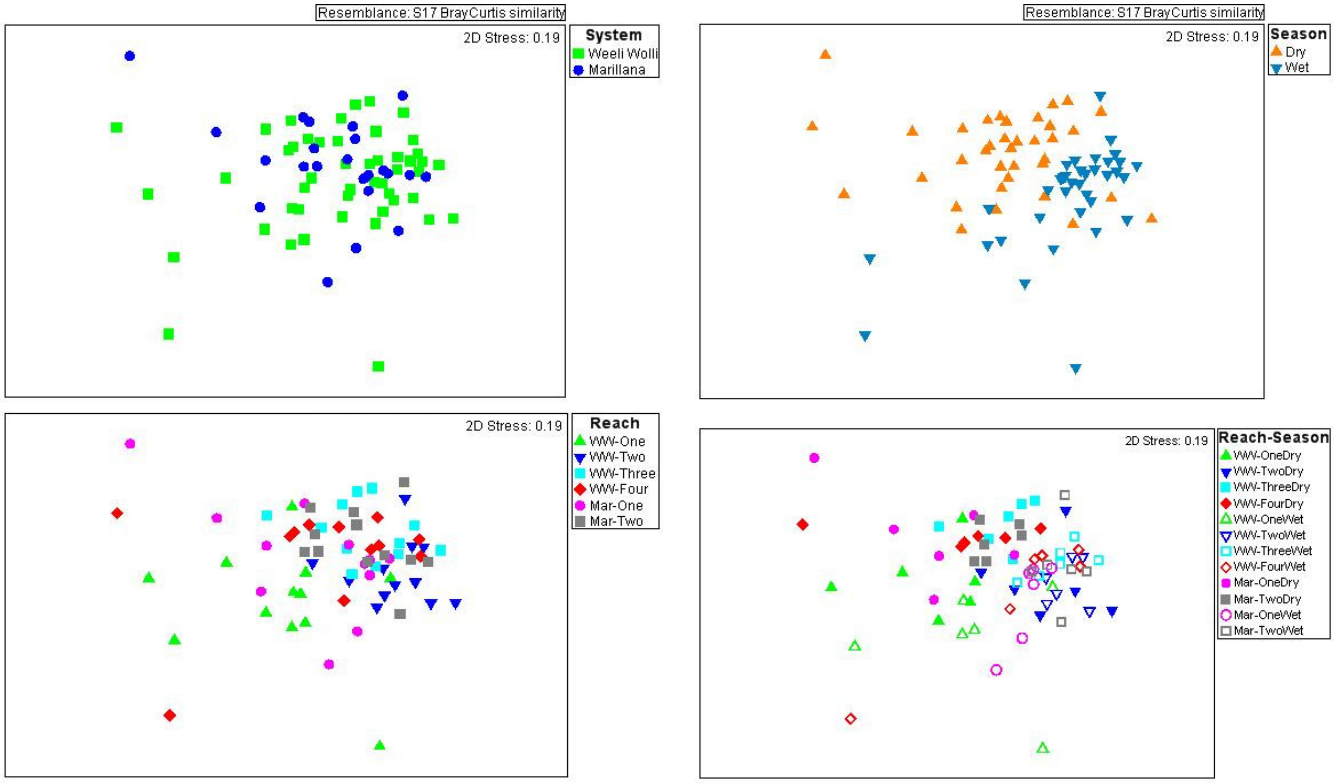



**Figure 25.** MDS ordination of macroinvertebrate log10 abundance data from Weeli Wolli Creek and Marillana Creek, showing samples identified by system (top left), season (top right), reach (bottom left), and reach-season (bottom right). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.19.

## 3.5 Fish

### 3.5.1 Species richness

The fish fauna of the Pilbara is characterised by low species diversity but high levels of endemicity, with over 42% of species recorded restricted to the region (Unmack 2001, Allen *et al.* 2002). Masini (1988) found the relatively clear waters of permanent and semi-permanent waterbodies supported the best developed fish assemblages in the region. In a study of the biogeography of Australian fish fauna, Unmack (2001) recognised ten distinct freshwater fish biogeographic provinces, of which the Pilbara Province was one. This region was considered distinct because its fauna did not cluster with other drainages in multivariate (parsimony and UPGMA) analysis of fish distribution patterns (Unmack 2001).

Three of the eleven freshwater fish species known from the Fortescue River were recorded from Marillana Creek during October 2008 and May 2009. These were the spangled perch *Leiopotherapon unicolor*, Hyrtl's tandan (eel-tailed catfish) *Neosiluris hyrtlii*[19] (Plate 3), and western rainbowfish *Melanotaenia australis.* All species were collected from both reaches in each season (Table 11). These three fish were also the only species collected from Marillana Creek during previous regional surveys (WRM 2009b), and are the only species known from Weeli Wolli Creek (Streamtec 2004, WRM 2009a, 2010).

**Plate 3.** Hyrtl's tandan catfish, *Neosiluris hyrtlii* (photo taken and provided by Mark Allen ©.

### 3.5.2 Abundance

A total of 1008 freshwater fish were collected from Marillana Creek during the October 2008 surveys, and 1149 during May 2009 (Table 12). Western rainbowfish were the most abundant species collected from both reaches during both seasons (Table 12). A greater abundance of fish was recorded from the downstream reach (Reach Two).

**Table 12.** Total number of fish caught from Marillana Creek during the dry (Oct-08) and wet seasons (May-09).

| ***October 2008*** | | | | |
|---|---|---|---|---|
| | ***Rainbowfish*** | ***Perch*** | ***Catfish*** | ***Total*** |
| **Reach 1** | 360 | 12 | 4 | 376 |
| **Reach 2** | 526 | 16 | 90 | 632 |
| **Total** | **886** | **28** | **94** | **1008** |
| ***May 2009*** | | | | |
| | ***Rainbowfish*** | ***Perch*** | ***Catfish*** | ***Total*** |
| **Reach 1** | 494 | 14 | 19 | 527 |
| **Reach 2** | 511 | 55 | 56 | 622 |
| **Total** | **1005** | **69** | **75** | **1149** |

[19] Taxonomy of *N hyrtlii* in the Pilbara is currently under revision as genetic analysis suggests it is a different species from *N. hyrtlii* in the Kimberley and eastern Australia. Therefore, the name for this species may change in the future.

### 3.5.3 Length-frequency analysis

Breeding characteristics of fish species in the Pilbara, such as fecundity and the size at first maturity, vary between river systems and rainfall zone. Beesley (2006) found life history strategies of fish species in the Fortescue River lay between 'opportunistic' and 'periodic', reflecting the seasonal yet unpredictable nature of rainfall in the region.

**Western rainbowfish**

Breeding in western rainbowfish (*Melanotaenia australis*) occurs throughout the year, with multiple spawning bouts which take full advantage of the regions intermittent rainfall and streamflow (Beesley 2006). Morgan *et al.* (2002) captured small juveniles on most sampling occasions in the Fitzroy River. The size at first maturity varies between river systems, but western rainbowfish generally attain a maximum size of 110 mm TL[20] (Morgan *et al.* 2002).

Length-frequency plots of western rainbowfish from Marillana Creek show that individuals of all age-classes were present in the population, from juveniles and sub-adults to large adults (Figure 26). This suggests successful breeding and recruitment. A greater proportion of new recruits (< 30 mm SL[21]) were collected from both reaches during May 2009 following wet season rains (MAR-One = 38%; MAR-Two = 27%), than during the dry (MAR-One = 19%; MAR-Two = 11%; Figure 26). The majority of new recruits were recorded from the upper reach (MAR-One; Figure 26).

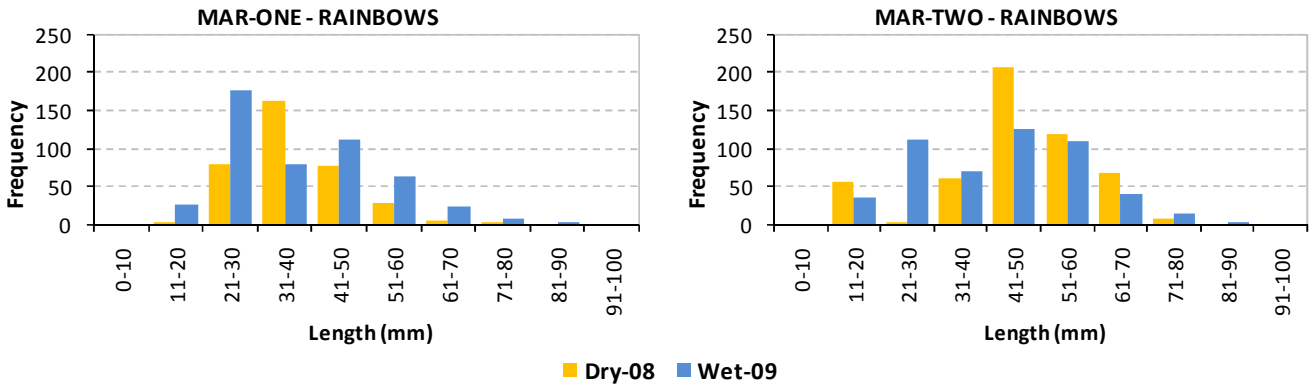



**Figure 26.** Length-frequency histograms for western rainbowfish collected from MAR-One (left) and MAR-Two (right) during the dry-08 and wet-09.

**Hyrtl's tandan catfish**

Very little is known of the breeding ecology of Hyrtl's tandan (*Neosiluris hyrtlii*). It is thought that individuals may mature in their first year at a size of approximately 135 mm TL for both sexes (Lake 1971, Bishop *et al.* 2001). Species of *Neosilurus* catfish usually attain a maximum size of only 200 mm however, *N. hyrtlii*, along with *N. ater*, can reach up to 400 mm TL (Lake 1971, Bishop *et al.* 2001). Breeding is thought to occur in the early wet season (Morgan *et al.* 2002, Bishop *et al.* 2001). It is at this time when initial flooding increases the

[20] TL = total length, measured from the tip of the snout to the tip of the longer lobe of the caudal fin.

[21] SL = standard length, measured from the tip of the snout to the posterior end of the last vertebra or to the posterior end of the midlateral portion of the hypural plate (i.e. this measurement excludes the length of the caudal fin). Standard length was measured in the current study.

area and diversity of aquatic habitat available, while also initiating increases in plankton and other foods (Bishop *et al.* 2001).

The greatest number of smaller Hyrtl's catfish (<70 mm SL) was recorded from the lower reach (MAR-Two) during the dry season (Figure 27). Few catfish were collected from MAR-One in either season, but those that were would be considered sub-adults to adults (Figure 27). Catfish of all age-classes were recorded from MAR-Two, including few juveniles, sub-adults, adults, and a number of larger sized adults (>150 mm SL; Figure 27).

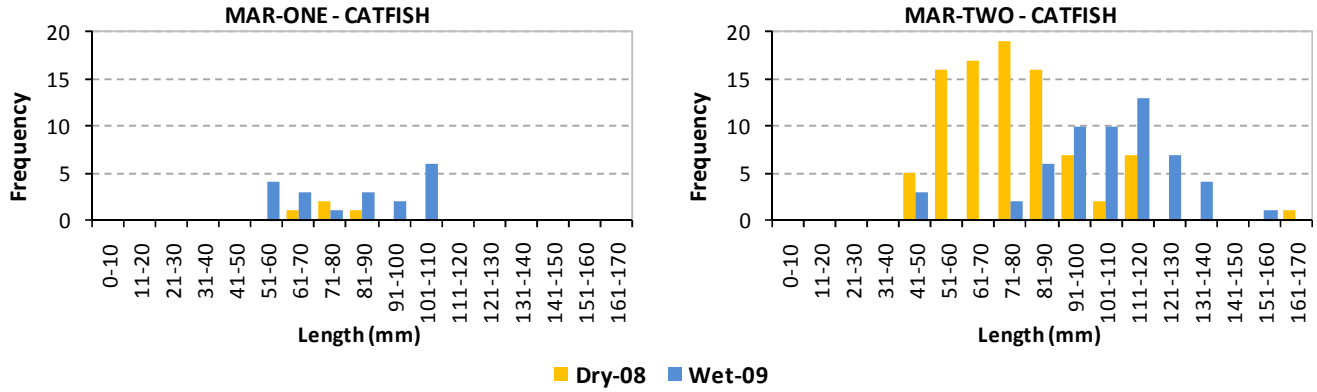



**Figure 27.** Length-frequency histograms for Hyrtl's tandan catfish collected from MAR-One (left) and MAR-Two (right) during the dry-08 and wet-09.

**Spangled perch**

Breeding in spangled perch (*Leiopotherapon unicolor*) of the Pilbara occurs during the summer wet season, between late November and March (Beesley 2006, Morgan *et al*. 2002). During this time, multiple spawning events are known to occur (Beesley 2006). In the Fitzroy River, Morgan *et al.* (2002) collected mature specimens in summer and larvae at the end of the wet season, indicating that spawning coincided with the flooding of the river. Spangled perch mature in their first year at approx. 58 mm TL for males and 78 mm TL for females. They reach a maximum size of 300 mm TL.

Length-frequency analysis of spangled perch captured from Marillana Creek showed that no juveniles (< 50 mm) were caught (Figure 28). This perhaps reflects the secretive nature of this species and its ability to quickly evade capture by hiding in snags and other cover. Further sampling of the creek should locate juveniles should they be present. Although adults (> 70 mm) were collected from both reaches during both seasons, no larger individuals were captured at the maximum size range (between 200 mm and 310 mm). The greatest number of spangled perch were recorded during the wet season at MAR-Two, and these were mostly adults, with only a few sub-adults recorded (50-70 mm SL; Figure 28).

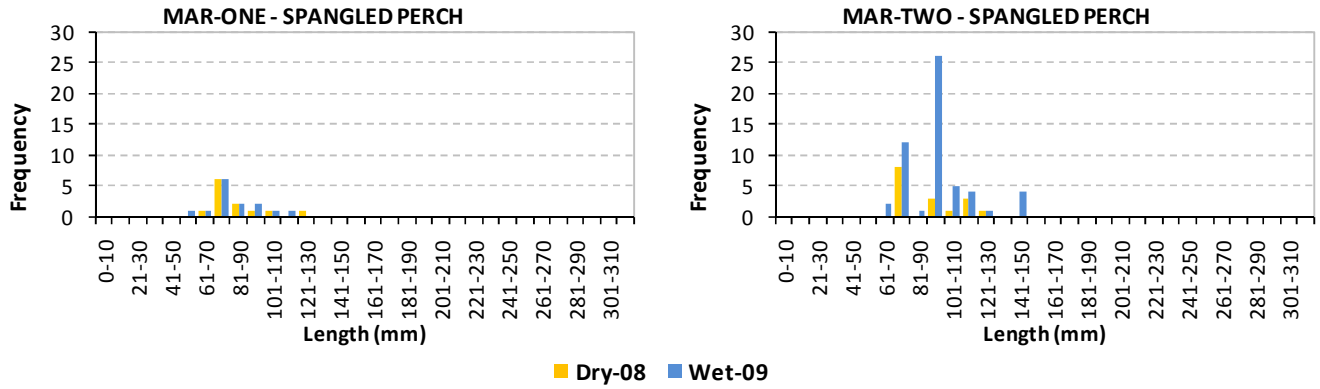



**Figure 28.** Length-frequency histograms for spangled perch collected from MAR-One (left) and MAR-Two (right) during the dry-08 and wet-09.

# 4 CONCLUSIONS

## 4.1 Water quality

The main water quality findings were:

- Super-saturated DO levels (>100%) were recorded from a number of sites along the creek in both seasons. These sites likely become anoxic overnight as respiration by plants, algae and fauna deplete DO. Super-saturated DO can also lead to fish bubble disease. One site in particular, MAR2-4 in October 2008, recorded exceptionally high DO levels (180%).
- Circum-neutral to slightly basic pH characteristic of Marillana Creek is not uncommon from similar waterbodies in the East Pilbara Region of W.A.
- All sites were fresh
- The high alkalinity levels recorded from all sites indicate that the buffering capacity of the waters of Marillana Creek is high
- The composition of major ions along Marillana Creek was typically dominated by sodium and hydrogen bicarbonate. This was similar to that reported from the lower end of Weeli Wolli Creek, downstream of the confluence with Marillana Creek
- Total nitrogen levels exceeded ANZECC/ARMCANZ (2000) guidelines at MAR2-1 and MAR2-2 in the dry season, and most sites during the wet. Total nitrogen levels were significantly higher from Reach Two. The cause of the elevated total nitrogen levels from the downstream Marillana reach is unknown, but may be coming from any number of potential sources, including pastoral activities and cattle stocking, local geology (i.e. soils or bedrock), and/or influence from Yandi discharge water and mining operations (see section 3.1.1). Potential sources for the increased total nitrogen from MAR-Two need to be investigated further before any conclusions can be drawn.
- Multivariate analyses showed that water quality was significantly different between reach and season. Dry season samples from Marillana Reach One formed the tightest group in the ordination, suggesting that samples within this group were most similar to each other, than any other group
- Using all water quality data collected from Weeli Wolli and Marillana Creek in October 2008 and May 2009, water quality was found to be significantly different between systems. Water quality was also significantly different amongst reach and season. During the dry season, Marillana Creek samples from both reaches grouped with Weeli Wolli Reach Four samples. This suggests that during the dry season, the water quality of Marillana Creek was similar to that recorded from the downstream Weeli Wolli reach (WW Reach Four). It appears that water quality of the downstream reach of Weeli Wolli Creek is influenced by Marillana Creek. During the wet season, WW-Four formed its own group, separate from Marillana Creek sites.

## 4.2 Microinvertebrates

The main microinvertebrate findings were:

- A total of 59 microinvertebrate taxa were recorded; 45 in October 2008 and 41 in May 2009

- The microinvertebrate fauna were typical of tropical systems reported elsewhere, with Branchionidae (Rotifera) being poorly represented, Lecanidae dominating the Rotifera, and the replacement of Daphniidae (Cladocera) with Chydoridae (Cladocera)
- Microinvertebrate taxa richness varied greatly between reach and season
- Using microinvertebrate data from Weeli Wolli Creek in the analysis, there was no significant difference in the average number of taxa between reach. There was, however, a significant difference between season , with a greater number of taxa being recorded in the dry season
- Multivariate analyses showed no significant difference in microinvertebrate assemblages between reach. While there did appear to be some separation of samples between season, groups were found to be barely separable. Dry season samples were significantly less variable than wet season samples
- The multivariate ordination incorporating all microinvertebrate abundance data recorded from Weeli Wolli and Marillana creeks during October 2008 and May 2009, showed no clear patterns. There was no significant separation between system, reach or season. The greatest similarity (i.e. lowest R-value and no significant difference) was between Marillana reaches One and Two. The greatest separation of microinvertebrate assemblages was between Weeli Wolli Reach One and Marillana Reach Two.

## 4.3 Hyporheic fauna

The main hyporheic fauna findings were:

- During the dry season, the vast majority of taxa collected in hyporheic samples were classified as stygoxene (72%) and do not have specialised adaptations for groundwater habitats. However, 5% of the taxa were classified as occasional hyporheos stygophiles, 5% were stygobites, and 9% were possible hyporheic taxa
- During the wet season, most taxa were stygoxene(81%), with 9% being considered hyporheos fauna (5% occasional hyporheos stygophiles, 2% stygobites, and 2% possible hyporheic taxa)
- Results from this study are similar to those reported previously in the Pilbara (Halse *et al.* 2002, WRM 2010), in that <20% of taxa collected in hyporheic habitats were entirely dependent on groundwater for their persistence as a species
- Hyporheos fauna were recorded from both reaches of Marillana Creek during both seasons. The greatest number of occurrences of hyporheos taxa was recorded from Reach Two in the wet season of May 2009, and the least from Reach One during the dry of October 2008
- Species considered to be restricted to the hyporheos were the stygobitic amphipod ?*Chydaekata* sp., possible hyporheos species Oligochaeta spp. and *Diacyclops* sp. (copepodites), and the occasional stygophiles Baetidae Genus 1 WA sp.1 (mayfly larvae), *Limbodessus occidentalis* and Dytiscidae spp. Larvae
- stygobitic amphipods collected from hyporheic samples were recorded as ?*Chydaekata* sp. because preliminary results from genetic analysis suggest that at least two species of stygal amphipod occur at Marillana Creek, including *Chydaekata* sp. and species D-Mar (Dr Terrie Finston, UWA, pers. comm.).

## 4.4 Macroinvertebrates

The main macroinvertebrate findings were:

- A total of 115 taxa of macroinvertebrates were recorded from the 12 riffle habitat sites along Marillana Creek during October 2008 and May 2009; 104 were recorded in October and 68 were recorded in May
- Taxa richness varied between reach and season, ranging from 23 taxa (MAR1-1 in the wet) to 55 (MAR 2-5 and MAR2-6 in the dry)
- Using macroinvertebrate data from Weeli Wolli Creek in the analysis, there was a significant difference in the average number of macroinvertebrate taxa between reach. Significantly lower taxa richness was recorded from WW Reach Two compared with all other reaches on Weeli Wolli and Marillana Creek. Across all reaches in Weeli Wolli and Marillana Creek, macroinvertebrate taxa richness was significantly greater in the dry than the wet season.
- The majority of taxa collected during October 2008 and May 2009 were common, ubiquitous species with distributions extending across Northern Australia (4%), Australasia (23%), and the world (cosmopolitan species; 5%). However, of interest was the collection of taxa endemic to Western Australia (1%) or, more specifically, the Pilbara region of Western Australia (3%). Taxa endemic to Western Australia included the mayfly Baetidae Genus 1 WA sp1 and the dragonfly *Austrogomphus gordoni*. Taxa with distributions restricted to the Pilbara region of Western Australia included the stygal amphipod *Chydaekata* sp., the dragonfly *Nannophlebia injabandi*, and the hydrophilid beetle *Laccobius billi*.
- A greater proportion of taxa endemic to the Pilbara were recorded from Marillana Creek during the wet season. No Western Australian endemic taxa were recorded from either reach during the dry season
- Multivariate analyses showed a distinct seasonal effect on macroinvertebrate assemblages of Marillana Creek. While there did appear to be some separation of samples based on reach, there was also some overlap, and analyses found the groups to be barely separable. This is likely due to the large variability evident within reaches, as well as similarities between reaches
- Analyses were also completed using all macroinvertebrate $\log_{10}$ abundance data recorded from Weeli Wolli Creek and Marillana Creek during October 2008 (dry season) and May 2009 (wet). There was no separation between system, indicating that at a broad scale the macroinvertebrate assemblages of Marillana Creek were similar to those from Weeli Wolli Creek in October 2008 and May 2009. The consistent seasonal trend, however, was still evident, with a significant separation between seasons being found. Overall, macroinvertebrate assemblages were also significantly separate amongst reaches, but some reaches were barely separable and recorded low R-values. The greatest separation was between WW-Two and both Marillana Creek reaches. The greatest similarity in macroinvertebrate assemblages was between both Marillana reaches. These reaches were also similar to the most downstream Weeli Wolli reach, WW-Four

## 4.5 Fish

The main fish findings were:

- Three of the eleven freshwater fish species known from the Fortescue River were recorded from Marillana Creek during October 2008 and May 2009; the spangled perch *Leiopotherapon unicolor*, Hyrtl's tandan (eel-tailed catfish) *Neosiluris hyrtlii*, and western rainbowfish *Melanotaenia australis*. These were the only species collected from Marillana Creek during previous regional surveys by the authors and are the only species known from Weeli Wolli Creek system
- A total of 1008 freshwater fish were collected during October 2008 and 1149 during May 2009. Western rainbowfish were the most abundant species collected from both reaches during both seasons. A greater abundance of fish was recorded from the downstream reach (Reach Two).
- Western rainbowfish of all age-classes were present in the population, from juveniles and sub-adults to large adults, suggesting successful breeding and recruitment. A greater proportion of new recruits (< 30 mm SL) were collected from both reaches during May 2009 following wet season rains. The majority of new recruits were recorded from the upper reach
- The greatest number of smaller Hyrtl's catfish (<70 mm SL) was recorded from the lower reach (MAR-Two) during the dry season. Few catfish were collected from MAR-One in either season, but those that were would be considered sub-adults to adults. Catfish of all age-classes were recorded from MAR-Two, including few juveniles, sub-adults, adults, and a number of larger sized adults
- No juvenile spangled perch (< 50 mm) were caught along Marillana Creek during the current study. This perhaps reflects the secretive nature of this species and its ability to quickly evade capture by hiding in snags and other cover. Further sampling of the creek should locate juveniles should they be present. Adults (> 70 mm) were collected from both reaches during both seasons, but no larger individuals were captured at the maximum size range (between 200 mm and 310 mm). The greatest number of spangled perch were recorded during the wet season at MAR-Two, and these were mostly adults, with only a few sub-adults recorded.

# 5 RECOMMENDATIONS

Recommendations for future monitoring include:

1. Continue monitoring in the same manner as documented here to detect any changes that may occur to the ecology of Marillana Creek as a result of increased discharge of dewatering water, and possible adverse conditions which may impact lower Weeli Wolli Creek
2. Future sampling should also include habitat assessments which can be compared with those taken along Weeli Wolli Creek
3. Establish Regional sites in Fortescue Marshes to ensure any cumulative impacts that may occur in the future do not adversely affect the marshes during times of connection
4. Deploy dissolved oxygen loggers for a period of 24 hours in pools with an abundance of algae to determine the extent of overnight DO depletion.

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# APPENDICES

# Appendix 1. Site photographs

For photographs of Weeli Wolli sites see WRM (2010).

## MARILLANA CREEK

## REACH ONE

**DRY 08** **WET 09**

**MAR1-1**

**MAR1-2**

**DRY 08** **WET 09**

**MAR1-3**

**MAR1-4**

**MAR1-5**

**DRY 08** **WET 09**

**MAR1-6**

**REACH TWO**

**DRY 08** **WET 09**

**MAR2-1**

**MAR2-2**

**DRY 08** **WET 09**

**MAR2-3**

**MAR2-4**

**MAR2-5**

**DRY 08**
**MAR2-6**

**WET 09**

# Appendix 2. ANZECC/ARMCANZ (2000) trigger values for the protection of aquatic systems in tropical northern Australia

**Table A2-1.** Default trigger values for some physical and chemical stressors for tropical Australia for slightly disturbed ecosystems (TP = total phosphorus; FRP = filterable reactive phosphorus; TN = total nitrogen; NOx = total nitrates/nitrites; NH4+ = ammonium). Data derived from trigger values supplied by Australian states and territories, for the Northern Territory and regions north of Carnarvon in the west and Rockhampton in the east (ANZECC/ARMCANZ 2000).

| | TP ($\mu g\ L^{-1}$) | FRP ($\mu g\ L^{-1}$) | TN ($\mu g\ L^{-1}$) | NOx ($\mu g\ L^{-1}$) | $NH_4^+$ ($\mu g\ L^{-1}$) | DO % saturation[f] | pH |
|---|---|---|---|---|---|---|---|
| **Aquatic Ecosystem** | | | | | | | |
| Upland River[e] | 10 | 5 | 150 | 30 | 6 | 90-120 | 6.0-7.5 |
| Lowland River[e] | 10 | 4 | 200-300[h] | 10[b] | 10 | 85-120 | 6.0-8.0 |
| Lakes & Reservoirs | 10 | 5 | 350[c] | 10[b] | 10 | 90-120 | 6.0-8.0 |
| Wetlands[3] | 10-50[g] | 5-25[g] | 350-1200[g] | 10 | 10 | 90[b]-120[b] | 6.0-8.0 |

b = Northern Territory values are 5µgL$^{-1}$ for $NO_x$, and <80 (lower limit) and >110% saturation (upper limit) for DO;
c = this value represents turbid lakes only. Clear lakes have much lower values;
e = no data available for tropical WA estuaries or rivers. A precautionary approach should be adopted when applying default trigger values to these systems;
f = dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability;
g = higher values are indicative of tropical WA river pools;
h = lower values from rivers draining rainforest catchments.

**Table A2-2.** Default trigger values for salinity and turbidity for the protection of aquatic ecosystems, applicable to tropical systems in Australia (ANZECC/ARMCANZ 2000).

| *Aquatic Ecosystem* | | *Comments* |
|---|---|---|
| ***Salinity*** | ***(µs/cm)*** | |
| **Aquatic Ecosystem** | | |
| Upland & lowland rivers | 20-250 | Conductivity in upland streams will vary depending on catchment geology. The fist flush may result in temporarily high values |
| Lakes, reservoirs & wetlands | 90-900 | Higher conductivities will occur during summer when water levels are reduced due to evaporation |
| ***Turbidity*** | ***(NTU)*** | |
| **Aquatic Ecosystem** | | |
| Upland & lowland rivers | 2-15 | Can depend on degree of catchment modification and seasonal rainfall runoff |
| Lakes, reservoirs & wetlands | 2-200 | Most deep lakes have low turbidity. However, shallow lakes have higher turbidity naturally due to wind-induced re-suspension of sediments. Wetlands vary greatly in turbidity depending on the general condition of the catchment, recent flow events and the water level in the wetland. |

# Appendix 3. Water quality data from October 2008 and May 2009.

For Weeli Wolli water quality data see WRM (2009).

**Table A3-1.** Water quality data from Marillana Creek, October 2008 (dry). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines.

| Reach | Site | pH | Temp (ºC) | EC (µS/cm) | DO (%) | DO (mg/L) |
|---|---|---|---|---|---|---|
| One | MAR1-1 | 7.76 | 25.1 | 983 | 56 | 4.4 |
| | MAR1-2 | 7.67 | 26.4 | 983 | 71 | 5.5 |
| | MAR1-3 | 7.98 | 25.3 | 1000 | 84 | 6.8 |
| | MAR1-4 | 7.83 | 25.7 | 1020 | 77 | 6.2 |
| | MAR1-5 | 7.98 | 26.2 | 1027 | 63 | 5.3 |
| | MAR1-6 | 7.66 | 27.8 | 1040 | 157 | 11.6 |
| Two | MAR2-1 | 8.06 | 30.6 | 927 | 147 | 10.7 |
| | MAR2-2 | 7.93 | 28.4 | 926 | 112 | 8.5 |
| | MAR2-3 | 8.26 | 29.3 | 907 | 165 | 12.4 |
| | MAR2-4 | 8.34 | 29.5 | 905 | 180 | 13.1 |
| | MAR2-5 | 7.75 | 25.9 | 942 | 79 | 6.3 |
| | MAR2-6 | 8.34 | 27.5 | 943 | 94 | 8.2 |

**Table A3-2.** Water quality data from Marillana Creek, May 2009 (wet). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines.

| Reach | Site | pH | Temp (ºC) | EC (µS/cm) | DO (%) | DO (mg/L) |
|---|---|---|---|---|---|---|
| One | MAR1-1 | 7.89 | 25.3 | 939 | 87 | 7.3 |
| | MAR1-2 | 7.86 | 23.8 | 985 | 105 | 9.2 |
| | MAR1-3 | 7.56 | 23.1 | 1000 | 44 | 3.9 |
| | MAR1-4 | 7.9 | 23 | 996 | 82 | 7.4 |
| | MAR1-5 | 8.01 | 22.3 | 1000 | 107 | 9.9 |
| | MAR1-6 | 7.89 | 23.9 | 1010 | 103 | 9.2 |
| Two | MAR2-1 | 8.06 | 24.8 | 987 | 122 | 10.7 |
| | MAR2-2 | 8.00 | 23.8 | 987 | 88 | 7.9 |
| | MAR2-3 | 8.60 | 19.8 | 963 | 133 | 11.5 |
| | MAR2-4 | 7.79 | 23.7 | 943 | 80 | 7.2 |
| | MAR2-5 | 7.70 | 24.8 | 939 | 60 | 5.1 |
| | MAR2-6 | 7.87 | 20.9 | 939 | 80 | 7.4 |

**Table A3-3.** Nutrient data from Marillana Creek, October 2008 (dry). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | N_NO3 | N_NH3 | Total N | Total P |
|---|---|---|---|---|---|
| One | MAR1-1 | 0.12 | 0.01 | 0.22 | 0.005 |
| | MAR1-2 | 0.03 | 0.005 | 0.1 | 0.005 |
| | MAR1-3 | 0.01 | 0.005 | 0.27 | 0.01 |
| | MAR1-4 | 0.01 | 0.005 | 0.07 | 0.005 |
| | MAR1-5 | 0.01 | 0.005 | 0.05 | 0.005 |
| | MAR1-6 | 0.01 | 0.005 | 0.09 | 0.005 |
| Two | MAR2-1 | 1.3 | 0.005 | 1.8 | 0.005 |
| | MAR2-2 | 0.84 | 0.005 | 1.2 | 0.005 |
| | MAR2-3 | 0.08 | 0.005 | 0.17 | 0.005 |
| | MAR2-4 | 0.03 | 0.005 | 0.1 | 0.005 |
| | MAR2-5 | 0.15 | 0.005 | 0.24 | 0.005 |
| | MAR2-6 | 0.04 | 0.03 | 0.16 | 0.005 |

**Table A3-4.** Nutrient data from Marillana Creek, May 2009 (wet). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | N_NO3 | N_NH3 | Total N | Total P |
|---|---|---|---|---|---|
| One | MAR1-1 | 0.42 | 0.005 | 0.68 | 0.04 |
| | MAR1-2 | 0.17 | 0.01 | 0.35 | 0.02 |
| | MAR1-3 | 0.02 | 0.005 | 0.15 | 0.02 |
| | MAR1-4 | 0.07 | 0.005 | 0.16 | 0.03 |
| | MAR1-5 | 0.01 | 0.01 | 0.07 | 0.02 |
| | MAR1-6 | 0.01 | 0.01 | 0.18 | 0.02 |
| Two | MAR2-1 | 1 | 0.005 | 1.4 | 0.04 |
| | MAR2-2 | 0.61 | 0.005 | 1.00 | 0.02 |
| | MAR2-3 | 0.37 | 0.005 | 0.74 | 0.02 |
| | MAR2-4 | 0.45 | 0.005 | 0.59 | 0.02 |
| | MAR2-5 | 0.12 | 0.005 | 0.24 | 0.02 |
| | MAR2-6 | 0.08 | 0.005 | 0.22 | 0.02 |

**Table A3-5.** Ionic composition data collected from Marillana Creek in October 2008 (dry). All values are mg/L.

| Reach | Site | Na | K | Ca | Mg | Cl | CO3 | HCO3 | SO4_S | Alkalinity | Hardness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 92.1 | 7.9 | 50 | 46.9 | 138 | 0.5 | 323 | 63.2 | 265 | 320 |
| | MAR1-2 | 92 | 7.7 | 49.3 | 46.4 | 143 | 0.5 | 311 | 62.8 | 255 | 310 |
| | MAR1-3 | 93.9 | 7.8 | 50.8 | 47.2 | 145 | 0.5 | 342 | 64.2 | 280 | 320 |
| | MAR1-4 | 102 | 7.6 | 52.8 | 49.6 | 153 | 0.5 | 329 | 67.3 | 270 | 340 |
| | MAR1-5 | 99.1 | 7.9 | 51.7 | 49.5 | 162 | 0.5 | 336 | 66.9 | 275 | 330 |
| | MAR1-6 | 98.2 | 7.5 | 52.7 | 49.3 | 144 | 0.5 | 342 | 68.5 | 280 | 330 |
| Two | MAR2-1 | 67.6 | 8.2 | 54.9 | 54.7 | 102 | 0.5 | 384 | 54.9 | 315 | 360 |
| | MAR2-2 | 76.7 | 8.2 | 50.6 | 53.8 | 99 | 0.5 | 366 | 57.6 | 300 | 350 |
| | MAR2-3 | 79 | 7.5 | 49.1 | 47.6 | 107 | 0.5 | 366 | 54.5 | 300 | 320 |
| | MAR2-4 | 86.4 | 7.9 | 46.8 | 50 | 113 | 0.5 | 366 | 56.9 | 300 | 320 |
| | MAR2-5 | 82.7 | 7.5 | 52.1 | 50.1 | 120 | 0.5 | 354 | 57.2 | 290 | 340 |
| | MAR2-6 | 83.7 | 7.5 | 51.4 | 50.6 | 125 | 0.5 | 342 | 58 | 280 | 340 |

**Table A3-6.** Ionic composition data collected from Marillana Creek in May 2009 (wet). All values are mg/L.

| Reach | Site | Na | K | Ca | Mg | Cl | CO3 | HCO3 | SO4_S | Alkalinity | Hardness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 82.7 | 7.3 | 45.6 | 45.3 | 111 | 0.5 | 311 | 53.7 | 255 | 300 |
| | MAR1-2 | 83.4 | 7.3 | 45.8 | 44.9 | 122 | 0.5 | 317 | 54.1 | 260 | 300 |
| | MAR1-3 | 86.3 | 7.3 | 48.1 | 45.5 | 129 | 0.5 | 323 | 56.1 | 265 | 310 |
| | MAR1-4 | 83.3 | 7.1 | 47.9 | 44.7 | 129 | 0.5 | 323 | 53 | 265 | 300 |
| | MAR1-5 | 86.1 | 7.1 | 47.7 | 45.5 | 124 | 0.5 | 323 | 56.5 | 265 | 310 |
| | MAR1-6 | 85.9 | 7.1 | 46.9 | 44.8 | 114 | 0.5 | 317 | 56.4 | 260 | 300 |
| Two | MAR2-1 | 67.9 | 7.7 | 52 | 51.2 | 100 | 0.5 | 366 | 51.7 | 300 | 340 |
| | MAR2-2 | 69.9 | 7.3 | 48.5 | 52.2 | 102 | 0.5 | 366 | 60.8 | 300 | 340 |
| | MAR2-3 | 72.3 | 7.4 | 48.3 | 50.5 | 99 | 0.5 | 305 | 51.6 | 280 | 330 |
| | MAR2-4 | 73.2 | 7.2 | 48.7 | 51.3 | 100 | 0.5 | 342 | 51.8 | 280 | 330 |
| | MAR2-5 | 73.1 | 7.3 | 50 | 48.5 | 104 | 0.5 | 336 | 51.5 | 275 | 320 |
| | MAR2-6 | 73.6 | 7.4 | 49.9 | 48.2 | 105 | 0.5 | 329 | 51.7 | 270 | 320 |

**Table A3-7.** Metals data collected from Marillana Creek in October 2008. Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | Al | As | B | Ba | Cd | Co | Cr | Cu | Fe | Mn | Mo | Ni | Pb | Se | U | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 0.0025 | 0.0005 | 0.36 | 0.036 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0025 | 0.0025 |
| | MAR1-2 | 0.0025 | 0.0005 | 0.34 | 0.035 | 0.0002 | 0.0025 | 0.0005 | 0.001 | 0.027 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0025 | 0.0025 |
| | MAR1-3 | 0.0025 | 0.0005 | 0.36 | 0.034 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0025 | 0.0025 |
| | MAR1-4 | 0.0025 | 0.0005 | 0.36 | 0.036 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0014 | 0.0025 | 0.0025 |
| | MAR1-5 | 0.0025 | 0.0005 | 0.35 | 0.033 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0012 | 0.0025 | 0.0025 |
| | MAR1-6 | 0.0025 | 0.0005 | 0.35 | 0.035 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.024 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.0025 | 0.0025 |
| Two | MAR2-1 | 0.0025 | 0.0005 | 0.31 | 0.013 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0025 | 0.0025 |
| | MAR2-2 | 0.0025 | 0.0005 | 0.35 | 0.027 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.0025 | 0.0025 |
| | MAR2-3 | 0.0025 | 0.0005 | 0.32 | 0.028 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0018 | 0.0025 | 0.0025 |
| | MAR2-4 | 0.0025 | 0.0005 | 0.34 | 0.024 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0015 | 0.005 | 0.0025 |
| | MAR2-5 | 0.0025 | 0.0005 | 0.3 | 0.035 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0021 | 0.0025 | 0.0025 |
| | MAR2-6 | 0.0025 | 0.0005 | 0.3 | 0.033 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.01 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0023 | 0.0025 | 0.0025 |

**Table A3-8.** Metals data collected from Weeli Wolli Creek, May 2009. Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | Al | As | B | Ba | Cd | Co | Cr | Cu | Fe | Mn | Mo | Ni | Pb | Se | U | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 0.028 | 0.0005 | 0.32 | 0.051 | 0.00005 | 0.0025 | 0.0008 | 0.0007 | 0.014 | 0.004 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0042 | 0.006 |
| | MAR1-2 | 0.0025 | 0.0005 | 0.3 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.00005 | 0.055 | 0.007 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0038 | 0.006 |
| | MAR1-3 | 0.0025 | 0.0005 | 0.29 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.0002 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0042 | 0.004 |
| | MAR1-4 | 0.0025 | 0.0005 | 0.29 | 0.051 | 0.00005 | 0.0025 | 0.0005 | 0.0003 | 0.018 | 0.005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0035 | 0.004 |
| | MAR1-5 | 0.0025 | 0.0005 | 0.3 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.0002 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0042 | 0.003 |
| | MAR1-6 | 0.026 | 0.0005 | 0.28 | 0.049 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0012 | 0.0044 | 0.006 |
| Two | MAR2-1 | 0.0025 | 0.0005 | 0.27 | 0.032 | 0.00005 | 0.0025 | 0.0005 | 0.00005 | 0.015 | 0.005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0016 | 0.004 |
| | MAR2-2 | 0.007 | 0.0005 | 0.31 | 0.042 | 0.00005 | 0.0025 | 0.0005 | 0.0001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0012 | 0.0046 | 0.004 |
| | MAR2-3 | 0.0025 | 0.0005 | 0.25 | 0.047 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0014 | 0.004 | 0.005 |
| | MAR2-4 | 0.0025 | 0.0005 | 0.25 | 0.048 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0015 | 0.0043 | 0.005 |
| | MAR2-5 | 0.0025 | 0.0005 | 0.25 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.003 | 0.004 |
| | MAR2-6 | 0.022 | 0.0005 | 0.26 | 0.055 | 0.00005 | 0.0025 | 0.0009 | 0.0007 | 0.02 | 0.02 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.0025 | 0.008 |

# Appendix 4. Microinvertebrate data from October 2008 and May 2009.

**Table A4-1.** Dry season, October 2008.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **PROTISTA** | | | | | | | | | | | | | | |
| **Ciliophora** | | *Didinium* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| | | *Euplotes* sp. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Rhizopoda** | | | | | | | | | | | | | | |
| | **Arcellidae** | *Arcella discoides* | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 |
| | | *Arcella* sp. [med., transp., domed] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Arcella* sp. [sm., brn] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Centropyxidae** | *Centropyxis aculeata* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 |
| | | *Centropyxis ecornis* | 2 | 3 | 2 | 2 | 3 | 2 | 1 | 1 | 2 | 2 | 2 | 1 |
| | | *Centropyxis* sp [med.] | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | | *Centropyxis* sp [sm, elongate] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | *Centropyxis* sp [tiny] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | **Cyclopyxidae** | *Cyclopyxis* sp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Difflugiidae** | *Difflugia elegans* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | | *Difflugia gramen* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Euglyphidae** | *Euglypha* sp. | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Lesquereusiidae** | *Lesquereusia spiralis* | 2 | 2 | 1 | 0 | 2 | 2 | 0 | 0 | 1 | 2 | 1 | 2 |
| | | *Netzelia tuberculata* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **ROTIFERA** | | | | | | | | | | | | | | |
| **Bdelloidea** | | | | | | | | | | | | | | |
| | | indet. bdelloid [v. sm.] | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Monogononta** | | | | | | | | | | | | | | |
| | **Atrochidae** | *Cupelopagis vorax* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Epiphanidae** | *Microcodides* cf. *chlaena* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Euchlanidae** | *Euchlanis* sp. | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | *Tripleuchlanis plicata* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| | **Lecanidae** | *Lecane bulla* | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| | | *Lecane curvicornis* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* cf. *elsa* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Lecane ludwigii* | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane luna* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* (*M.*) a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| | | *Lecane* (*M.*) b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | **Lepadellidae** | *Colurella* sp. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | *Lepadella* sp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Mytillinidae** | *Mytilinia ventralis* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Notommatidae** | *Eosphora anthadis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | | *Notommata copeus* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Notommata* sp. | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **COPEPODA** | | | | | | | | | | | | | | |
| **Cyclopoida** | | | | | | | | | | | | | | |
| | | *?Tropocyclops* sp. | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | ?*Microcyclops* [late copepodite only] | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | cyclopoid copepodites | 0 | 0 | 0 | 2 | 2 | 1 | 2 | 2 | 3 | 2 | 1 | 1 |
| | | cyclopoid nauplii | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 2 | 2 | 1 | 1 | 0 |
| | | | | | | | | | | | | | | |
| **CLADOCERA** | | | | | | | | | | | | | | |
| | **Chydoridae** | *Armatalona macrocopa* | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 2 |
| | | *Alona rigidicaudis* | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Alona* cf. *verrucosa* | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Ephemeroporus barroisi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **OSTRACODA** | | | | | | | | | | | | | | |
| | | *Diacypris* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | *Limnocythere* sp. | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 |
| | | juv. ostracods, indet. | 0 | 2 | 1 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 1 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **9** | **8** | **8** | **9** | **11** | **5** | **10** | **8** | **19** | **16** | **7** | **6** |

**Table A4-2.** Wet season, May 2009.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **PROTISTA** | | | | | | | | | | | | | | |
| **Rhizopoda** | | | | | | | | | | | | | | |
| | **Arcellidae** | *Arcella discoides* | 2 | 1 | 2 | 3 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 |
| | **Centropyxidae** | *Centropyxis aculeata* | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| | | *Centropyxis ecornis* | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Centropyxis* sp [med.] | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Centropyxis* sp [tiny] | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Difflugiidae** | *Difflugia* [sm, ovoid] | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Euglyphidae** | *Euglypha* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Lesquereusiidae** | *Lesquereusia modesta* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lesquereusia spiralis* | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Netzelia tuberculata* | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Trinematidae** | *Trinema* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **ROTIFERA** | | | | | | | | | | | | | | |
| **Bdelloidea** | | indet. bdelloid [sm.] | 0 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | indet. bdelloid [tiny] | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Monogononta** | | | | | | | | | | | | | | |
| | **Brachionidae** | *Keratella tropica* | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Dicranophoridae** | *Dicranophorus sp.* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Epiphanidae** | *Microcodides* cf. *chlaena* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Euchlanidae** | *Euchlanis incisa* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Euchlanis* sp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tripleuchlanis plicata* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Lecanidae** | *Lecane batillifer* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane bulla* | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane lunaris* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* cf. *thalera* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* (*M.*) a | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* (*M.*) b | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Lepadellidae** | *Colurella* sp. | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Notommatidae** | *Cephalodella* cf. *forficula* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Notommata copeus* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Trichocercidae** | *Trichocerca* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Trichotriidae** | *Macrochaetus* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **COPEPODA** | | | | | | | | | | | | | | |
| **Cyclopoida** | | | | | | | | | | | | | | |
| | | *?Tropocyclops* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Thermocyclops decipiens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | cyclopoid copepodites | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| | | cyclopoid nauplii | 0 | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **CLADOCERA** | | | | | | | | | | | | | | |
| | **Chydoridae** | *Alona rigidicaudis* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | *Alona* cf. *verrucosa* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Chydorus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Karualona karua* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Daphniidae** | *Ceriodaphnia cornuta* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **OSTRACODA** | | | | | | | | | | | | | | |
| | | *Limnocythere* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | juv. ostracods, indet. | 0 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **4** | **6** | **20** | **18** | **1** | **0** | **6** | **2** | **1** | **2** | **1** | **3** |

# Appendix 5. Hyporheic data from October 2008 and May 2009.

**Table A5-1.** Dry season, October 2008.

| | | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Species* | *CAT* | *MAR1-1dry* | *MAR1-2dry* | *MAR1-3dry* | *MAR1-4dry* | *MAR1-5dry* | *MAR1-6dry* | *MAR2-1dry* | *MAR2-2dry* | *MAR2-3dry* | *MAR2-4dry* | *MAR2-5dry* | *MAR2-6dry* |
| **ANNELIDA** | | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | **P** | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| **CRUSTACEA** | | | | | | | | | | | | | | | |
| **Amphipoda** | | | | | | | | | | | | | | | |
| **Crangonyctoid** | **Paramelitidae** | *?Chydaekata* sp. | **S** | 0 | 4 | 0 | 0 | 0 | 0 | 6 | 4 | 0 | 5 | 24 | 4 |
| | | | | | | | | | | | | | | | |
| **Copepoda** | | | | | | | | | | | | | | | |
| **Cyclopoida** | **Cyclopodidae** | *Microcyclops varicans* | **X** | 0 | 6 | 0 | 0 | 3 | 8 | 0 | 0 | 3 | 2 | 0 | 0 |
| | | *Diacyclops* sp. [copepodites] | **P** | | | | 3 | | | | | | | | |
| | | Cyclopodidae: copepodites/males | **X** | 0 | 10 | 1 | 9 | 7 | 15 | 0 | 1 | 3 | 5 | 0 | 2 |
| | | | | | | | | | | | | | | | |
| **ARACHNIDA** | | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | **U** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | | |
| **COLLEMBOLLA** | | Collembolla spp. | **X** | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| **INSECTA** | | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Baetidae** | *Baetidae Genus 1 WA sp.1* | **O** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | | | | | | | | | | | | | | | |
| **COLEOPTERA** | **Hydrophilidae** | Hydrophilidae spp. | **U** | 0 | 6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 |
| | **Scirtidae** | *Scirtidae* sp. (L) | **X** | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 14 | 0 |
| | | | | | | | | | | | | | | | |
| **DIPTERA** | | Diptera instar spp. | **X** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| | **Chironomidae** | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Chironominae | *Paratendipes "K1"* | **X** | 0 | 36 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Cryptochironomus griseidorsum* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Polypedilum sp.* | **X** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tanytarsus sp.* | **X** | 0 | 6 | 4 | 0 | 0 | 6 | 0 | 0 | 0 | 1 | 0 | 0 |
| | Orthocladiinae | Unknow n genus (WW08) | **X** | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Tanypodinae | *Paramerina sp.* | **X** | 0 | 22 | 1 | 1 | 0 | 9 | 0 | 0 | 0 | 4 | 3 | 6 |
| | | *Procladius sp.* | **X** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | **Ceratopogonidae** | Ceratopogoniinae spp. | **X** | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 0 |
| | | Ceratopogoniinae spp. (P) | **X** | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | Dasyheilenae | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| | | | | | | | | | | | | | | | |
| **LEPIDOPTERA** | **Pyralidae** | Nymphulinae spp. | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 |
| | | | | | | | | | | | | | | | |
| | | **TAXA RICHNESS** | | **0** | **13** | **4** | **3** | **3** | **5** | **3** | **3** | **2** | **13** | **6** | **7** |

**Table A5-2.** Wet season, May 2009.

| | | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class/Order | Family | Species | CAT | MAR1-1wet | MAR1-2wet | MAR1-3wet | MAR1-4wet | MAR1-5wet | MAR1-6wet | MAR2-1wet | MAR2-2wet | MAR2-3wet | MAR2-4wet | MAR2-5wet | MAR2-6wet |
| **CNIDARIA** | | | | | | | | | | | | | | | |
| **HYDROZOA** | **Hydridae** | *Hydra* sp. | **X** | 0 | 2 | 0 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| **NEMATODA** | | Nematoda spp. | **U** | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ANNELIDA** | | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | **P** | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **GASTROPODA** | | | | | | | | | | | | | | | |
| | **Lymnaeidae** | *Austropeplea lessoni* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **CRUSTACEA** | | | | | | | | | | | | | | | |
| **AMPHIPODA** | | | | | | | | | | | | | | | |
| **Crangonyctoid** | **Paramelitidae** | *?Chydaekata* sp. | **S** | 1 | 2 | 3 | 2 | 3 | 2 | 4 | 3 | 4 | 3 | 3 | 0 |
| **COPEPODA** | | | | | | | | | | | | | | | |
| **Cyclopoida** | **Cyclopodidae** | Cyclopidae: copepodites/males | **U** | 0 | 4 | 9 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| | | *Ectocyclops phaleratus* | **X** | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Microcyclops varicans* | **X** | 0 | 4 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| **ARACHNIDA** | | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | **U** | 0 | 2 | 2 | 0 | 2 | 1 | 2 | 2 | 2 | 0 | 2 | 0 |
| | | Oribatida spp. | **U** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| **COLLEMBELA** | | Collembolla spp. | **X** | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | **Entomobryoidea** | Entomobryoidea spp. | **X** | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 |
| | | Poduroidea spp. | **X** | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **INSECTA** | | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Baetidae** | *Genus 1 WA sp. 1* | **O** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 1 |
| | **Caenidae** | *Tasmanacoenis arcuata* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 3 |
| **COLEOPTERA** | **Dytiscidae** | Dytiscidae spp. (L) | **O** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Limbodessus occidentalis* | **O** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Platynectes decempunctatus* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Elmidae** | *Austrolimnius sp. (L)* | **U** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Hydraenidae** | *Hydraena sp.* | **X** | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | **Hydrophilidae** | Hydrophilidae spp. (L) | **U** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | *Enochrus sp. (L)* | **X** | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 2 | 2 | 0 |
| | | *Enochrus mastersii* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Helochares sp. (L)* | **X** | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 1 | 0 | 2 | 0 |
| | | *Laccobius sp. (L)* | **X** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class/Order | Family | Species | CAT | MAR1-1wet | MAR1-2wet | MAR1-3wet | MAR1-4wet | MAR1-5wet | MAR1-6wet | MAR2-1wet | MAR2-2wet | MAR2-3wet | MAR2-4wet | MAR2-5wet | MAR2-6wet |
| | | *Paranacaena sp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Sternolophus sp. (L)* | X | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Hygrobidae** | *Hygrobia spp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | **Scirtidae** | *Scirtidae sp. (L)* | X | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 2 | 4 |
| | | | | | | | | | | | | | | | |
| **HEMIPTERA** | **Hebridae** | *Hebrus axillaris* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | | |
| **ODONATA** | | | | | | | | | | | | | | | |
| **Anisoptera** | | Anisoptera sp. (imm) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| **Zygoptera** | | Zygoptera sp. (imm) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | | | | | | | | | | | | | | |
| **DIPTERA** | **Chironomidae** | | | | | | | | | | | | | | |
| | Chironominae | *Paratendipes "K1"* | X | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | | *Cryptochironomus griseidorsum* | X | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tanytarsus sp.* | X | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | WWTS5 | X | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 |
| | Orthocladiinae | *Rheocricotopus sp.* | X | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Cricotopus albitarsis* | X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Thienemanniella sp.* | X | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Corynonoeura sp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | Unknown genus (WW08) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| | Tanypodinae | *Paramerina sp.* | X | 6 | 64 | 1 | 0 | 36 | 0 | 26 | 6 | 32 | 1 | 34 | 15 |
| | | *Thienemannimyia sp.* | X | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Nilotanypus sp.* | X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | | *Larsia ?albiceps* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Ceratopogonidae** | Ceratopogonidae (P) | X | 0 | 0 | 2 | 0 | 1 | 2 | 2 | 0 | 2 | 0 | 2 | 0 |
| | | Ceratopogoninae sp. | X | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 3 | 2 | 3 | 2 |
| | | Dasyheleinae sp. | X | 2 | 3 | 3 | 2 | 1 | 2 | 2 | 0 | 2 | 2 | 3 | 2 |
| | | Forcipomyiinae sp. | X | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Dolichopodidae** | Dolichopodidae spp. | X | 2 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | **Ephydridae** | Ephydridae spp. | X | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Simuliidae** | Simuliidae spp. | X | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Syrphidae** | Syrphidae spp. | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Thaumaleidae** | Thaumaleidae spp. | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | **Tipulidae** | Tipulidae spp. | X | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| **TRICHOPTERA** | **Hydropsychidae** | *Cheumatopsyche sp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | **Lepidoptera** | Lepidoptera spp. (imm) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| | **Philpotomidae** | *Chimarra uranka* | X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | | | | | | | | | | | | | | |
| | | **Taxa richness** | | **16** | **15** | **19** | **6** | **15** | **13** | **20** | **7** | **20** | **8** | **17** | **22** |

# Appendix 6. Macoinvertebrate data from October 2008 and May 2009.

**Table A6-1.** October 2008.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **CNIDARIA** | | | | | | | | | | | | | | |
| **Hydrozoa** | | *Hydra* sp. | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 |
| **ANNELIDA** | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | 3 | 0 | 2 | 0 | 1 | 4 | 0 | 0 | 3 | 3 | 2 | 3 |
| **MOLLUSCA** | | | | | | | | | | | | | | |
| **GASTROPODA** | **Ancylidae** | *Ferissa petterdi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Lymnaeidae** | *Austropeplea lessoni* | 0 | 2 | 0 | 3 | 3 | 4 | 1 | 2 | 3 | 2 | 2 | 2 |
| | **Planorbidae** | *Gyraulus hesperus* | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 2 | 2 | 2 | 0 | 2 |
| **ARACHNIDA** | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | 3 | 0 | 0 | 4 | 2 | 0 | 2 | 4 | 3 | 3 | 4 | 3 |
| **ORIBATIDA** | | Oribatida spp. | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| **INSECTA** | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Caenidae** | Caenidae spp. (imm.) | 0 | 0 | 0 | 3 | 0 | 2 | 2 | 0 | 0 | 3 | 0 | 0 |
| | | *Tasmanocoenis arcuata* | 4 | 2 | 3 | 3 | 2 | 2 | 2 | 0 | 3 | 4 | 2 | 3 |
| | **Baetidae** | Baetidae spp. (imm.) | 0 | 0 | 0 | 4 | 3 | 2 | 2 | 0 | 0 | 0 | 4 | 0 |
| | | *Baetidae Genus 1 WA sp.1* | 4 | 1 | 3 | 4 | 2 | 0 | 4 | 4 | 3 | 4 | 4 | 4 |
| | | *Cloeon* sp. | 0 | 0 | 0 | 0 | 4 | 3 | 0 | 0 | 0 | 4 | 0 | 0 |
| **ODONATA** | | | | | | | | | | | | | | |
| **Anisoptera** | | Anisoptera spp.(imm) | 2 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 2 | 2 | 0 |
| | **Libellulidae** | Libellulidae spp. (imm.) | 1 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 2 |
| | | *Diplacodes haematodes* | 2 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 0 | 2 |
| | | *Nannophlebia injabandi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | | *Orthetrum caledonicum* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | *Zyxomma elgneri* | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| **HEMIPTERA** | **Belostomatidae** | *Diplonychus eques* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Corixidae** | Corixidae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Gerridae** | Gerridae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Limnogonus fossarum gilguy* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | *Rhagadotarsus anomolus* | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Hebridae** | Hebridae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 0 |
| | | *Hebrus axillaris* | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| | **Nepidae** | *Laccotrephes tristis* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Naucoridae** | *Naucoris subopacus* | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| | **Notonectidae** | *Anisops* sp. (F) | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Pleidae** | *Paraplea brunni* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Velidae** | Veliidae spp.(imm.) | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | *Microvelia australiensis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **COLEOPTERA** | **Dytiscidae** | *Platynectes* sp. (L) | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | *Platynectes decempunctatus var decemp.* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 0 |
| | | *Tiporus tambreyi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Elmidae** | *Austrolimnius* sp. (A) | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Austrolimnius* sp. (L) | 0 | 0 | 0 | 3 | 0 | 1 | 1 | 2 | 3 | 0 | 2 | 1 |
| | **Gyrinidae** | *Aulonogyrus strigosus* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Aulonogyrus/Macrogyrus* sp. (L) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | | *Dineatus australis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | **Hydraenidae** | *Hydraena sp.* | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Hydrophilidae** | *Berosus* sp. (L) | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 3 | 0 | 0 |
| | | *Berosus dallasae* | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Coelostoma sp.* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 |
| | | *Helochares* sp. (L) | 2 | 2 | 1 | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | 2 |
| | | *Helochares tatei* | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 0 | 1 |
| | | *Laccobius bili* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Paracymus pygmaeus* | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Sternolophus* sp. (L) | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Hydrochidae** | *Hydrochus* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 2 |
| | **Scirtidae** | Scirtidae spp. (L) | 2 | 2 | 0 | 3 | 0 | 1 | 0 | 1 | 2 | 0 | 2 | 1 |
| **DIPTERA** | **Chironomidae** | Chironomidae spp. (P) | 2 | 2 | 3 | 4 | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 3 |
| | | *Paramerina sp.* | 2 | 1 | 0 | 3 | 3 | 0 | 0 | 0 | 2 | 2 | 3 | 3 |
| | | *Thienemannimyia sp.* | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 2 | 3 | 3 | 2 | 3 |
| | | *Nilotanypus sp.* | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 1 |
| | | *Larsia ?albiceps* | 2 | 2 | 2 | 2 | 3 | 0 | 2 | 2 | 3 | 1 | 3 | 3 |
| | | *Procladius sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Ablabesmyia hilli* | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 1 |
| | | *Rheocricotopus sp.* | 3 | 2 | 2 | 3 | 0 | 0 | 3 | 2 | 1 | 2 | 3 | 1 |
| | | *nr. Parametriocnemus* | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Cricotopus albitarsis* | 2 | 2 | 3 | 0 | 0 | 0 | 3 | 3 | 2 | 3 | 4 | 3 |
| | | *Thienemanniella sp.* | 3 | 1 | 1 | 3 | 2 | 0 | 3 | 3 | 2 | 2 | 4 | 2 |
| | | *Corynonoeura sp.* | 2 | 1 | 3 | 4 | 3 | 0 | 2 | 0 | 0 | 1 | 3 | 3 |
| | | *Paratendipes "K1"* | 0 | 3 | 1 | 3 | 2 | 0 | 2 | 1 | 0 | 1 | 0 | 0 |
| | | *Chironomus sp.* | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | *Cryptochironomus griseidorsum* | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 0 | 1 | 0 | 2 | 2 |
| | | *Polypedilum nubifer* | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Dicrotendipes sp1* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| | | *Dicrotendipes sp2* | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 3 | 0 |
| | | *Cladopelma curtivala* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| | | *Polypedilum watsoni* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | | *Paracladopelma sp "M1"* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | *Polypedilum sp.* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 |
| | | WWC17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

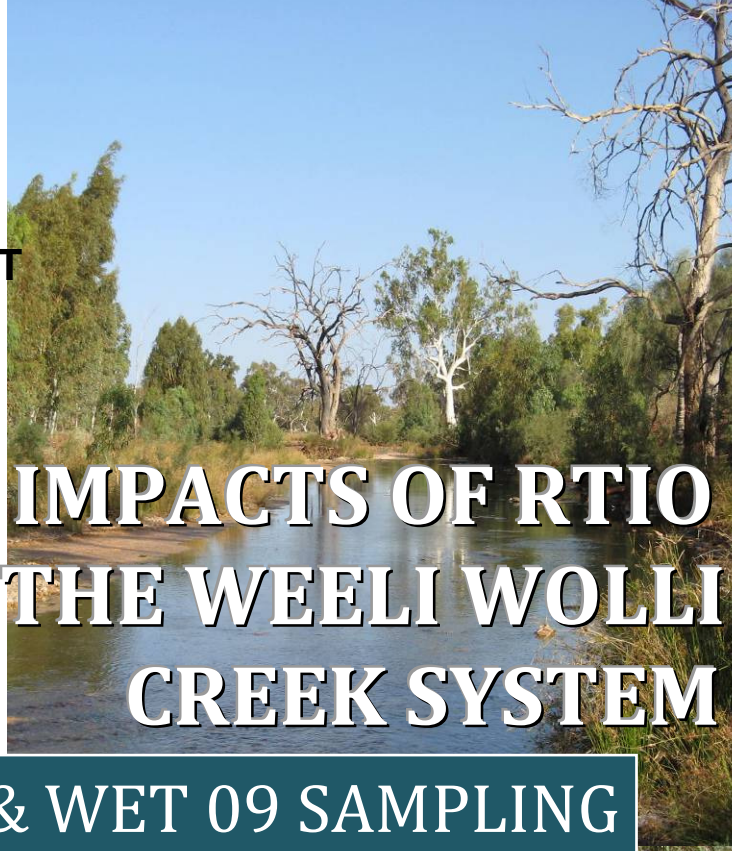
| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| | | *Tanytarsus sp.* | 1 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 3 |
| | | *Paratanytarsus sp.* | 0 | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 0 |
| | | *Cladotanytarsus sp.* | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | WWTS5 | 1 | 2 | 2 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 |
| | **Ceratopogonidae** | Ceratopogoniinae spp. | 2 | 2 | 3 | 3 | 4 | 2 | 2 | 1 | 2 | 2 | 3 | 3 |
| | | Dasyheilenae spp. | 3 | 2 | 0 | 3 | 4 | 2 | 0 | 4 | 3 | 4 | 2 | 0 |
| | | Forcypomiinae spp. | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 2 | 0 |
| | | Ceratopogonidae spp. (P) | 0 | 2 | 2 | 3 | 1 | 2 | 0 | 2 | 2 | 2 | 2 | 2 |
| | **Culicidae** | *Anopheles* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | Culicidae spp. (P) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Dolichopidae** | Dolichopodidae spp. | 3 | 0 | 2 | 3 | 2 | 0 | 2 | 2 | 2 | 2 | 2 | 2 |
| | **Ephydridae** | Ephydridae spp. | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 1 | 1 |
| | **Simuliidae** | Simulidae spp (P) | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 0 | 2 |
| | | Simulidae spp. | 3 | 3 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 | 2 | 2 |
| | **Stratiomyidae** | Stratiomyidae spp. | 0 | 2 | 0 | 0 | 0 | 2 | 1 | 0 | 3 | 0 | 2 | 1 |
| | **Tabanidae** | Tabanidae spp. | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 1 | 0 |
| | **Tipulidae** | Tipulidae spp. | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TRICHOPTERA** | | Trichoptera spp. (P) | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 1 |
| | **Ecnomidae** | *Ecnomus* sp. | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 2 |
| | **Hydropsychidae** | *Cheumatopsyche wellsae (spAV11)* | 4 | 3 | 2 | 4 | 2 | 1 | 4 | 4 | 4 | 4 | 5 | 4 |
| | **Hydroptilidae** | *Hellyethira* sp | 0 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 3 | 1 |
| | **Orthotrichidae** | *Orthotrichia spp.* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Leptoceridae** | Oecetis spp. | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| | | *Triaenodes spp.* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Triplectides australis* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Triplectides ciskus seductus* | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 1 |
| | **Philopotamidae** | Philopotamidae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | *Chimmara* sp. | 4 | 3 | 1 | 3 | 0 | 0 | 4 | 3 | 3 | 3 | 2 | 3 |
| **LEPIDOPTERA** | **Pyralidae** | *Nymphulinae cf sp. 3* | 2 | 3 | 3 | 3 | 3 | 0 | 2 | 3 | 2 | 3 | 0 | 2 |
| | | *Nymphulinae cf sp. 37* | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 3 | 0 | 0 |
| | | Nymphulinae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 3 | 0 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **35** | **40** | **36** | **46** | **33** | **34** | **40** | **31** | **47** | **47** | **52** | **52** |

**Table A6-2.** May 2009.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **ANNELIDA** | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 1 | 2 | 0 |
| | | | | | | | | | | | | | | |
| **MOLLUSCA** | | | | | | | | | | | | | | |
| **GASTROPODA** | **Planorbidae** | *Gyraulus hesperus* | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 0 | 0 | 0 |
| | **Ancylidae** | *Ferrissia petterdi* | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **CRUSTACEA** | | | | | | | | | | | | | | |
| **AMPHIPODA** | **Paramelitidae** | *?Chydaekata* sp. | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **ARACHNIDA** | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 2 | 2 | 3 | 4 | 4 |
| **ORIBATIDA** | | Oribatidae spp. | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **INSECTA** | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Baetidae** | Baetidae spp (dam) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | *Genus 1 WA sp. 1* | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 5 | 5 | 5 | 4 | 4 |
| | **Caenidae** | *Tasmanacoensis arcutata* | 2 | 4 | 4 | 2 | 2 | 3 | 1 | 0 | 2 | 3 | 0 | 4 |
| **ODONATA** | | | | | | | | | | | | | | |
| **Anisoptera** | | Anisoptera spp. (imm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Aeshnidae** | Aeshnidae spp. (imm) | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Gomphidae** | *Austrogomphus gordoni* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Libellulidae** | *Diplacodes haematodes* | 0 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Nannophlebia injabandi* | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 |
| **Zygoptera** | **Coenagrionidae** | Coenagrionidae spp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **HEMIPTERA** | **Gerridae** | *Limnogonus fossarum gilguy* | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 1 |
| | **Mesoveliidae** | *Mesoveliidae spp. (imm)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Naucoridae** | *Naucoris subopacus* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **COLEOPTERA** | **Dytiscidae** | *Platynectes decempunctatus var decem.* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Platynectes* sp. (L) | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tiporus centralis* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Elmidae** | *Austrolimnius* sp (A) | 0 | 0 | 2 | 3 | 3 | 2 | 1 | 1 | 0 | 2 | 0 | 1 |
| | | *Austrolimnius* sp. (L) | 0 | 0 | 1 | 3 | 4 | 3 | 2 | 2 | 0 | 2 | 2 | 0 |
| | **Gyrinidae** | *Aulonogyrus strigosus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Dineutus australis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | **Hydrophilidae** | Hydrophilidae spp. (L) | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 0 | 1 |
| | | *Berosus dallasae* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | *Helochares tatei* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Helochares* sp. (L) | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| | **Scirtidae** | Scirtidae spp. (L) | 2 | 0 | 0 | 2 | 0 | 1 | 0 | 3 | 3 | 2 | 3 | 3 |
| **DIPTERA** | **Ceratopogonidae** | Ceratopogoniinae spp. | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 3 | 2 | 2 |
| | | Dasyheleinae spp. | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Forcipomyiinae spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MAR1-1 | MAR1-2 | MAR1-3 | MAR1-4 | MAR1-5 | MAR1-6 | MAR2-1 | MAR2-2 | MAR2-3 | MAR2-4 | MAR2-5 | MAR2-6 |
| | **Chironomidae** | Chironomidae spp. (P) | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 0 | 0 | 0 |
| | | *Paramerina sp.* | 0 | 2 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 2 |
| | | *Thienemannimyia sp.* | 1 | 3 | 1 | 2 | 2 | 1 | 0 | 1 | 2 | 3 | 2 | 3 |
| | | *Nilotanypus sp.* | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 0 | 2 | 1 | 2 |
| | | *Larsia ?albiceps* | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 0 | 3 |
| | | *Procladius sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | *Ablabesmyia hilli* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Rheocricotopus sp.* | 3 | 3 | 0 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 |
| | | *Cricotopus albitarsis* | 3 | 2 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 3 |
| | | *Thienemanniella sp.* | 3 | 2 | 0 | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
| | | *Corynonoeura sp.* | 1 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | *Paracladopelma "K2"* | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Paratendipes "K1"* | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| | | *Cryptochironomus griseidorsum* | 0 | 2 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| | | *Dicrotendipes sp1* | 2 | 2 | 3 | 3 | 3 | 2 | 0 | 0 | 1 | 0 | 2 | 2 |
| | | *Dicrotendipes sp2* | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 2 | 2 |
| | | *Tanytarsus sp.* | 2 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 1 |
| | | *Cladotanytarsus sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | WWTS5 | 2 | 2 | 0 | 2 | 0 | 0 | 2 | 1 | 2 | 2 | 2 | 2 |
| | **Dolichopodidae** | Dolichopodidae spp. | 0 | 3 | 0 | 2 | 2 | 3 | 2 | 0 | 2 | 1 | 0 | 0 |
| | **Simulidae** | Simulidae spp. | 3 | 4 | 1 | 3 | 3 | 4 | 3 | 3 | 4 | 3 | 2 | 2 |
| | | Simuliidae sp (P) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 |
| | **Syrphidae** | Syrphidae spp. | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Tabanidae** | Tabanidae spp. | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 |
| | **Tanyderidae** | Tanyderidae spp. | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TRICHOPTERA** | **Ecnomidae** | *Ecnomus sp.* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Hydroptilidae** | Hydroptilidae sp (imm) | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Hellyethira sp.* | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | **Hydropsychidae** | *Cheumatopsyche wellsae* | 4 | 4 | 1 | 4 | 4 | 0 | 5 | 5 | 0 | 4 | 4 | 4 |
| | **Leptoceridae** | *Oecetis sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | *Triplectides ciuskus seductus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Philopotamidae** | *Chimarra* sp. | 3 | 4 | 0 | 3 | 3 | 0 | 4 | 3 | 0 | 3 | 3 | 3 |
| **LEPIDOPTERA** | **Nymphulinae** | *Nymphulinae sp. 3* | 3 | 4 | 3 | 4 | 4 | 4 | 0 | 3 | 3 | 3 | 3 | 4 |
| | | *Nymphulinae sp. 18* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 2 |
| | | *Nymphulinae sp. 37* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **23** | **26** | **32** | **30** | **29** | **26** | **27** | **23** | **30** | **26** | **25** | **33** |

RIO TINTO
HAMERSLEY HOPE MANAGEMENT SERVICES



# CUMULATIVE IMPACTS OF RTIO MINING ON THE WEELI WOLLI CREEK SYSTEM

## DRY 08 & WET 09 SAMPLING
## FINAL REPORT

*Wetland Research & Management*

July 2010

## Study Team

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## Disclaimer



This document has been printed on 'Reflex Green Recycled Paper'.

Frontispiece (top to bottom): Marillana Creek at MAR2-5; MAR2-3; and, riffle at MAR1-3 (all photos taken by WRM personnel).

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## TABLES



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# 1 INTRODUCTION

## 1.1 Background

The Rio Tinto Iron Ore (RTIO) mine at Yandi is located in the East Pilbara region of Western Australia. A number of temporary creeklines traverse the mine area, including Marillana, Yandicoogina, Phil's and Weeli Wolli creeks (Figures 1 & 2). The mine has been operating since 1996, and as part of mine operations de-watering of the Yandi JSE and Central pits has been necessary since 1998, with excess water discharged directly into Marillana Creek. Since late 2007, excess water has also been discharged into Weeli Wolli Creek (from discharge outlet D06; see Figure 2). For the period 1998-2009, average annual discharge into Marillana Creek from all outlets combined was 0.61 GL/year (Figure 3). Peak average discharge into Marillana Creek was 1.29 GL/year in 2009. Average annual discharge into Weeli Wolli Creek between 2008 and 2009 was 0.15 GL/year (Figure 3). Projected average discharge into Marillana Creek and Weeli Wolli Creek is anticipated to be 1.06 GL/year and 0.92 GL/year, respectively (Figure 3). Upstream of RTIO Yandi on Marillana Creek, the BHP-BIO Yandi mine (operating since 1994) also dewaters their developing pit, with discharge occurring into the upstream section of Marillana creek. It is likely that discharge from BHP-BIO will increase over the next few years as an increase in their abstraction rate to a peak of 15GL/year has been approved, with excess water likely being discharged into Marillana Creek. Downstream of these mining operations, Marillana Creek flows into Weeli Wolli Creek (see Figures 1 & 2), into which RTIO's Hope Downs 1 (HD1) operation also discharges their dewatering water. Discharge from HD1 is predominantly via a single gabion structure adjacent to the main creek, however a system of spur lines deliver water as seepage flows to important trees and pools upstream of the gabion, in the area of the historic spring and permanent pools. Approximately 10% of dewatering discharge is released via the system of spur lines, with the remainder released from the gabion. The total volume discharged from HD1 into Weeli Wolli Creek varies between years, but was approx. 25.55 GL/year during 2008/09.

Discharge from Yandi (RTIO & BHPBIO) operations pose potential impacts to the aquatic ecosystem of Marillana Creek, and also to the lower Weeli Wolli Creek system downstream of the confluence with Marillana; this section of Weeli Wolli Creek is also impacted by discharge water from HD1, adding to the cumulative impact on this section of the creekline. An added issue is the proposed listing of the Fortescue Marshes as a Ramsar Wetland of International Importance. Weeli Wolli flows to the north, where it drains into the Fortescue River via the Fortescue Marsh. The Marsh is approximately 20 km downstream from the Marillana - Weeli Wolli Creek confluence. Historically the two systems are only connected during flooding associated with intense cyclonic events. With additional discharge from BHP-BIO's Yandi, RTIO's Yandi and RTIO's HD1 operations, surface flows along Weeli Wolli will continue to increase, and the concern from the regulators is ensuring that permanent flows do not reach the Marsh. Prior to dewatering discharge at HD1, the spring resulted in perennial surface flow for approximately 2 km along the upper section of Weeli Wolli Creek. Since the commencement of discharge from HD1, surface flows in Weeli Wolli Creek now extend approximately 20 km downstream of historic perennial flow, and currently extend past Yandi operations, beyond the confluence with Marillana Creek, downstream of Gray's Crossing.

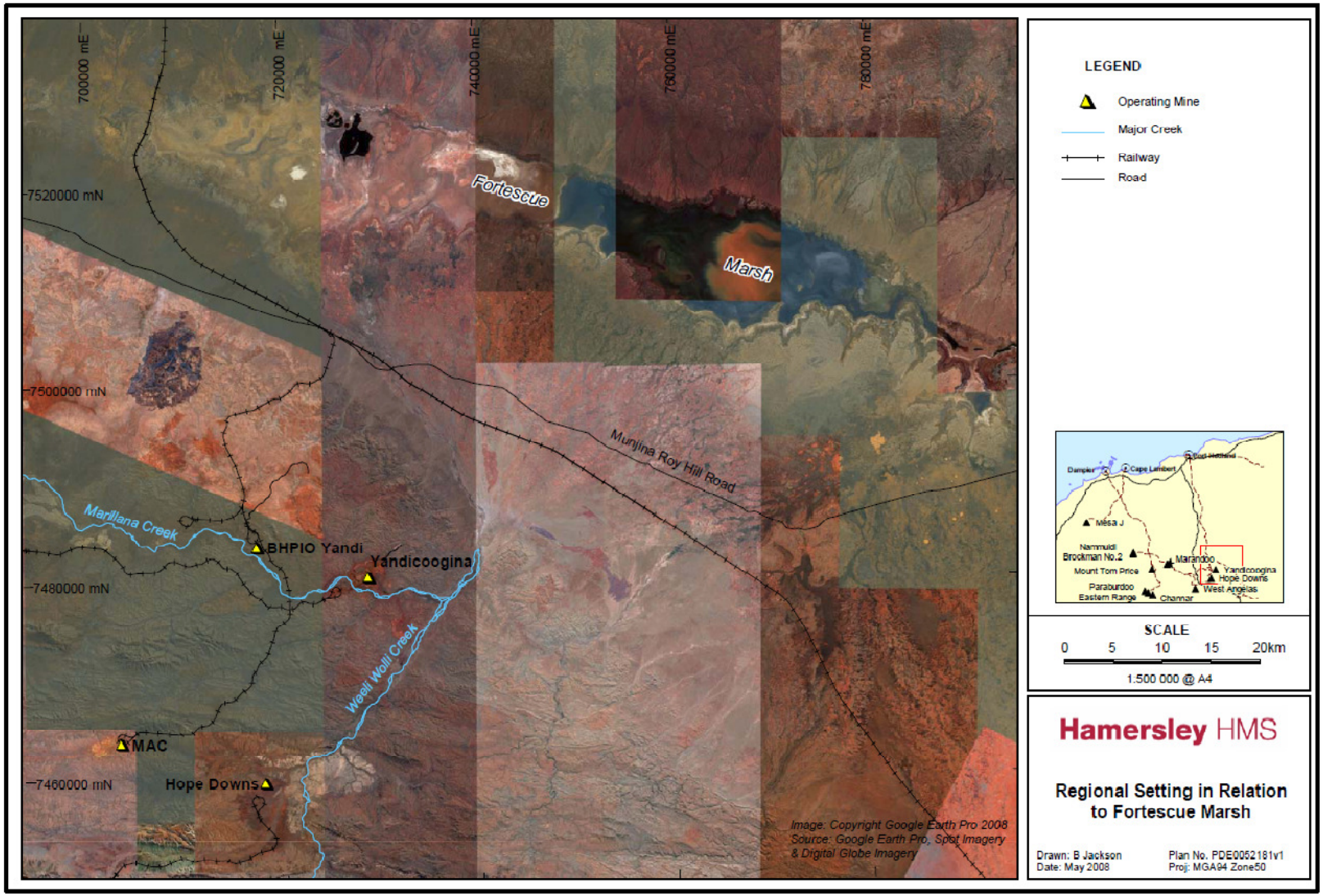



**Figure 1.** Map showing the location of Marillana Creek and Weeli Wolli Creek with respect to the Fortescue Marshes in the Pilbara Region of Western Australia.

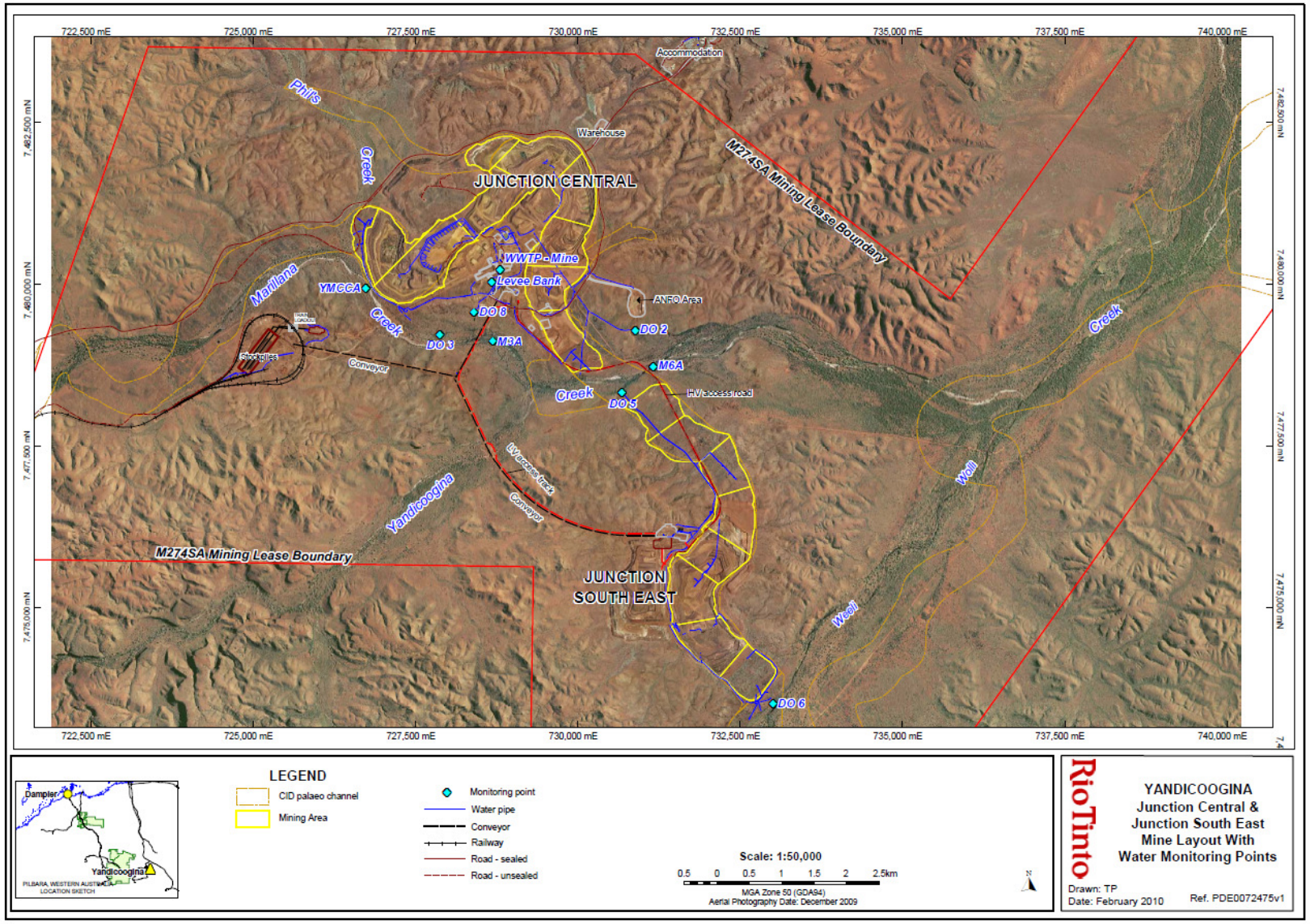



**Figure 2.** Map showing the location of all discharge outlets (D01-D09) across the Yandi mine lease.

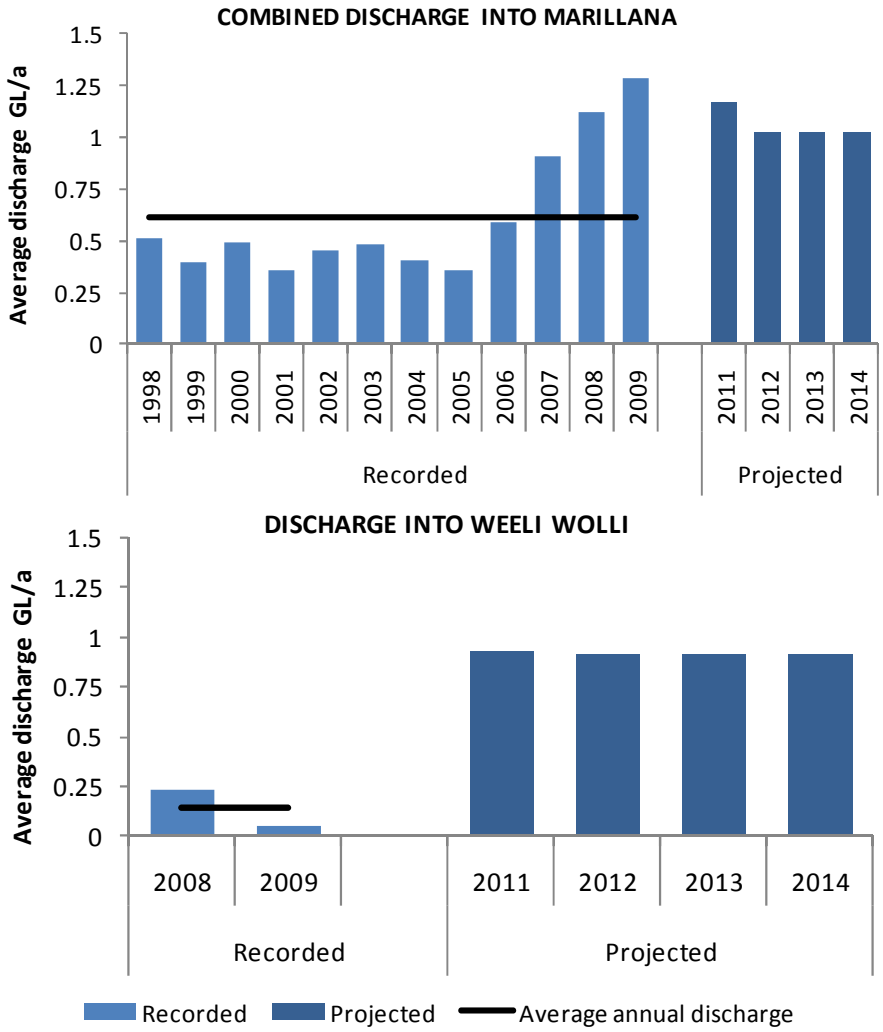



**Figure 3.** Current and projected average discharge (GL/year) into Marillana Creek for all outlets combined (top), and into Weeli Wolli Creek (bottom). Information provided by RTIO.

The specific and cumulative effects of these operations need to be assessed. Therefore, RTIO commissioned *Wetland Research and Management* to undertake a study of the aquatic biota of Marillana Creek. The purpose of this was to a.) assess specific effects of RTIO's (and BHPIO's) Yandi operations on Marillana Creek, and b.) provide data that supports the HD1 Living Water Survey, to assess Cumulative Impacts on the Weeli Wolli system. To this end, Marillana Creek was broken into two reaches of differing discharge regimes to document current ecological condition. The two study reaches were; 1.) downstream of BHP-BIO's discharge but upstream of RTIO's Yandi discharge, and 2.) downstream of RTIO's Yandi discharge as far as surface flows reach (approx. 0.5 km upstream of the confluence with Weeli Wolli).

Similarly, the Living Water Survey aimed to characterise Weeli Wolli Creek in four reaches of differing flow regime to document current ecological condition. The four study reaches were; (1.) the spring where permanent pools were located, 2.) within the reach of historic permanent flow downstream of the spring, 3.) within the area of creek which was highly ephemeral and dry for much of the year but is now perennial as far as the confluence with

Marillana Creek due to discharge[1], and 4.) the now perennial reach below the confluence with Marillana Creek[2], which varies in length depending on season and dewatering discharge.

This report presents the findings from two rounds of sampling at both Marillana and Weeli Wolli creeks (October 2008 & May 2009; see WRM 2009a).

## 1.2 Study objectives

The aim of this study was to document current ecological condition of Marillana Creek and Weeli Wolli Creek with respect to water quality and aquatic biota assemblages (microinvertebrates, macroinvertebrates, hyporheic fauna[3] and fish) to establish baseline conditions, assess current effects of RTIO's Yandi mine, and provide data to feed into a Cumulative Impacts study of the Weeli Wolli system.

[1] Discharge from RTIO's Yandi at outlet D06 is into Reach Three on Weeli Wolli Creek.

[2] As this reach is downstream of the confluence with Marillana Creek, it is also influenced by discharge from RTIO and BHP-BIO's Yandi mines.

[3] Aquatic invertebrate fauna which reside in the area below the streambed where water percolates through spaces between the rocks and cobbles.

# 2 METHODS

## 2.1 Study area

Marillana Creek and Weeli Wolli Creek are located approximately 75 km north-west of Newman, in the Pilbara Region of Western Australia. The main drainage system in the area is the Fortescue River, which arises near Newman, flows north and then northwest into the Fortescue Marsh (see Figure 1).

Marillana Creek drains eastward before joining Weeli Wolli Creek. Streamflow is seasonal, with flows usually occurring in response to heavy rainfall events. On average, Marillana Creek historically flows for 30 to 60 days a year. Annual streamflow in the area around Yandi can range from negligible to tens of millions of cubic metres.

Weeli Wolli Creek is approximately 70 km in length, and has a catchment area of 4100 $km^2$. A dense network of ephemeral tributary streamlines is associated with the system. Weeli Wolli flows to the north, where it drains into the Fortescue River via the Fortescue Marsh. The creek is fed by Weeli Wolli Spring which arises as a result of groundwater flow being "dammed" by the Brockman Formation, which forces groundwater to the surface, appearing as the perennial spring.

Weeli Wolli Spring is considered to be of high ecological, social and cultural value (EPA 2001, Kendrick 2001, Gardiner 2003, van Leeuwen 2009). It has high environmental significance in the Pilbara region because it is a permanent water body. Due to the aridity of the region, such systems are rare. Halse *et al.* (2002) suggested that such systems provide an important "source of animals for colonisation of newly flooded pools and maintenance of populations of invertebrate species at the regional level". The creek is also of significance to indigenous people as it holds mythological and ceremonial importance (EPA 2001), and has social value in the form of local tourism (van Leeuwen 2009). In 2009 the spring was nominated for listing as a Threatened Ecological Community at the State level, on the basis of floristic communities as well as the diverse aquatic invertebrate and significant stygofauna communities (van Leeuwen 2009).

## 2.2 Sites and sampling design

Marillana Creek was broken into two main reaches, reflecting differences in mining operations and discharge:

- Reach One – downstream of BHP-BIO's Yandi discharge and upstream of RTIO's Yandi discharge,
- Reach Two - downstream of RTIO's Yandi discharge as far as flows reach (just upstream of the confluence with Weeli Wolli) (Figure 4).

Weeli Wolli Creek was also stratified into separate reaches of differing historic flow regime. Four reaches along Weeli Wolli Creek were sampled, including:

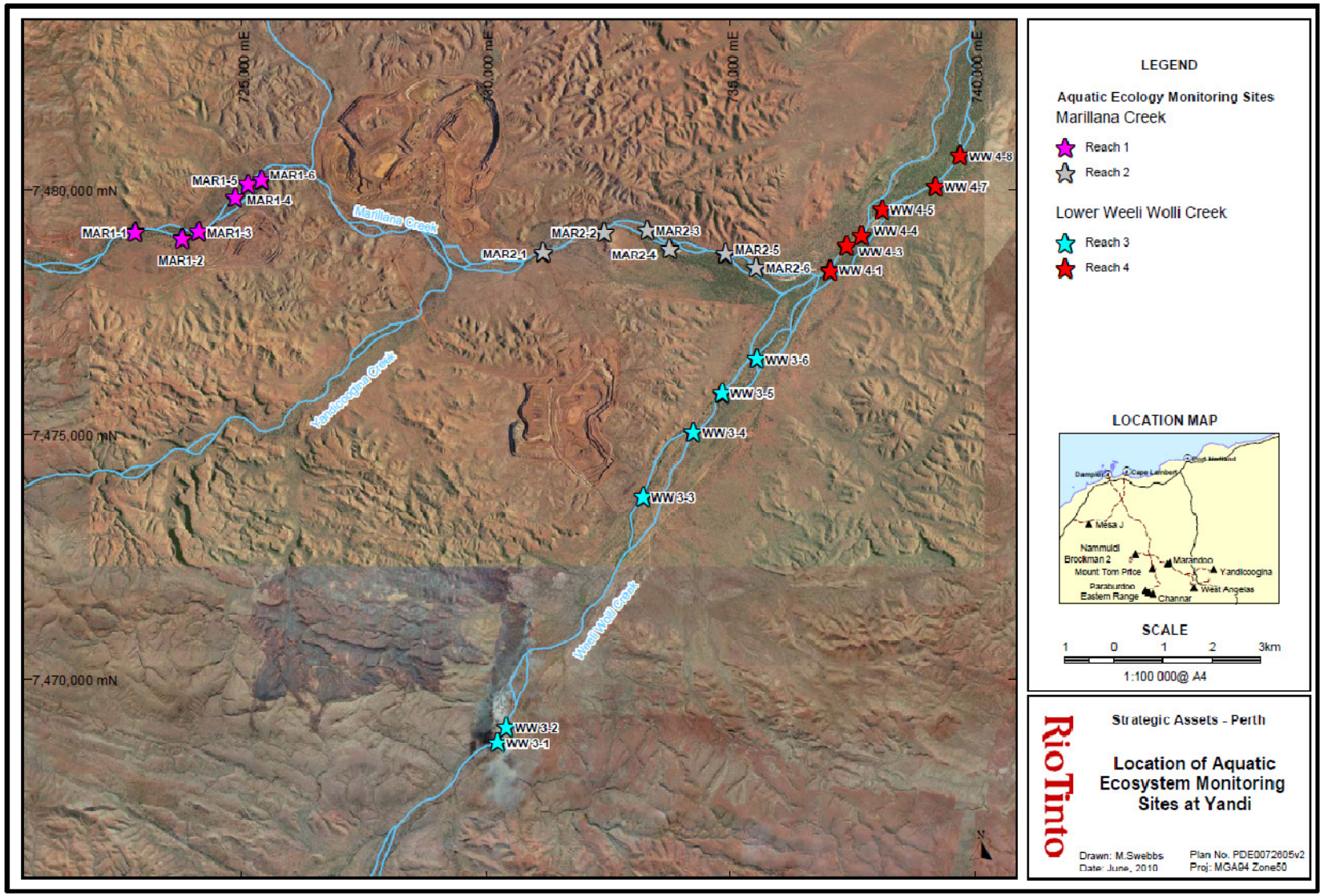



**Figure 4.** Location of the reaches and sampling sites along Marillana Creek and lower Weeli Wolli Creek.

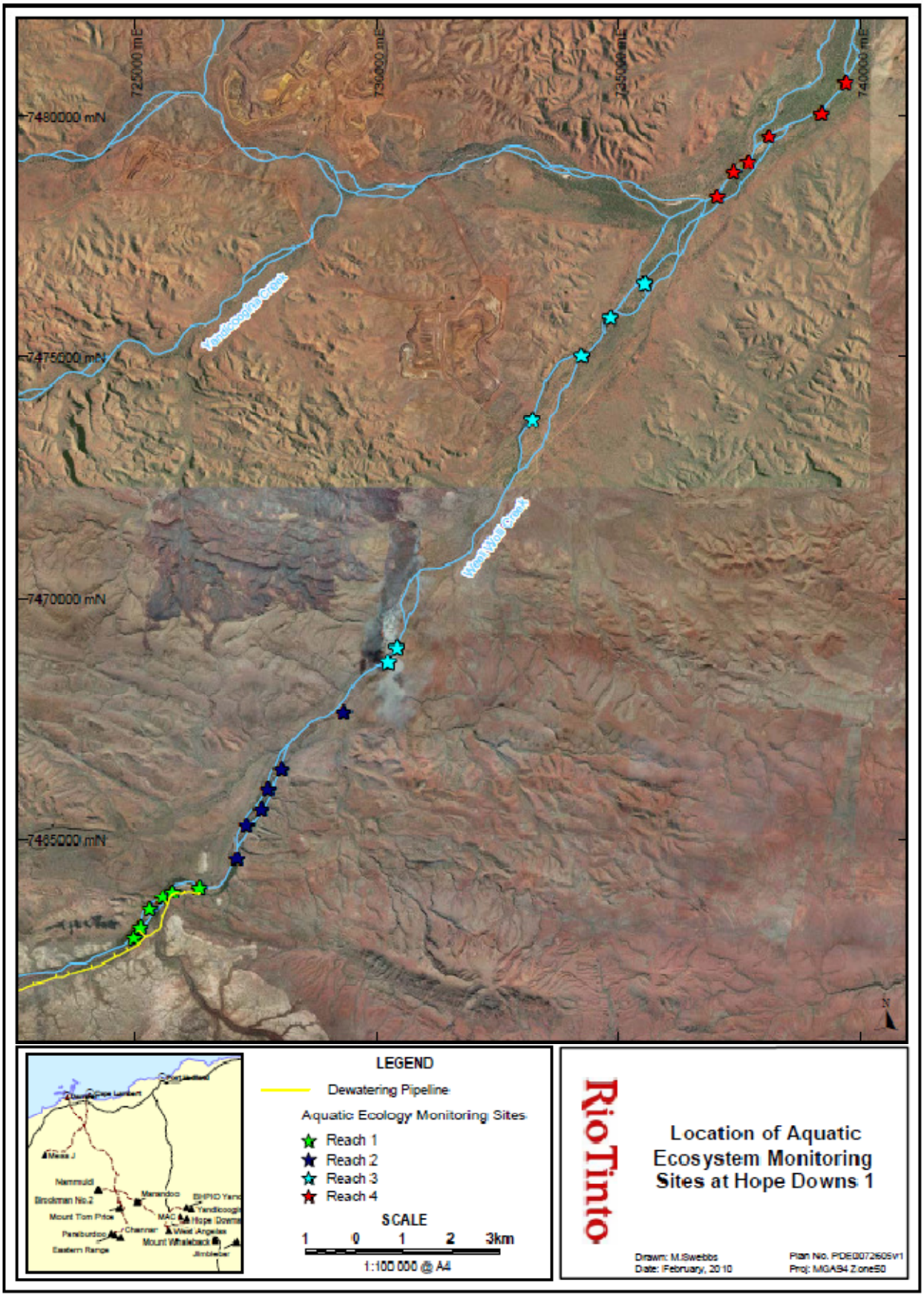



**Figure 5.** Location of the reaches and sampling sites along Weeli Wolli Creek.

- Reach One – in the area of Weeli Wolli Spring where permanent pools historically were located,
- Reach Two - within the historic reach of continuous permanent flow downstream of the spring,
- Reach Three - downstream of this point to the junction with Marillana Creek, where the creek historically was highly ephemeral and dry for much of the year, and
- Reach Four - the now permanent reach below the Marillana Creek confluence towards Fortescue Marshes (WRM 2009a; see Figures 4 and 5).

Six replicate samples were taken within each reach to characterise the fauna and conditions along each reach, and to provide adequate statistical power for analyses (Tables 1 and 2). Replicates were located to provide a geographical spread within each reach, but positions were influenced by access (Figures 4 and 5).

Site photographs are provided in Appendix 1.

**Table 1.** GPS location (UTM WGS84) of sites sampled along Marillana Creek.

| *Reach* | *Historic flows* | *Site* | *GPS Location* | |
|---|---|---|---|---|
| | | | *Easting* | *Northing* |
| 1 | Upstream of RTIO's Yandi discharge | MAR1-1 | 50 722832 | 7479165 |
| | | MAR1-2 | 50 723796 | 7479028 |
| | | MAR1-3 | 50 724135 | 7479167 |
| | | MAR1-4 | 50 724876 | 7479864 |
| | | MAR1-5 | 50 725143 | 7480136 |
| | | MAR1-6 | 50 725416 | 7480219 |
| 2 | Downstream of RTIO's Yandi discharge | MAR2-1 | 50 731178 | 7478739 |
| | | MAR2-2 | 50 732424 | 7479151 |
| | | MAR2-3 | 50 733306 | 7479198 |
| | | MAR2-4 | 50 733764 | 7478806 |
| | | MAR2-5 | 50 734906 | 7478710 |
| | | MAR2-6 | 50 735531 | 7478436 |

## 2.3 Water quality

At each site a number of water quality variables were recorded *in situ* using portable WTW field meters, including pH, electrical conductivity (µS/cm), dissolved oxygen (% and mg/L), and water temperature (°C). Water depth was measured using a graduated pole. Undisturbed water samples were taken for laboratory analyses of ionic composition, nutrients and metals. Samples collected for nutrients and metals were filtered through 0.45 µm Millipore nitrocellulose filters. All water samples were kept cool in an esky while in the field, and frozen as soon as possible for subsequent transport to the laboratory. All laboratory analyses were conducted by the Natural Resources Chemistry Laboratory, Chemistry Centre, WA (a NATA accredited laboratory). Water quality variables measured are summarised in Table 3.

**Table 2.** GPS location (UTM WGS84) of sites sampled along Weeli Wolli Creek.

| *Reach* | *Historic flows* | *Site* | *GPS Location* | |
|---|---|---|---|---|
| | | | *Easting* | *Northing* |
| 1 | springs and permanent pools | WW1-1 | 50 724996 | 7463013 |
| | | WW1-2 | 50 725118 | 7463229 |
| | | WW1-3 | 50 725314 | 7463617 |
| | | WW1-4 | 50 725578 | 7463854 |
| | | WW1-5 | 50 725784 | 7463974 |
| | | WW1-6 | 50 726338 | 7464051 |
| 2 | permanent flows | WW2-1 | 50 727121 | 7464649 |
| | | WW2-2 | 50 727314 | 7465349 |
| | | WW2-3 | 50 727622 | 7465670 |
| | | WW2-4 | 50 727760 | 7466098 |
| | | WW2-5 | 50 728036 | 7466500 |
| | | WW2-6 | 50 729320 | 7467676 |
| 3 | highly ephemeral flows, where the creek was dry for much of the year | WW3-1 | 50 730243 | 7468720 |
| | | WW3-2 | 50 730424 | 7469027 |
| | | WW3-3 | 50 733220 | 7473739 |
| | | WW3-4 | 50 734243 | 7475063 |
| | | WW3-5 | 50 734838 | 7475862 |
| | | WW3-6 | 50 735545 | 7476564 |
| 4 | Highly ephemeral flows, where the creek was dry for much of the year (but has been influenced by discharge from BHP's Yandi mine) | WW4-1 | 50 737041 | 7478376 |
| | | WW4-3 | 50 737381 | 7478874 |
| | | WW4-4 | 50 737684 | 7479082 |
| | | WW4-5 | 50 738105 | 7479616 |
| | | WW4-7 | 50 739194 | 7480091 |
| | | WW4-8 | 50 739700 | 7480735 |

Water quality data were compared against ANZECC/ARMCANZ (2000) water quality guidelines. ANZECC/ARMCANZ (2000) provides trigger values for a range of water quality parameters for the protection of aquatic ecosystems. These trigger values may be adopted in the absence of adequate site-specific data. ANZECC/ARMCANZ (2000) recommends different levels of species protection applied to different levels of ecosystem condition. The 99% value is applied to high conservation/ecological value ecosystems, the 95% value to slightly to moderately disturbed ecosystems and the 90% or 80% values to highly disturbed ecosystems. In the ANZECC/ARMCANZ (2000) water quality management framework, the decision about the ecosystem condition is typically a joint one between stakeholders. Based on the observed condition of creeks in the vicinity of Weeli Wolli Creek, it is suggested that either the 99% or possibly the 95% values are applied. When applying trigger values (TVs), ANZECC/ARMCANZ (2000) state the following:

> "*Trigger values are concentrations that, if exceeded, would indicate a potential environmental problem, and so 'trigger' a management response, e.g. further investigation and subsequent refinement of the guidelines according to local conditions*." (Section 2.1.4); and
>
> "*Exceedances of the trigger values are an 'early warning' mechanism to alert managers of a potential problem. They are not intended to be an instrument to assess 'compliance' and should not be used in this capacity*." (Section 7.4.4).

**Table 3.** All water quality parameters measured.

| *Parameter* | *Units* | *Parameter* | *Units* |
|---|---|---|---|
| pH | pH units | Aluminium (Al) | mg/L |
| Electrical conductivity | µS/cm | Arsenic (As) | mg/L |
| Dissolved oxygen | % saturation | Boron (B) | mg/L |
| Dissolved oxygen | mg/L | Barium (Ba) | mg/L |
| Water temp | ℃ | Cadmium (Cd) | mg/L |
| Average water depth | m | Cobalt (Co) | mg/L |
| Maximum water depth | m | Chromium (Cr) | mg/L |
| Sodium (Na) | mg/L | Copper (Cu) | mg/L |
| Potassium (K) | mg/L | Iron (Fe) | mg/L |
| Calcium (Ca) | mg/L | Manganese (Mn) | mg/L |
| Magnesium (Mg) | mg/L | Molybdenum (Mo) | mg/L |
| Chloride (Cl) | mg/L | Nickel (Ni) | mg/L |
| $CO_3$ | mg/L | Lead (Pb) | mg/L |
| $HCO_3$ | mg/L | Selenium (Se) | mg/L |
| $SO_4$ | mg/L | Uranium (U) | mg/L |
| Alkalinity | mg/L | Vanadium (V) | mg/L |
| Hardness | mg/L | Zinc (Zn) | mg/L |
| Nitrate ($NO_3$) | mg/L | | |
| Ammonium ($NH_3$) | mg/L | | |
| Total Nitrogen (total N) | mg/L | | |
| Total Phosphorus (total P) | mg/L | | |

Hence, TVs should not be used in a 'pass-fail' approach to water quality management. Their main purpose is to inform managers and regulators that changes in water quality are occurring and may need to be investigated. In the case of baseline data collection, the guidelines may be used to establish background levels relative to TVs, and show where certain elements may be naturally elevated (i.e. due to geological features). This allows future discrimination of mine effects from natural enrichment. Where background levels are elevated, then it is desirable to establish site-specific TVs.

The guidelines recommend, that where an appropriate default TV does not exist, or the default TV is consistently lower than natural background concentrations, natural background data should be used to derive the TV. In these instances, the 80$^{th}$ percentile (and 20$^{th}$ percentile in the case of variables that require an upper and lower guidelines, e.g. pH) of a baseline dataset should be used. This value is then compared to the median value of the subject water (i.e. the dewatering water) (for further details see Sections 3.3.2.4 and 7.4.4 of ANZECC/ARMCANZ 2000). It is also recommended that TV are based on at least two years of monthly monitoring data.

## 2.4 Microinvertebrates

Microinvertebrate samples were collected from each site by gentle sweeping over an approximate 15 m distance with a 53 µm mesh pond net. Care was taken not to disturb the benthos (bottom sediments). Samples were preserved in 70% ethanol and sent to Dr Russ Shiel of Adelaide University for processing. Dr Shiel is a world authority on microfauna, with extensive experience in fauna survey and impact assessment across Australasia.

Microinvertebrate samples were processed by identifying the first 200-300 individuals encountered in an agitated sample decanted into a 125 $mm^2$ gridded plastic tray, with the tray then scanned for additional missed taxa also taken to species, and recorded as 'present'. Specimens were identified to the lowest taxon possible, i.e. species or morphotypes. Where specific names could not be assigned, vouchers were established. These vouchers are held by Dr Shiel at Adelaide University, Adelaide, Australia.

## 2.5 Hyporheic fauna

At each site, hyporheic sampling was conducted by digging a hole approximately 20 cm deep and 40 cm diameter in alluvial gravels in dry streambed adjacent to the waters edge. The hole was allowed to infiltrate with water, and then the water column was swept with a modified 53 µm mesh plankton net immediately after the hole had filled, and again after approx. 30 minutes, after other sampling had been conducted.

Samples were preserved in 70% ethanol and returned to the laboratory for processing. Any hyporheic fauna present was removed from samples by sorting under a low power dissecting microscope. Specimens were sent to appropriate taxonomic experts for identification and confirmation of their status as hyporheic fauna.

Chironomidae (non-biting midges) were sent to Dr Don Edward (The University of Western Australia), Amphipoda to Dr Terrie Finston (The University of Western Australia) for genetic analysis, Copepoda and Ostracoda to Dr Russ Shiel (Adelaide University).

All taxa recorded from hyporheic samples were classified using Boulton's (2001) categories;

- stygobite – obligate groundwater species, with special adaptations to survive such conditions
- permanent hyporheos stygophiles - epigean[4] species which can occur in both surface- and groundwaters, but is a permanent inhabitant of the hyporheos
- occasional hyporheos stygophiles – use the hyporheic zone seasonally or during early life history stages
- stygoxene (species that appear rarely and apparently at random in groundwater habitats, there by accident or seeking refuge during spates or drought; not specialised for groundwater habitat).

4 Epigean – living or occurring on or near the surface of the ground.

## 2.6 Macroinvertebrates

Macroinvertebrate sampling was conducted with a 250 µm mesh FBA pond net to selectively collect the macroinvertebrate fauna. In order to allow comparisons to be made between sites and systems, a standardised sampling approach was adopted, whereby riffle habitats were selectively sampled at each site. This standardises for habitat and avoids issues with greater diversity due to greater habitat diversity on any reach. Each sample was washed through a 250 µm sieve to remove fine sediment, leaf litter and other debris (Plate 1). Samples were then preserved in 70% ethanol.

**Plate 1.** Using the 250 µm sieve at MAR2-4 to remove fine sediment, leaf litter and other debris.

In the laboratory, macroinvertebrates were removed from samples by sorting under a low power dissecting microscope. Collected specimens were then identified to the lowest possible level (genus or species level) and enumerated to $\log_{10}$ scale abundance classes (*i.e.* 1 = 1 - 10 individuals, 2 = 11 - 100 individuals, 3 = 101-1000 individuals, 4 = >1000). In-house expertise was used to identify invertebrate taxa using available published keys and through reference to the established voucher collections held by WRM. External specialist taxonomic expertise was sub-contracted to assist with Chironomidae (non-biting midges) (Dr Don Edward, The University of Western Australia).

## 2.7 Fish

Fish fauna were sampled using a variety of methods in order to effectively collect as many individuals as possible in each reach. Fish sampling methods included electrofishing, seine nets, gill nets and dip nets.

Electrofishing was conducted with a Smith-Root Model 12-B battery powered backpack electrofisher (Plate 2). Electrofishing is an extremely useful and efficient sampling tool in rivers with clear, low salinity, slow flow water. All meso-habitats within a 40 metre reach were shocked with the intention of recovering as many species/ individuals as possible. Shocking was not continuous, but targeted areas of optimum habitat, whereby the operator would shock, move to a new habitat before shocking again, and so prevent fish being driven along in front of the electrical field.

Smaller species and juveniles were sampled by beach seine (10 m net, with a 2 m drop and 6 mm mesh) deployed in shallow areas where there was little vegetation or large woody debris. Generally, two seines were conducted at each site to maximise the number of individuals caught.

**Plate 2.** Electrofishing at MAR2-1.

**Principles of electrofishing**: a DC voltage is passed from a negative electrode (cathode) to a positive electrode (anode) whilst the electrodes are immersed in the water. If a fish is caught in the electrical field generated, a process referred to as 'Galvanotaxis' occurs. This is the involuntary movement of the fish towards the anode, until it reaches an electrical field strong enough to stun it ('galvanoarcosis'). The Smith-Root electrofisher uses a pulsed DC current, which is more effective than a flat DC signal because the body of the fish flexes with each pulse, accentuating the involuntary swimming action towards the anode. Once the current is switched-off, or the fish removed from the electrical field, the fish quickly recovers. Some damage to fish may occur if they are caught in a high electrical field close to the anode for an extended period. The operator of the electrofisher carries the anode (in the form of a modified pond net) whilst trailing the cathode (a stainless steel cable approximately 3.5 m long, referred to as a 'rat tail'). The Smith-Root backpack electrofisher has an effective range of approximately 3 m. Galvanotaxis can be used to 'pull' fish and crayfish out from under debris, logs, boulders and bank undercuts.

Gillnetting involved setting 10 m light-weight fine mesh gill nets with a 2 m drop (of varying stretched mesh net size 13mm and 19 mm) at each site. Nets were left for the duration of sampling at that particular site.

All fish were identified in the field, measured and then released alive. Fish nomenclature followed that of Allen *et al.* (2002). Measuring the fish captured provided information on the size structure, breeding and recruitment of the fish population.

## 2.8 Data analysis

### 2.8.1 Univariate analysis

Univariate statistics were performed using SPSS software (Version 17.0 for Windows). Independent samples were used as replicates and two-way analysis of variance (ANOVA) was applied to test for significant differences in species richness (of microinvertebrates and macroinvertebrates) between reaches, systems and/or seasons. Two-way ANOVA was also undertaken on some physico-chemical parameters, including water temperature, total nitrogen concentration, magnesium, sulphate, etc.

A Levene's test was used in the first instance to test for equality of variances. Tukeys post-hoc tests were utilised in the case of significant differences to locate reach differences.

### 2.8.2 Multivariate analysis

Multivariate analyses were performed using the PRIMER package v 6 (Plymouth Routines in Multivariate Ecological Research; Clarke and Gorley 2006) to investigate differences in aquatic fauna assemblages (macroinvertebrates and microinvertebrates) across reaches, seasons and sampling events, and relationships with physico-chemical characteristics from each site. The PRIMER package, developed for multivariate analysis of marine fauna

samples, has been applied extensively to analysis of freshwater invertebrate data. Analyses applied to the data included some or all of the following:

1. Describing pattern amongst the fauna assemblage data (macroinvertebrates and microinvertebrates) using ordination techniques based on Bray-Curtis similarity matrices (Bray and Curtis 1957). The clustering technique uses a hierarchical agglomerative method where samples of similar assemblages are grouped and the groups themselves form clusters at lower levels of similarity. A group average linkage was used to derive the resultant dendrogram. Ordination of data was by Multi-Dimensional Scaling (MDS) (Clarke and Warwick 2001). Ordinations were depicted as two-dimensional plots based on the site by site similarity matrices. For environmental data, the Euclidean Distance Measure was used to create resemblances, and the data was first transformed (where necessary) and normalised.
2. Cluster analysis to produce SIMPROF results which were overlain on the ordination where necessary.
3. For any groups found in (1) or selected *a priori* (*i.e.* reach and season), Two-way Crossed Analysis of Similarity (ANOSIM) – effectively an analogue of the univariate two-way ANOVA – was conducted to determine if reaches and sampling events were significantly different from one another. The ANOSIM test statistic reflects the observed differences *between* groups (*e.g.* between reaches) with the differences amongst replicates *within* the groups. The test is based upon rank similarities between samples in the underlying Bray-Curtis similarity matrix. The analysis presents the significance of the overall test (Significance level of sample statistic), and significance of each pairwise comparison (Significance level %), with degree of separation between groups (R-statistic), 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. A significance level <5% = significant effect/difference.
4. The SIMPER routine was used to examine which taxa were contributing to the differences of any groups that were found to be different according to the ANOSIM procedure or otherwise found to be separated in cluster or ordination analyses.
5. The relationship between the environmental and biotic data was assessed in two ways:
    - The BIOENV routine was used to calculate the minimum suite of parameters that explain the greatest percent of variation (i.e. the parameters which most strongly influence the species ordination)
    - For visualisation, the numeric value of key environmental data (as determined by BIOENV) were superimposed onto MDS ordinations, as circles of differing sizes – so-called 'bubble plots'.
6. Differences in multivariate dispersions among groups (i.e. seasons) was investigated using PERMDISP (Anderson 2006) in PERMANOVA (Anderson 2005). PERMDISP can be undertaken on the basis of any distance measure (i.e. Euclidean Distance) or similarity (i.e. Bray-Curtis) measure of choice. The test can be considered in two steps, 1) calculation of the distances from observations to their centroids, and 2) comparison of the average of these distances among groups, using ANOVA (Anderson 2006). A p-value is obtained using permutation of the observations. The approach is a multivariate analogue to Levene's Test (Levene 1960).

# 3 RESULTS AND DISCUSSION

## 3.1 Water quality

As mentioned previously, water quality data were compared against ANZECC/ARMCANZ (2000) water quality guidelines. The default trigger values for physical and chemical stressors applicable to tropical northern Australia are provided in Appendix 2.

### 3.1.1 Physico-chemistry

**Dissolved oxygen (DO)**

Dissolved oxygen levels in the current study ranged from 56% (MAR1-1) to 180% (MAR2-4) during October 2008, and 44% (MAR1-3) to 133% (MAR2-3) in May 2009 (Appendix 3). During the dry season of Oct-08, all but two sites (MAR2-2 & MAR2-6) recorded DO levels outside the recommended ANZECC/ARMCANZ (2000) guidelines for the protection of lowland river systems in the tropical north of Australia (Appendices 2 and 3). Low DO can impact the aquatic ecosystem through a slowing in growth rates of aquatic fauna, reproductive difficulties, stress, increased susceptibility to disease, and in some cases increased mortality. Low DO also promotes the accelerated release of nutrients and heavy metals from sediments, which can have a toxic effect on aquatic flora and fauna. In most cases, the 'low' DO levels (<85%) recorded during the current study were unlikely to be low enough to have an ecological impact. DO concentrations less the ~20% typically represent environmental conditions of 'stress' to resident aquatic fauna, particularly fish with high metabolic demand for oxygen. DO values as low as this were not recorded during the current study. However, oxygen needs of aquatic biota differ between species and between life history stages. The 'high' DO values recorded during the current study may be cause for concern. Super-saturation (DO>100%) occurs when net photosynthesis exceeds total oxygen consumption and is common in areas of high macrophyte and algal growth. Such sites would experience oxygen stress overnight, as respiration by plants, algae, bacteria and other aquatic fauna deplete DO. Super-saturated DO can also lead to fish bubble disease. One site in particular, MAR2-4 in October 2008, recorded exceptionally high DO levels (180%). Super-saturation can occur in systems with good light penetration and nutrient inputs which lead to excessive algal and macrophyte growth.

**pH**

Most river systems in Western Australia (including those in the Pilbara *e.g* Robe, Harding and lower Fortescue at Millstream) have a natural pH range circum-neutral. In the absence of baseline data, ANZECC/ARMCANZ (2000) guidelines recommend average pH should be between 6 and 8 in lowland rivers of tropical northern Australia. Generally, the pH values recorded during the current study were within these guidelines and were circum-neutral to slightly basic. During the dry season, pH ranged from 7.7 (MAR1-6) to 8.3 (MAR2-4 & MAR2-6), and during the wet from 7.6 (MAR1-3) to 8.6 (MAR2-3). The slightly basic pH recorded from Marillana Creek is not likely to cause adverse impacts to aquatic biota. WRM (2009b) reported similarly basic pH from Marillana Creek previously, while Johnson and Wright (2003), Streamtec (2004), and WRM (2009a, b, 2010) recorded slightly basic pH from other systems in the East Pilbara, including Weeli Wolli Creek, Coondiner Creek, Kalgan Creek and the Fortescue River (WRM 2009b).

**Electrical conductivity (Ec)**

All sites were fresh as classified by the DoE (2003)[5] (Appendix 3). Conductivity ranged from 905 µS/cm (MAR2-4) to 1040 µS/cm (MAR1-6) during the dry season of 2008, and from 939 µS/cm (MAR1-1, MAR2-5 & MAR2-6) to 1010 µS/cm (MAR1-6) in the wet season (Appendix 3). Whilst all conductivity values were above ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems, all sites were considered fresh and their conductivity is likely to be of little ecological consequence. There is a general acceptance that when conductivity is less than 1500 µS/cm, freshwater ecosystems experience little ecological stress (Hart *et al.* 1991, Horrigan *et al.* 2005).

**Ions**

Alkalinity refers to the capacity of water to neutralise acid and is an expression of buffering capacity. It essentially relates to the amount of bases[6] in water which buffer against sudden changes in pH (McDonald and Wood 1993, Riethmuller *et al.* 2001, Lawson 2002). Bases are able to buffer water by absorbing hydrogen ions when the water is acid and releasing them when the water becomes basic (Lawson 2002). Therefore, alkalinity is important for aquatic fauna as it can protect against rapid pH changes (Riethmuller *et al.* 2001). Alkalinity of less than 20 mg/L is considered low; waters would be poorly buffered and the removal of carbon dioxide during photosynthesis would result in rapidly rising pH (Sawyer and McCarty 1978, Romaire 1985, Lawson 2002). If alkalinity is naturally low (< 20 mg/L) there can be no greater than a 25% reduction in alkalinity. In the current study, alkalinity was high at all sites along the length of Marillana Creek (Appendix 3). Alkalinity ranged from 255 mg/L at MAR1-2 to 315 mg/L at MAR2-1 during the dry, and 255 mg/L (MAR1-1) to 300 mg/L (MAR2-1 & MAR2-2) in the wet (Appendix 3). This suggests that the buffering capacity of waters along Marillana Creek is high.

The ionic composition of waters is determined by rain-borne salts (*i.e.* wind-blown dusts) and geology (*e.g*. weathering of soils) of the catchment (DeDeckker and Williams 1986). However, the composition over the warmer months, particularly in shallow reaches, will be altered by evapo-concentration and precipitation of less soluble salts, such as calcium carbonate and magnesium sulphate (Hart and McKelvie 1986). The ionic composition of inland waters in Australia is known to vary widely, but the proportions of calcium, magnesium and bicarbonate are often enriched compared to seawater (DeDeckker and Williams 1986).

The composition of major ions along Marillana Creek was typically dominated by sodium and hydrogen bicarbonate ($Na^+ > Ca^{2+} > Mg^{2+} > K^+$: $HCO_3^- > Cl^- > SO_4^{2-} > CO_3^-$). This did not change between seasons. The dominance of major ions at Marillana Creek was the same as that reported from Weeli Wolli Creek downstream of the confluence with Marillana Creek (i.e. WW Reach Four; WRM 2009a, 2010).

[5] Fresh defined as < 1500 µS/cm, Brackish = 1500 – 4500 µS/cm, Saline = 4500 – 50,000 µS/cm, Hypersaline > 50,000 µS/cm (DoE 2003). Classifications were presented as TDS (mg/L) in DoE (2003) so a conversion factor of 0.68 was used to convert to conductivity µS/cm as recommended by ANZECC/ARMCANZ (2000).

[6] Bases are ions which release hydroxyl ions (OH-) when dissolved in water. Generally these bases are principally bicarbonate and carbonate ions (Lawson 2002).

**Nutrients**

Total nitrogen levels along Marillana Creek varied between reach and season, ranging from 0.05 mg/L at MAR1-5 in the dry, to 1.8 mg/L at MAR2-1 also in the dry season (Figure 6 and Appendix 3). The ANZECC/ ARMCANZ (2000) trigger value[7] was exceeded at two sites in the dry season (MAR2-1 & MAR2-2), and six sites in the wet (MAR1-1, MAR1-2, MAR2-1, MAR2-2, MAR2-3 & MAR2-4) (Figure 6 and Appendix 3). Total phosphorus ranged from 0.005 mg/L (at all sites except MAR1-3) in the dry, to 0.04 mg/L (MAR1-1 & MAR2-1) during the wet season (Figure 6 and Appendix 3). The ANZECC/ARMCANZ (2000) trigger value[8] was exceeded at all sites during the wet season (Figure 6 and Appendix 3).

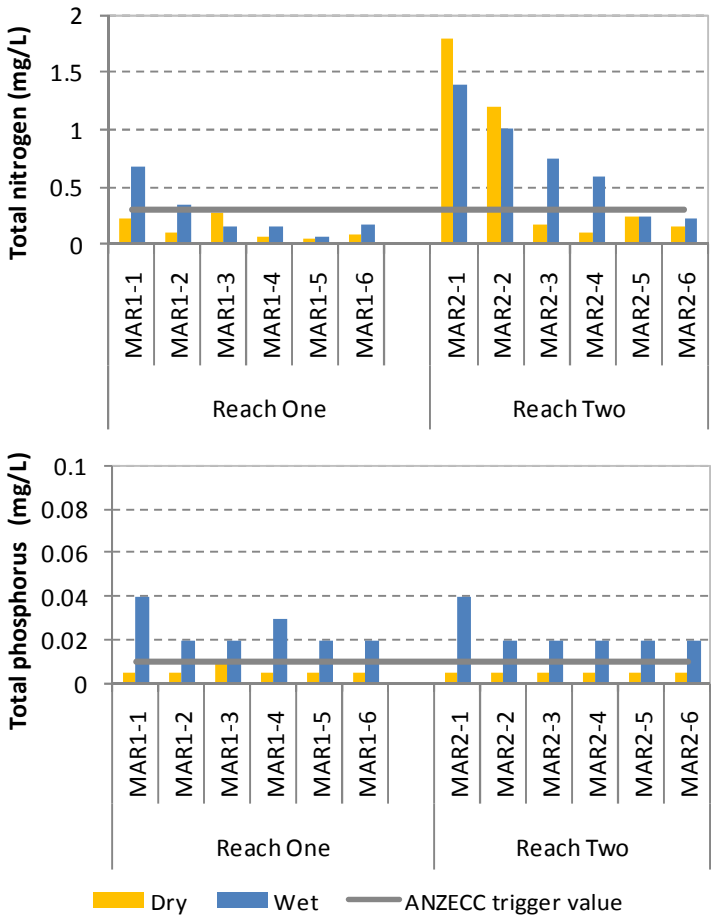



**Figure 6.** Nutrient levels (mg/L) recorded from Marillana Creek during the wet (Oct-08) and dry season (May-09), showing total nitrogen (top) and total phosphorus (bottom). The ANZECC/ARMCANZ (2000) trigger value is indicated by the grey line.

Total nitrogen levels recorded from Marillana Creek were significantly different between reach (Two-way ANOVA; df = 1, p= 0.01) but not season (Two-way ANOVA; df = 1, p = 0.13; Table 4). Significantly higher total nitrogen levels were recorded from Reach Two when compared to Reach One (Figure 7 and Table 4). The cause of the elevated total nitrogen levels from the downstream Marillana reach is unknown, but may be coming from any number of potential sources, including current pastoral activities and cattle stocking, past cattle use and leaching from soils, and/or some influence from Yandi operations such as elevated total nitrogen in groundwater discharge water, contamination of groundwater from ammonium nitrate storage or septic systems, and/or elevated total nitrogen in mine process water discharged into the creek. Although elevated nitrogen levels are not uncommon in creeks of this area due to pastoral activities and cattle stocking, the significantly higher levels recorded from Marillana Reach Two do suggest another source may be present, as cattle were seen along the length of Marillana Creek

[7] The ANZECC/ARMCANZ (2000) guidelines recommend that total nitrogen should not exceed 0.3 mg/L in tropical northern Australian lowland rivers.

[8] The ANZECC/ARMCANZ (2000) guidelines recommend that total phosphorus should not exceed 0.01 mg/L in tropical northern Australian lowland rivers.

during sampling. Elevated total nitrogen and total phosphorus levels have been recorded from mine process water which is discharged from the levee bank discharge point upstream of Marillana Reach Two (Table 5 & see Figure 3 for the location of the discharge point). However, potential sources for the increased total nitrogen from MAR-Two need to be investigated further before any conclusions can be drawn.

**Table 4.** Two-way ANOVA of nutrient data by reach and season.

| *Type* | *Source* | *df* | *F-value* | *p-value* |
|---|---|---|---|---|
| **Log total nitrogen** | **Reach** | 1 | 8.95 | 0.007 |
| | **Season** | 1 | 2.54 | 0.127 |
| | **Reach*Season** | 1 | 0.01 | 0.904 |
| | **Total** | 23 | | |
| **Log total phosphorus** | **Reach** | 1 | 0.81 | 0.379 |
| | **Season** | 1 | 210.60 | 0.000 |
| | **Reach*Season** | 1 | 0.05 | 0.816 |
| | **Total** | 23 | | |

**Table 5.** Total nitrogen (mg/L) and total phosphorus (mg/L) concentrations in mine process water recorded from the levee bank discharge point at RTIOs Yandi. Data provided by RTIO Yandi. Shading indicates the value exceeds ANZECC/ARMCANZ (2000) guidelines.

| *Year* | *Sample date* | *Total N (mg/L)* | *Total P (mg/L)* |
|---|---|---|---|
| **2009** | 27/01/2009 | 1.7 | 1.7 |
| | 25/02/2009 | 2.9 | 1.6 |
| | 24/03/2009 | 15 | 9.2 |
| | 15/04/2009 | 20 | 5 |
| | 26/05/2009 | 17 | 20 |
| | 17/06/2009 | 26 | 13 |
| | 28/07/2009 | 19 | 23 |
| | 27/08/2009 | 57 | 0.83 |
| | 16/09/2009 | 6.9 | 10 |
| | 28/10/2009 | 12 | 8.9 |
| | 30/11/2009 | 3.1 | 7.3 |
| **2010** | 19/01/2010 | 2.5 | 5.9 |
| | 15/02/2010 | 3.1 | 7.4 |

Total phosphorus levels of Marillana Creek were significantly different between season (Two-way ANOVA; df = 1, p= 0.00), but not reach (Two-way ANOVA; df = 1, p = 0.38; Table 4). In this case, significantly greater phosphorus levels were recorded during the wet season (Figure 7 and Table 4).

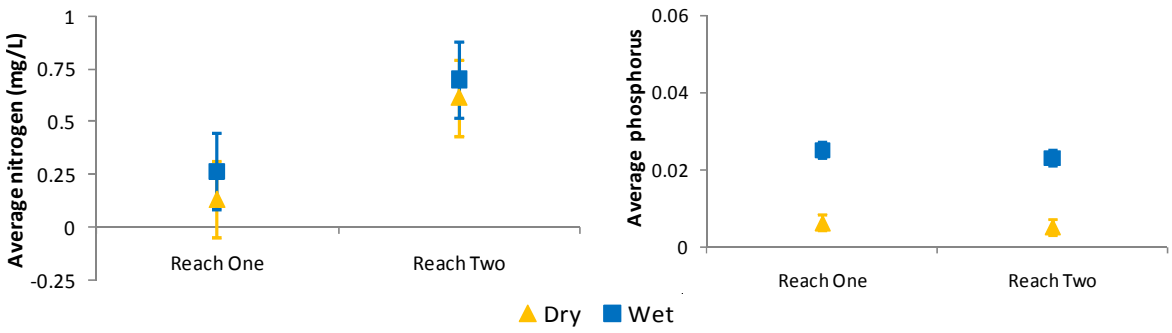



**Figure 7.** Average nutrient concentration (±se) per reach and season, showing average total nitrogen (left) and average total phosphorus (right).

### 3.1.2 Patterns in water quality data

Patterns were evident within the water quality ordination, with samples forming groups according to reach and season (Figure 8). Water quality was found to be significantly different between reach (Two-way crossed ANOSIM; sample statistic = 0.63; significance of sample statistic p = 0.0001) and season (Two-way crossed ANOSIM; sample statistic = 0.73; significance of sample statistic p = 0.0001). Samples within each grouping, however, seemed to be highly variable (Figure 8). Dry season samples from Marillana Reach One formed the tightest group in the ordination (Figure 8), suggesting that samples within this group were most similar to each other, than any other group.

Water quality variables influencing the separation of samples amongst seasons were total phosphorus and zinc, with total phosphorus being higher in the wet season and zinc being lower in the wet season (Figure 9). The concentration of total nitrogen influenced the separation of samples amongst reaches, and was higher from Reach Two (Figure 9).

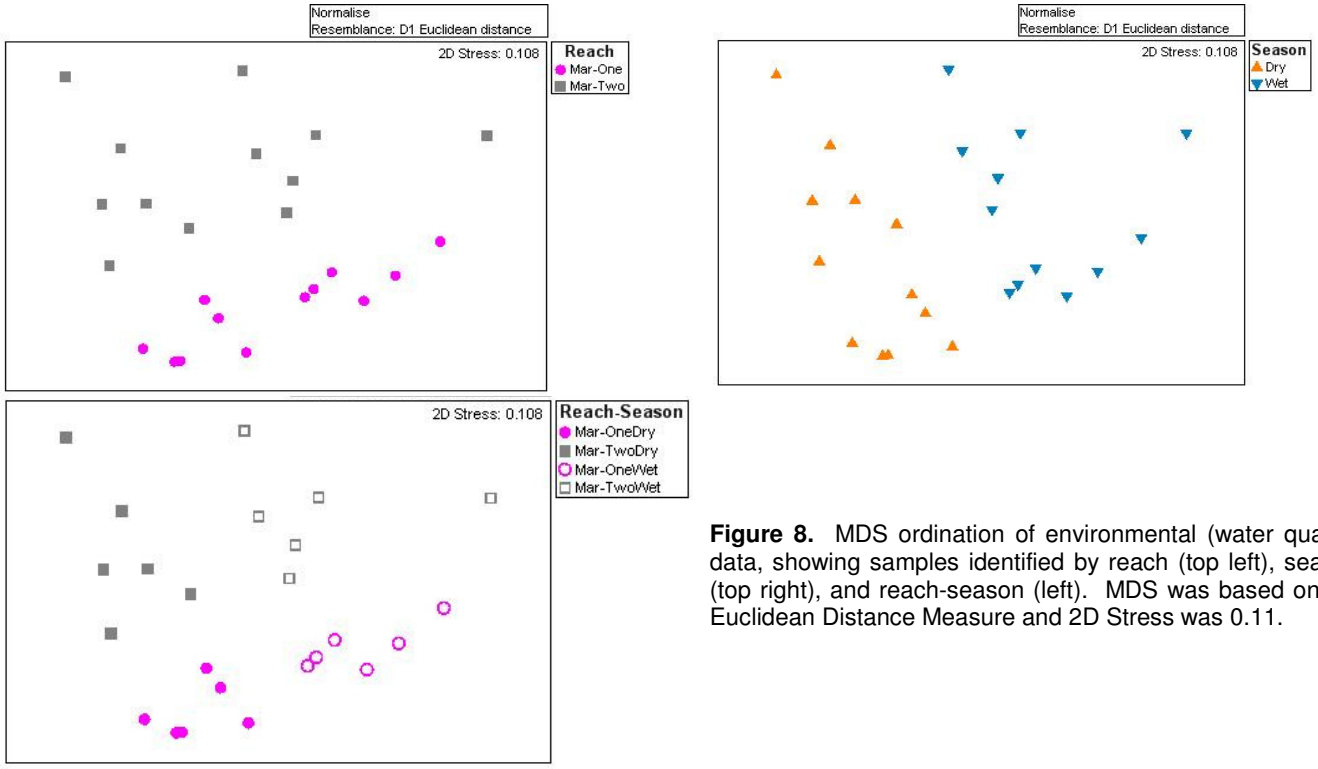



**Figure 8.** MDS ordination of environmental (water quality) data, showing samples identified by reach (top left), season (top right), and reach-season (left). MDS was based on the Euclidean Distance Measure and 2D Stress was 0.11.

### 3.1.3 Comparisons with Weeli Wolli water quality data

Using all water quality data collected from Weeli Wolli and Marillana Creek in October 2008 and May 2009, patterns were evident in ordination space (Figure 10). Water quality was significantly separate between systems (i.e. Weeli Wolli compared with Marillana Creek; One-way ANOSIM; sample statistic = 0.57, significance of sample statistic p = 0.0001).

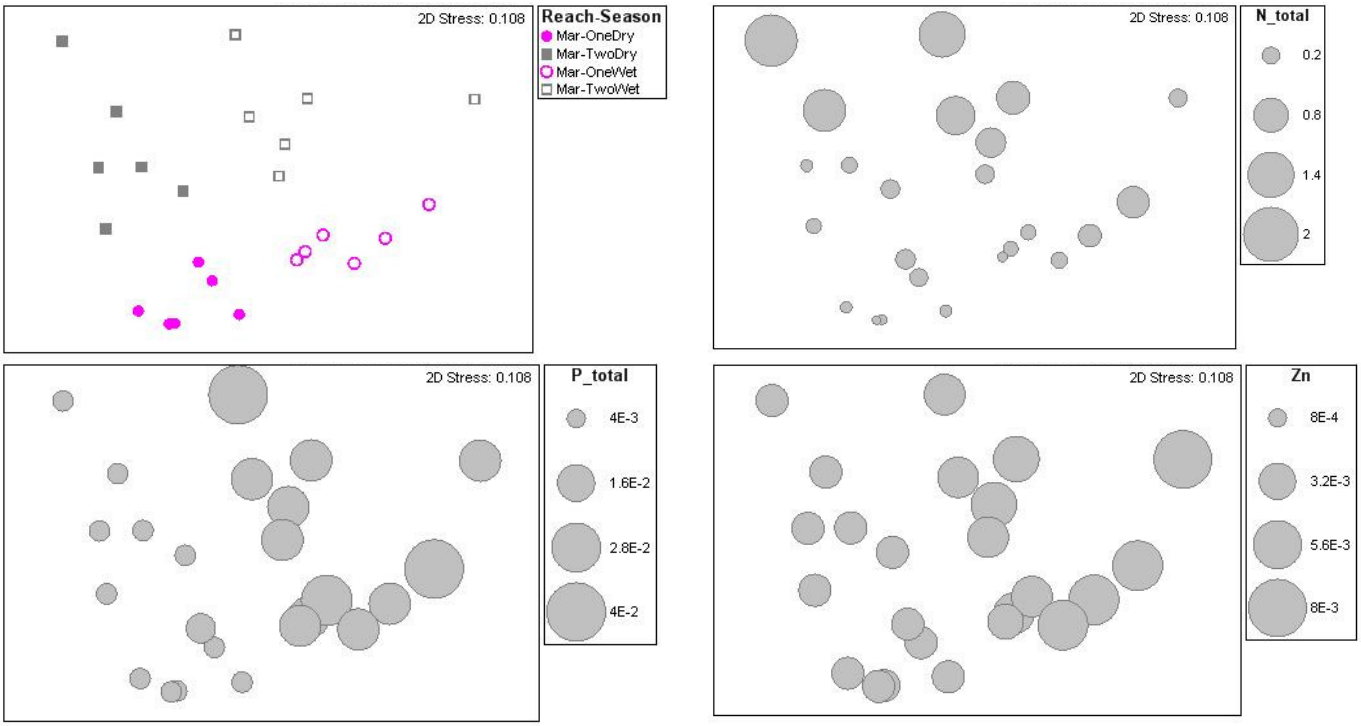



**Figure 9.** Bubble plots showing water quality parameters which contributed to the separation between reaches (top right; total nitrogen), and seasons (bottom; total phosphorus and zinc).

In addition, water quality was significantly different amongst season (Two-way crossed ANOSIM; sample statistic = 0.74, significance of sample statistic p = 0.0001) and reach (Figure 10 & Table 6; Two-way crossed ANOSIM; sample statistic = 0.79, significance of sample statistic p = 0.0001). All reaches were in fact significantly separate from one another, but a longitudinal pattern was also evident, with samples from Weeli Wolli Reach One being most similar to Reach Two (R=0.69) and least similar to Weeli Wolli Reach Four (R=0.92); and samples from Weeli Wolli Reach Four being most similar to Marillana Reach Two (R=0.68), and least similar to Marillana Reach One (R=0.91; Table 6). The two most similar reaches were those along Marillana Creek; MAR One and MAR Two (R=0.42; Table 6).

**Table 6.** Pair-wise ANOSIM results of water quality amongst reach, showing R-values (sample statistic)[9], * = groups significantly different.

| | *WW One* | *WW Two* | *WW Three* | *WW Four* | *MAR One* |
|---|---|---|---|---|---|
| **WW One** | | | | | |
| **WW Two** | 0.69* | | | | |
| **WW Three** | 0.87* | 0.37* | | | |
| **WW Four** | 0.92* | 0.97* | 0.86* | | |
| **MAR One** | 0.99* | 1.00* | 0.99* | 0.91* | |
| **MAR Two** | 0.83* | 0.87* | 0.78* | 0.68* | 0.42* |

[9] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barley separable.

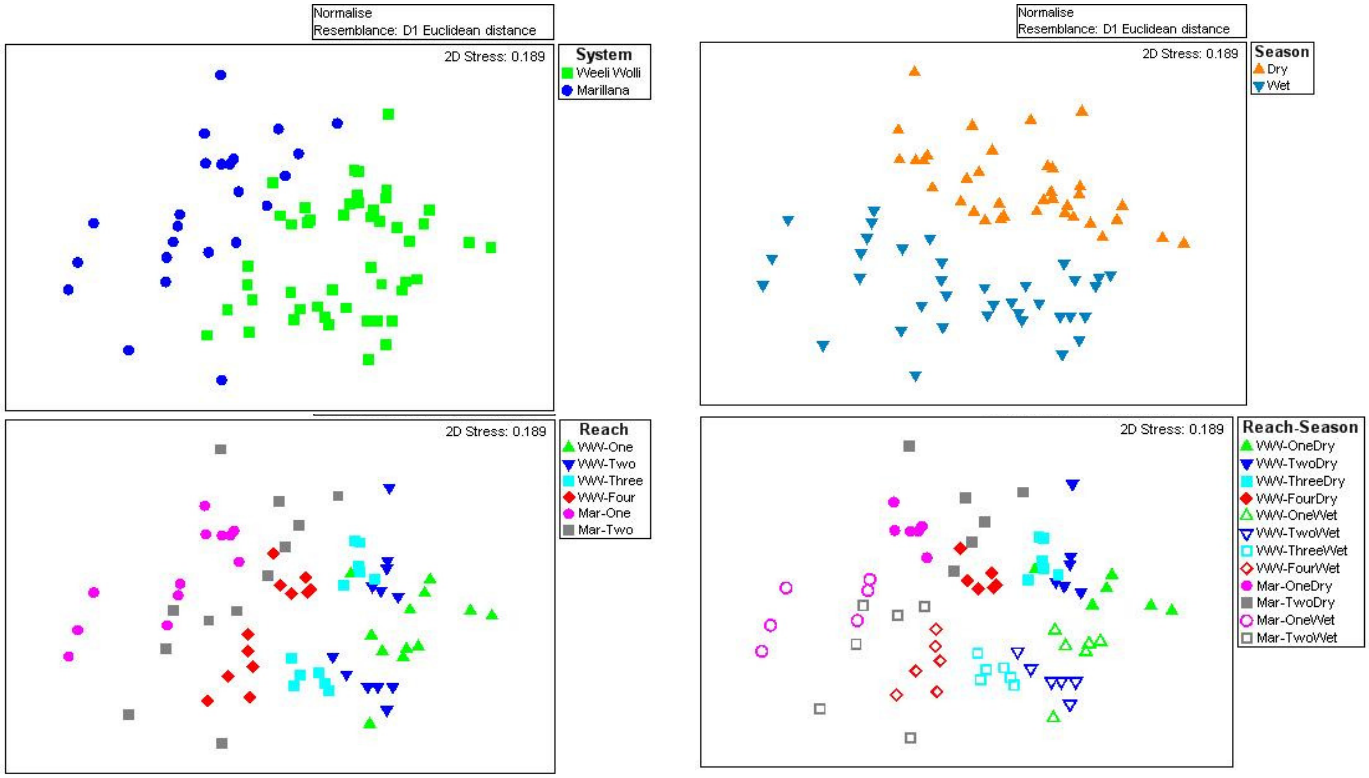



**Figure 10.** MDS ordination of environmental (water quality) data from Weeli Wolli Creek and Marillana Creek, showing samples identified by system (top left), season (top right), reach (bottom left), and reach-season (bottom right). MDS was based on the Euclidean Distance Measure and 2D Stress was 0.19.

In order to see more clearly the separations amongst reaches, individual ordinations were undertaken for each season and significant SIMPROF clusters overlain on the MDS (Figures 11 & 12). The dry season plot clearly shows Marillana Creek samples from both reaches grouped with Weeli Wolli Reach Four samples (Figure 11). This suggests that during the dry season, the water quality of Marillana Creek was similar to that recorded from the downstream Weeli Wolli reach (WW Reach Four). It appears that water quality of the downstream reach of Weeli Wolli Creek is influenced by Marillana Creek.

Weeli Wolli Reaches Two and Three formed their own group, and Weeli Wolli Reach One also formed a distinct group (Figure 11). One site from Marillana Creek, MAR2-6, separated from other Marillana and WW-Four sites based on its higher concentration of ammonia (NH3; Figure 11) Other water quality variables influencing the ordination were barium[10], which was highest from Marillana Creek and WW-Four, and sodium, which was lower from WW-One (Figure 11).

[10] No trigger value exists within the ANZECC/ARMCANZ (2000) guidelines for barium, so it is not known whether the higher values reported from Marillana Creek and Weeli Wolli Reach Four are of ecological concern.

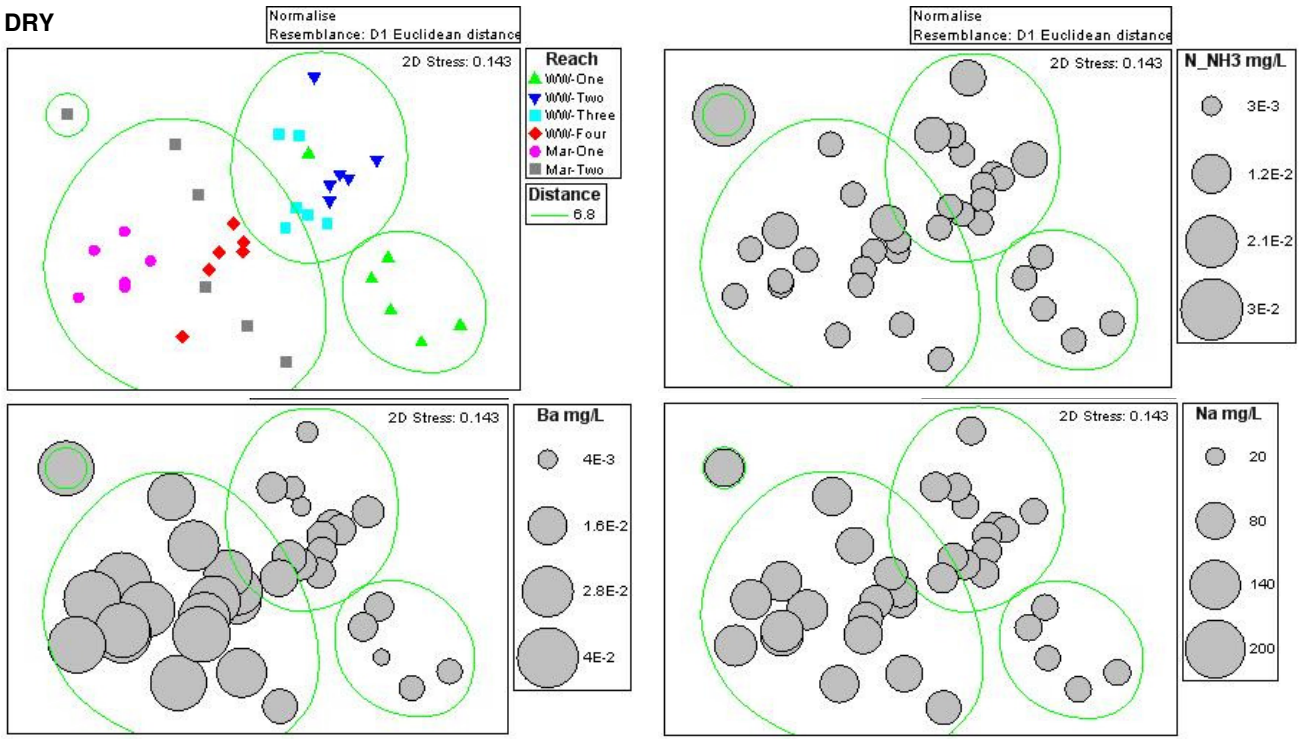



**Figure 11.** Dry season MDS ordination of environmental (water quality) data from Weeli Wolli Creek and Marillana Creek (top left). Samples are identified by reach and are grouped within significant SIMPROF clusters at a Euclidean Distance of 6.8. The MDS was based on the Euclidean Distance Measure and 2D Stress was 0.14.

This pattern was slightly different in the wet season, with WW-Four forming its own distinct group, separate from Marillana Creek sites (Figure 12). Once again, WW-One formed its own group, and WW-Two and WW-Three formed another separate group. In this case, all sites within Marillana Creek were found to have similar water quality, with the exception of MAR2-1 (Figure 12).

Water quality variables found to contribute to the patterns in the ordination included total nitrogen, barium, copper, and manganese (Figure 12). The concentration of total nitrogen was highest from MAR2-1, and influenced the separation of this site from all others, including other Marillana Creek sites (Figure 12). As was recorded during the dry season, Barium was again higher from Marillana Creek and WW-Four sites. Higher copper concentrations were recorded from Weeli Wolli Reach One, and higher manganese from WW-Two and WW-Three (Figure 12). However, the concentrations of both these dissolved metals were still below ANZECC/ARMCANZ (2000) guidelines for the protection of 99% of species, and are therefore not of ecological concern.

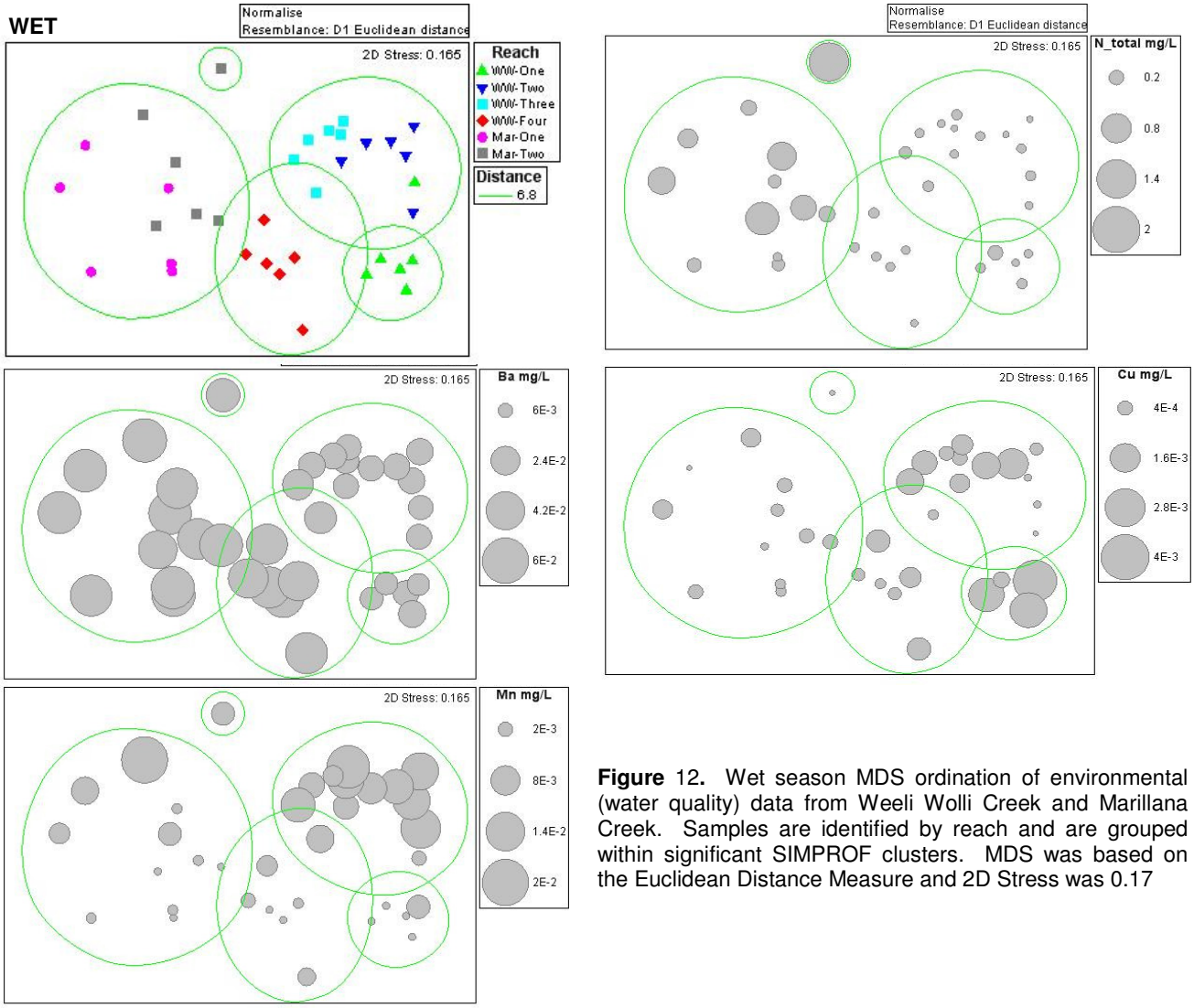



**Figure** 12**.** Wet season MDS ordination of environmental (water quality) data from Weeli Wolli Creek and Marillana Creek. Samples are identified by reach and are grouped within significant SIMPROF clusters. MDS was based on the Euclidean Distance Measure and 2D Stress was 0.17

## 3.2 Microinvertebrates

### 3.2.1 Taxonomic composition and species richness

A total of 59 taxa of microinvertebrates were recorded from Marillana Creek during the current study, with 45 being recorded in October 2008, and 41 taxa in May 2009 (Appendix 4). The microinvertebrate fauna comprised Protista (Ciliophora & Rhizopoda), Rotifera (Bdelloidea & Monogonata), Cladocera (water fleas), Copepoda (Cyclopoida) and Ostracoda (seed shrimp).

The microinvertebrate fauna were typical of tropical systems reported elsewhere (e.g. Koste and Shiel 1983, Tait *et al.* 1984, Smirnov and De Meester 1996, Segers *et al*. 2004). For example, Brachionidae within the Rotifera were poorly represented. This family tends to dominate temperate rotifer plankton, but is overshadowed by Lecanidae in tropical waters, as was the case here. Within the Cladocera fauna, daphniids tend to predominate in temperate waters, with low representation in the tropics. No daphniids were recorded from Marillana Creek during the current study, however, one species has been recorded from Flat Rocks upstream of the Yandi mine on Marillana Creek during the Regional Survey (Jess Delaney, WRM, unpub. data). In tropical systems throughout the world, daphniids tend to be replaced by sidids, moinids, and in the case of heavily vegetated or shallow waters, by chydorids, as seen here (see Appendix 4).

Microinvertebrate taxa richness varied greatly between reach and season (Figure 11). During the dry season of October 2008, the greatest number of microinvertebrate taxa was recorded from MAR2-3 (19 taxa), and the least from MAR1-6 (5 taxa). During the wet, the greatest number of taxa was recorded from MAR1-3 (20 taxa). No microinvertebrate taxa were collected from MAR1-6 during the wet season (Figure 13 and Appendix 4). More microinvertebrate taxa were recorded during the dry season (Figures 13 and 14).

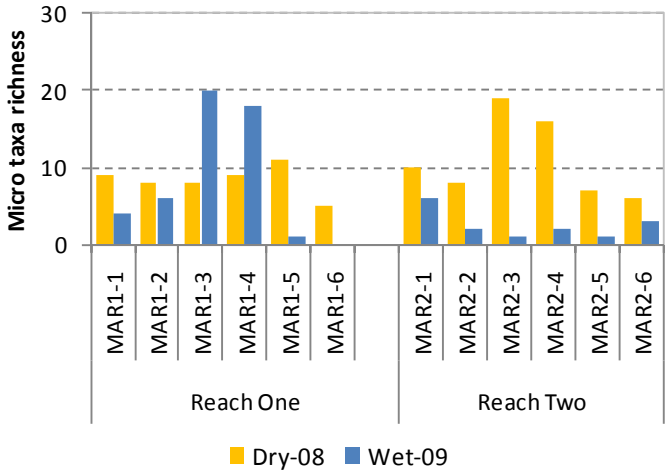



**Figure 13**. Microinvertebrate taxa richness recorded from each site along Marillana Creek during both seasons.

Using microinvertebrate data from Weeli Wolli Creek in the analysis, there was no significant difference in the average number of taxa between reach (Two-way ANOVA; df = 5, p= 0.14; Figure 14 and Table 7). There was, however, a significant difference in microinvertebrate taxa richness between season (Two-way ANOVA; df = 1, p= 0.02; Table 7), with a greater number of taxa being recorded during the dry (Figure 14). There was no interaction between reach and season (Table 7). Microinvertebrate taxa richness was highly variable within reach and within season as seen by the large standard error bars, particularly during the dry season (see Figure 14).

**Table 7.** Two-way ANOVA results for macroinvertebrate taxa richness by reach and season (including Weeli Wolli data), showing degrees of freedom, f-value and p-value.

| *Source* | *df* | *F* | p |
|---|---|---|---|
| **Reach** | 5 | 1.76 | 0.14 |
| **Season** | 1 | 6.31 | 0.02 |
| **Reach*Season** | 5 | 1.76 | 0.13 |
| **Total** | 69 | | |

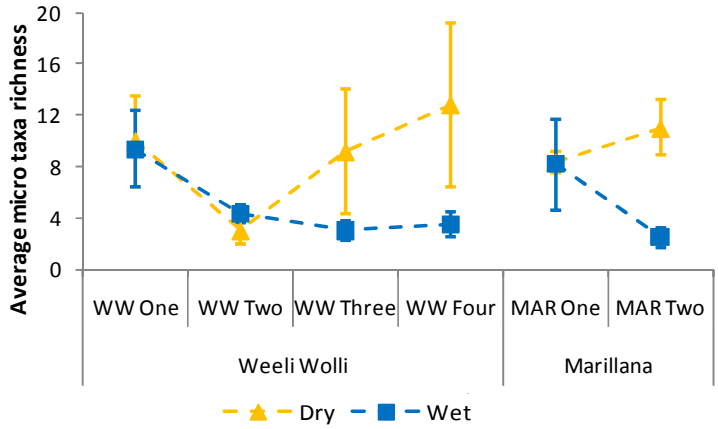
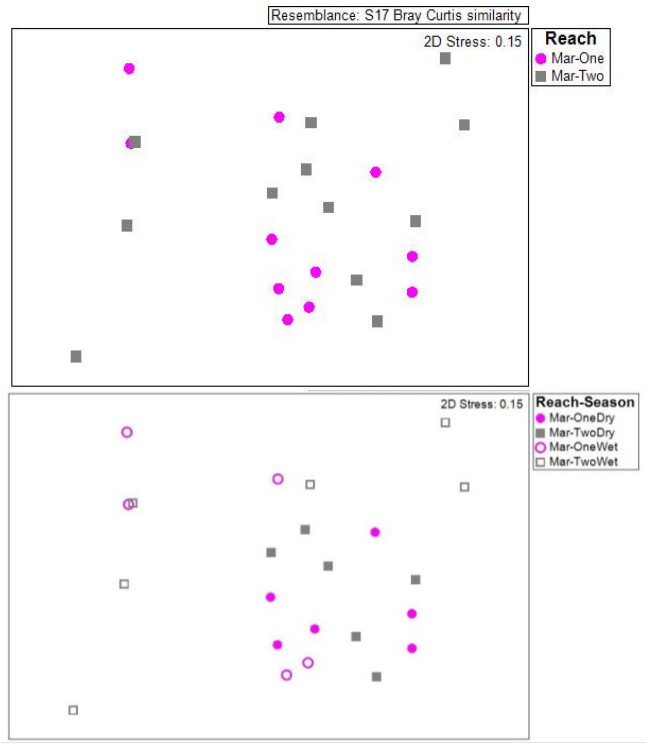



**Figure 14.** Average microinvertebrate taxa richness (±se) from all reaches (including those along Weeli Wolli Creek) showing data for both the dry (October 2008) and wet season (May 2009).

### 3.2.2 Patterns in microinvertebrate assemblage structure

No microinvertebrates were recorded from MAR1-6 during the wet season and this had an over-riding effect on the microinvertebrate abundance ordination for Marillana Creek. This site was therefore removed from further multivariate analysis.

No patterns were evident within the microinvertebrate abundance ordination (Figure 15). There was no significant difference in the microinvertebrate assemblages between reach (Two-way crossed ANOSIM; sample statistic = 0.025; significance of sample statistic p = 0.361). While there did appear to be some separation of samples between season (Figure 15), groups were found to be barely separable (Two-way crossed ANOSIM; sample statistic = 0.34; significance of sample statistic p = 0.0004). However, dry season samples did appear to be less variable than wet season samples (Figure 15). The variability within each season, as measured by the deviation of samples from their centroid (i.e. centre of each sampling group in ordination space), was significantly lower during the dry season (PERMDISP; f = 13.52, df1 = 1, df2 = 21; p = 0.003; Figure 16).



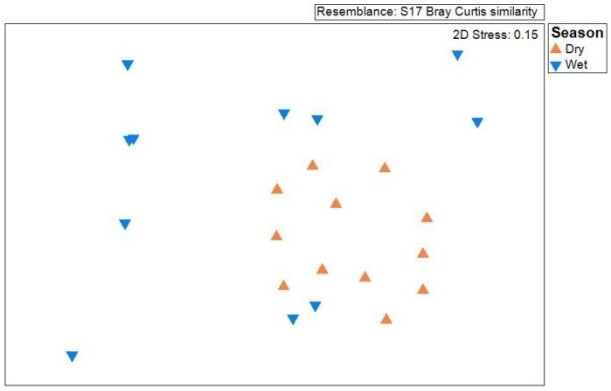




**Figure 15.** MDS ordination of microinvertebrate $\log_{10}$ abundance data with MAR1-6 removed from analyses, showing samples identified by reach (top left), season (top right), and reach-season (left). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.15.

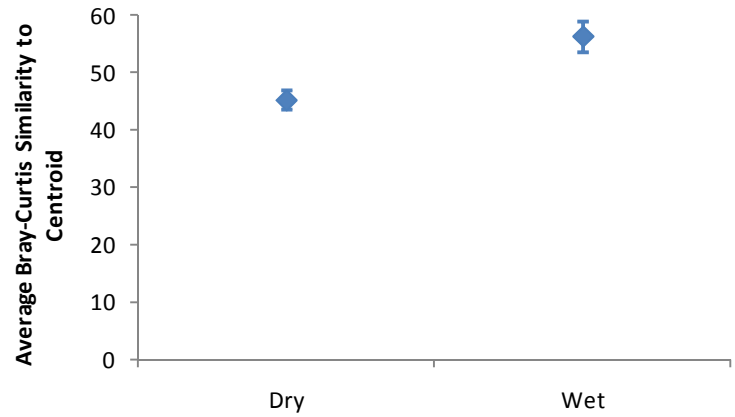



**Figure 16.** Average Bray-Curtis similarities to centroids (±se) for each season, using Marillana Creek microinvertebrate abundance data.

### 3.2.3 Comparison of microinvertebrate assemblages with Weeli Wolli Creek

The multivariate ordination incorporating all microinvertebrate abundance data recorded from Weeli Wolli and Marillana creeks during October 2008 and May 2009, showed no clear patterns (Figure 17). There was no significant separation between system (One-way ANOSIM; sample statistic = -0.07; significance level of sample statistic p = 0.969; Figure 17), indicating that the microinvertebrate assemblages of Marillana Creek were generally similar to those from Weeli Wolli Creek in October 2008 and May 2009. Season groups were also found to be barely separable (Two-way Crossed ANOSIM; sample statistic = 0.25; significance level of sample statistic p = 0.0001; Figure 17). Overall, differences in microinvertebrate assemblages between reach were also barely separable (Two-way

Crossed ANOSIM; sample statistic = 0.18; significance level of sample statistic p = 0.0001). The greatest similarity (i.e. lowest R-value and no significant difference) was between Marillana reaches One and Two (Table 8). The greatest separation of microinvertebrate assemblages was between Weeli Wolli Reach One and Marillana Reach Two (Table 8).

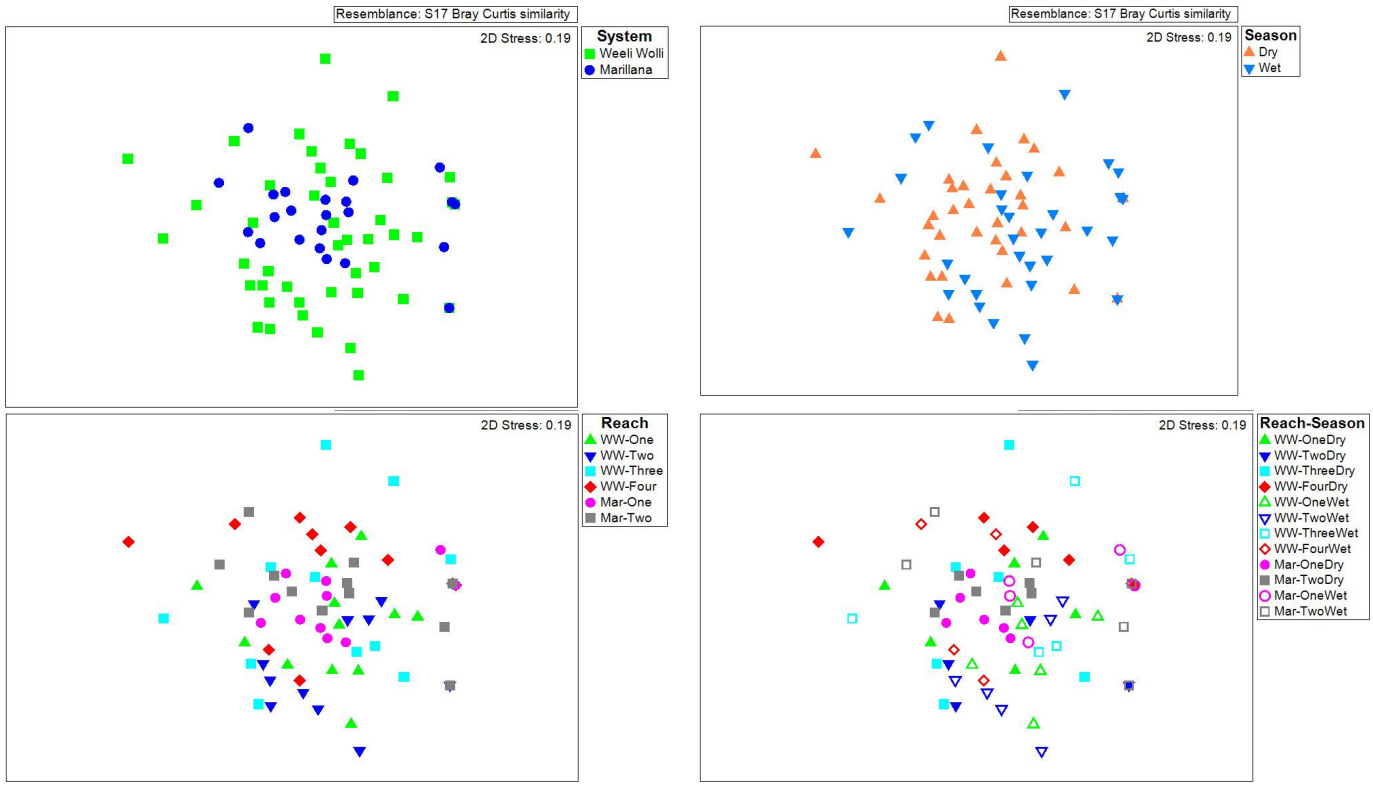



**Figure 17.** MDS ordination of microinvertebrate log10 abundance data from Weeli Wolli Creek and Marillana Creek, showing samples identified by system (top left), season (top right), reach (bottom left), and reach-season (bottom right). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.19.

**Table 8.** Pair-wise ANOSIM results of microinvertebrate $log_{10}$ abundance data amongst reach, showing R-values (sample statistic)[11], * = groups significantly different.

| | *WW One* | *WW Two* | *WW Three* | *WW Four* | *MAR One* |
|---|---|---|---|---|---|
| **WW One** | | | | | |
| **WW Two** | 0.16 | | | | |
| **WW Three** | 0.20* | 0.14 | | | |
| **WW Four** | 0.22* | 0.19* | 0.15* | | |
| **MAR One** | 0.23* | 0.23* | 0.07 | 0.20* | |
| **MAR Two** | 0.37* | 0.32* | 0.11 | 0.18* | 0.02 |

[11] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barley separable.

## 3.3 Hyporheic fauna

### 3.3.1 Taxonomic composition and species richness

A total of 22 taxa were recorded from hyporheic samples collected along Marillana Creek in October 2008, and 58 taxa were recorded in May 2009 (Appendix 5). Of the taxa recorded in the dry season of October 2008, the vast majority were classified as stygoxene (72%) and do not have specialised adaptations for groundwater habitats. However, 5% of the taxa were classified as occasional hyporheos stygophiles, 5% were stygobites[12], and 9% were possible hyporheic taxa. There were no taxa classified as permanent hyporheic stygophiles, and 9% were unknown due to insufficient taxonomy and/or information (Figure 18). Of the taxa recorded during the wet season, most were stygoxene taxa (81%), with 9% being considered hyporheos fauna[13] (5% occasional hyporheos stygophiles, 2% stygobites, and 2% possible hyporheic taxa) (Figure 18). Classifications followed those by Boulton (2001), however, this type of analysis should be treated with some caution as results are likely affected by available information on life history, taxonomic resolution, and interpretation of classification categories.

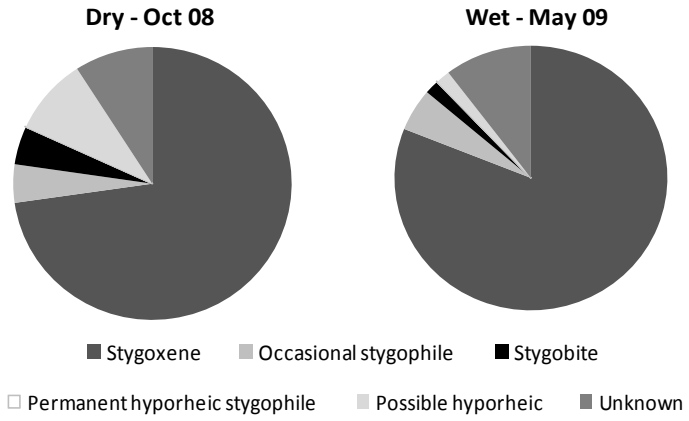



**Figure 18.** Proportion of species from each hyporheic classification category, showing data collected in Oct-08 (left) and May-09 (right).

The results from this study are similar to those reported previously in the Pilbara (Halse *et al.* 2002, WRM 2009a, WRM 2010), in that <20% of taxa collected in hyporheic habitats were entirely dependent on groundwater for their persistence as a species. Halse *et al*. (2002) suggested that it is not surprising that the hyporheos is dominated by species with some affinity for surface water, because the hyporheos is an "ecotone between productive, species-rich surface water systems and nutrient-poor groundwater systems with lower number of species per sampling unit".

Hyporheos fauna were recorded from both reaches of Marillana Creek during both seasons (Figure 19). The greatest number of occurrences of hyporheos taxa was recorded from Reach Two in the wet season of May 2009, and the least from Reach One during the dry of October 2008 (Figure 19).

[12] A stygobite is an aquatic animal that is restricted to groundwater and/or hyporheic environments (i.e. stygofauna). They have adaptations to survive such conditions, including elongated appendages and antennas, no eyes, and a lack of pigmentation. There are likely to be a greater percentage of stygobites at Weeli Wolli than reported here because genetic studies have so far determined that at least four species of stygal amphipod occur along Weeli Wolli and Marillana creeks.

[13] Hyporheos fauna – animals restricted to hyporheic environments.

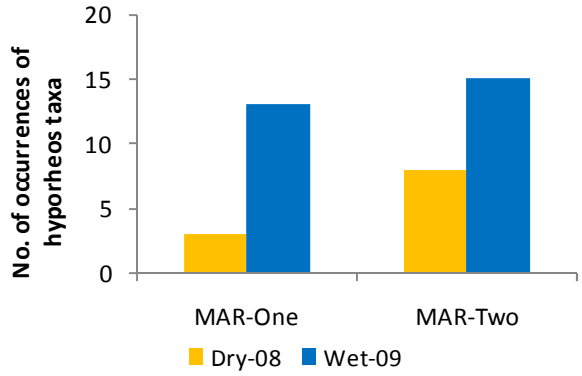



**Figure 19.** Number of occurrences of taxa considered hyporheos recorded from each reach along Marillana Creek during the dry 2008 and May 2009.

### 3.3.2 Hyporheos taxa

Species considered to be restricted to the hyporheos were the stygobitic amphipod ?*Chydaekata* sp., possible hyporheos species Oligochaeta spp. and *Diacyclops* sp. (copepodites), and the occasional stygophiles Baetidae Genus 1 WA sp.1 (mayfly larvae), *Limbodessus occidentalis* and Dytiscidae spp. larvae (Appendix 5).

The stygobitic amphipods collected from hyporheic samples were recorded as ?*Chydaekata* sp. because preliminary results from genetic analysis suggest that at least two species of stygal amphipod occur at Marillana Creek, including *Chydaekata* sp. and species D-Mar (Dr Terrie Finston, UWA, pers. comm.). The *Chydaekata* sp. seem to be the most abundant species along the creek, and are currently known from multiple bores in Marillana and Weeli Wolli creeks. Other species of *Chydaekata*, whose distributions are restricted to distinct tributaries, are known from Ethel Creek, Spearhole Creek, Tuccamunna Creek, and Roy Hill (Finston *et al.* 2007). Species D is currently undescribed, but it has been recorded previously from Marillana Creek and Weeli Wolli Creek (Dr Terrie Finston, UWA, pers. comm.; our WW WRM report 2010). No morphological data exist for Species D so genetic analysis is currently the only means of distinguishing this species. Stygal amphipods were recorded from both reaches along Marillana Creek during the current study (see Appendix 5) and were also abundant along all reaches of Weeli Wolli Creek (WRM 2010).

Of the copepod species collected from hyporheic samples, at least one was considered a possible hyporheic species, the Cyclopodidae *Diacyclops* sp. (copepodites). These copepodites were too small (juvenile) to identify accurately, but may have been *Diacyclops humphreysi* which was recently recorded from hyporheic samples of Weeli Wolli Creek (WRM 2010). This species is relatively common and widespread throughout Western Australia (Karanovic 2006). In the Pilbara, it has been recorded from the Marandoo[14] area (Biota 2008), Barrow Island (Biota 2005), the coastal side of the North-West Coastal Highway between the Fortescue River and Dampier (Bennelongia 2007), Cape Preston

[14] *D. humphreysi* was recorded from bores within the Marandoo area by Biota (2008). This species was also recorded from the Marandoo area during the DEC Pilbara Biological Survey from Warp2 (May 2004) and Tom Price North (July 2003) (Biota 2008).

(Bennelongia 2008) and the Pardoo area, approximately 70 km east of Port Hedland (Coffey 2009). Given the likelihood of the *Diacyclops* sp. (copepodites) collected during the current study being juvenile *D. humphreysi*, they were considered possible hyporheic taxa. *Diacyclops* sp. (copepodites) were recorded from MAR1-4 during the dry season (see Appendix 5).

Other taxa considered possible hyporheics were the Oligochaeta spp. In the past, Oligochaeta from hyporheic samples taken from Weeli Wolli Creek were formally identified by Dr Adrian Pinder (DEC), with at least five species considered to be occasional stygophiles (WRM 2009a). Oligochaetes were not able to be definitively identified, but were considered possible hyporheic species given the presence of occasional stygophiles from the adjacent Weeli Wolli Creek.

The occasional stygophile Baetidae Genus 1 WA sp.1 was collected from benthos (surface water macroinvertebrate samples) and hyporheos during the current study. This species is known to be common in surface waters and hyporheic habitats of Weeli Wolli Creek (Halse *et al*. 2002, WRM 2009a, WRM 2010). It occurs widely across north-western Australia (Suter 1997). Baetidae Genus 1 WA sp.1 were collected from hyporheic samples from sites MAR2-1, MAR-2-5 and MAR2-6 (see Appendix 5).

The dytiscid beetle *Limbodessus occidentalis*[15] recorded from MAR-One (1-3) during the wet season is also an occasional hyporheos stygophile. This species is known from both epigean and stygal habitats. It has been recorded from calcrete aquifers while sampling bores at Moorarie and Killara North, but is most commonly recorded from the edge of pools in sandy riverbeds and interstitially to at least two meters from the water's edge in an upstream direction (Watts and Humphreys 2004). This species has been previously recorded from interstitial samples taken from Weeli Wolli in September 2003 during surveys conducted by the DEC (Adrian Pinder, DEC, unpub. data) and more recently during the Living Water Study undertaken by the authors (WRM 2009a).

[15] Previously known as *Boongurrus occidentalis* sp. nov. (Watts and Humphreys 2004). The genus *Boongurrus* has since been synomised with *Limbodessus* (Balke and Ribera 2004).

## 3.4 Macroinvertebrates

### 3.4.1 Taxonomic composition and species richness

A total of 115 taxa of macroinvertebrates were recorded from the 12 riffle habitat sites along Marillana Creek during October 2008 and May 2009 (Table 9 and Appendix 6). Of these, 104 were recorded in October (dry) and 68 were recorded in May (wet) (Table 9 and Appendix 6). The macroinvertebrate fauna included Cnidaria (freshwater hydra), Mollusca (freshwater snails), Oligochaeta (aquatic segmented worms), Crustacea (side swimmers), Acarina (water mites), Ephemeroptera (mayfly larvae), Odonata (dragonfly and damselfly larvae), Hemiptera (true aquatic bugs), Coleoptera (aquatic beetles), Diptera (two-winged fly larvae), Trichoptera (caddisfly larvae), and Lepidoptera (aquatic moth larvae).

**Table 9.** Composition of macroinvertebrates recorded from Marillana Creek in October 08 (dry season) and May 09 (wet).

| *Macroinvertebrates* | *No. of taxa* | |
|---|---|---|
| | Oct-08 | May-09 |
| Cnidaria (freshwater hydra) | 1 | 0 |
| Mollusca (snails & bivalves) | 3 | 2 |
| Oligochaeta (aquatic worms) | 1+ | 1+ |
| Crustacea (side swimmers) | 0 | 1+ |
| Acarina (water mites) | 2+ | 2+ |
| Ephemeroptera (mayflies) | 5 | 3 |
| Odonata (dragonflies & damselflies) | 6 | 6 |
| Hemiptera (true bugs) | 13 | 3 |
| Coleoptera (aquatic beetles) | 19 | 12 |
| Diptera (two-winged flies) | 40 | 28 |
| Trichoptera (caddis-flies) | 11 | 7 |
| Lepidoptera (moths) | 3 | 3 |
| **Total number of taxa** | **104** | **68** |

The taxonomic listing includes records of larval and pupal stages for groups such as Diptera and Coleoptera. Current taxonomy is not sufficiently developed to allow identification of larval and pupal stages of all members of these groups to species level. In many instances, it is likely that these stages are the same species as the larval/adult stages recorded from the same location. However, because this could not be definitively determined, they were treated as separate taxa. In any case, different life stages often have different functional roles in the ecosystem and therefore it makes sense to treat them as separate taxa.

Taxa richness varied between reach and season. During the dry season of October 2008, the greatest number of macroinvertebrate taxa was recorded from MAR2-5 and MAR2-6 (55 taxa), and the least from MAR2-2 (32 taxa). During the wet, the greatest number of taxa was again collected from MAR2-6 (33 taxa), and the least from MAR1-1 (23 taxa) (Figure 20 and Appendix 6). More macroinvertebrate taxa were recorded during the dry season (Figures 20 and 21).

Using macroinvertebrate data from Weeli Wolli Creek in the analysis, there was a significant difference in the average number of macroinvertebrate taxa between reach (Two-way ANOVA; df = 5, p= 0.002) and season (Two-way ANOVA; df = 1, p= 0.000; see Table 10 and Figure 21). There was also a significant interaction between the wet and dry seasons for WW Reach Two, and between seasons for Marillana Reach Two (Figure 21). Significantly lower taxa richness was recorded from WW Reach Two[16] compared with all other reaches on Weeli Wolli and Marillana Creek (Table 10 and Figure 21). Across all reaches in Weeli Wolli and Marillana Creek, macroinvertebrate taxa richness was significantly greater in the dry season (Table 10 and Figure 21).

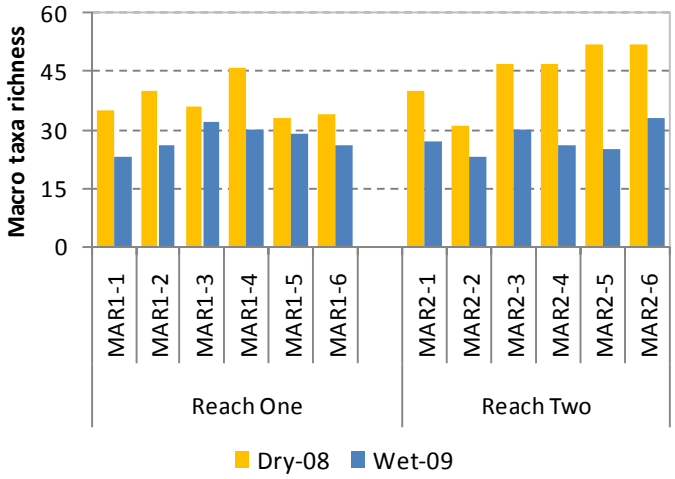



**Figure 20**. Macroinvertebrate taxa richness recorded from each site along Marillana Creek during both seasons.

**Table 10.** Two-way ANOVA results for macroinvertebrate taxa richness by reach and season (including Weeli Wolli data), showing degrees of freedom, f-value and p-value. Tukeys post-hoc results are presented in ascending order of mean taxa richness, with groups of no difference in means joined by a black line.

| *Source* | *df* | *F* | p | Tukeys post-hoc | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | WW 2 | MAR 1 | WW 3 | MAR 2 | WW 4 | WW 1 |
| **Reach** | 5 | 4.27 | 0.002 | | | | | | |
| **Season** | 1 | 31.05 | 0.000 | | | | | | |
| **Reach*Season** | 5 | 2.38 | 0.049 | | | | | | |
| **Total** | 71 | | | | | | | | |

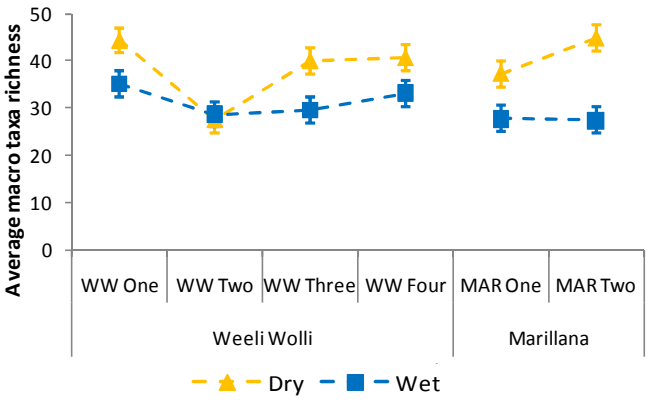



**Figure 21.** Average macroinvertebrate taxa richness (±se) from all reaches (including those along Weeli Wolli Creek) showing data for both the dry (October 2008) and wet season (May 2009).

[16] Weeli Wolli Reach Two is the reach immediately below the gabion and is likely impacted by greatly increased flows which will likely adversely affect species preferring low flows/low velocity

### 3.4.2 Conservation significance of macroinvertebrates

While the majority of taxa collected during October 2008 and May 2009 were common, ubiquitous species with distributions extending across Northern Australia (4%), Australasia (23%), and the world (cosmopolitan species; 5%), a number of taxa were endemic to Western Australia (1%) or, more specifically, the Pilbara region of Western Australia (3%). Taxa endemic to Western Australia included the mayfly Baetidae Genus 1 WA sp1 and the dragonfly *Austrogomphus gordoni*. Taxa with distributions restricted to the Pilbara region of Western Australia included the stygal amphipod *Chydaekata* sp., the dragonfly *Nannophlebia injabandi*, and the hydrophilid beetle *Laccobius billi*. Over 64% of macroinvertebrate taxa were classified as indeterminate, due to insufficient taxonomy/knowledge.

Indeterminate taxa made up the greatest proportion of taxa from each reach during each season (Figure 22). This was generally followed by Australasian taxa, with distributions across Australia and the south-east Asian region, and then cosmopolitan or Northern Australian species (Figure 22). A greater proportion of taxa endemic to the Pilbara were recorded from Marillana Creek during the wet season (Figure 22). No Western Australian endemic taxa were recorded from either reach during the dry season.

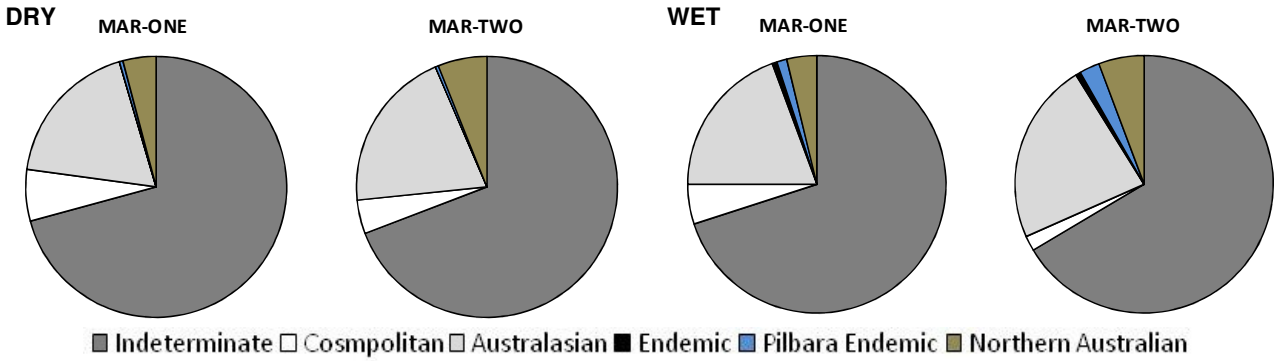



**Figure 22.** Proportions of species from each conservation category recorded from both reaches during the October 2008 dry season (left) and the May 2009 wet season (right).

### 3.4.3 Patterns in macroinvertebrate assemblage structure

The macroinvertebrate abundance ordination showed some clear patterns (Figure 23). In a similar manner to the water quality data, there was a distinct seasonal effect, with samples taken during the dry season separating from those taken during the wet (Figure 23). This was found to be significant (Two-way crossed ANOSIM; sample statistic = 0.54; significance of sample statistic p = 0.0001). While there did appear to be some separation of samples based on reach, there was also some overlap (Figure 23). Further analysis revealed that while macroinvertebrate assemblages were significantly separate between reach, the groups were barely separable[17] (Two-way crossed ANOSIM; sample statistic = 0.11; significance of sample statistic p = 0.0001). This is likely due to the large variability evident

[17] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barely separable.

within reaches, as well as similarities between reaches, represented as overlap in ordination space (Figure 23).

Water quality variables found to be contributing to patterns within the macroinvertebrate ordination of Marillana Creek were dissolved oxygen, chloride, sodium, log total phosphorus and sulphate (BIOENV; Rho =0.56, significance of sample statistic p = 0.01). Sodium concentrations were lower from Reach Two during the wet, sulphate was higher during the dry season, and log total phosphorus was higher during the wet (Figure 24).

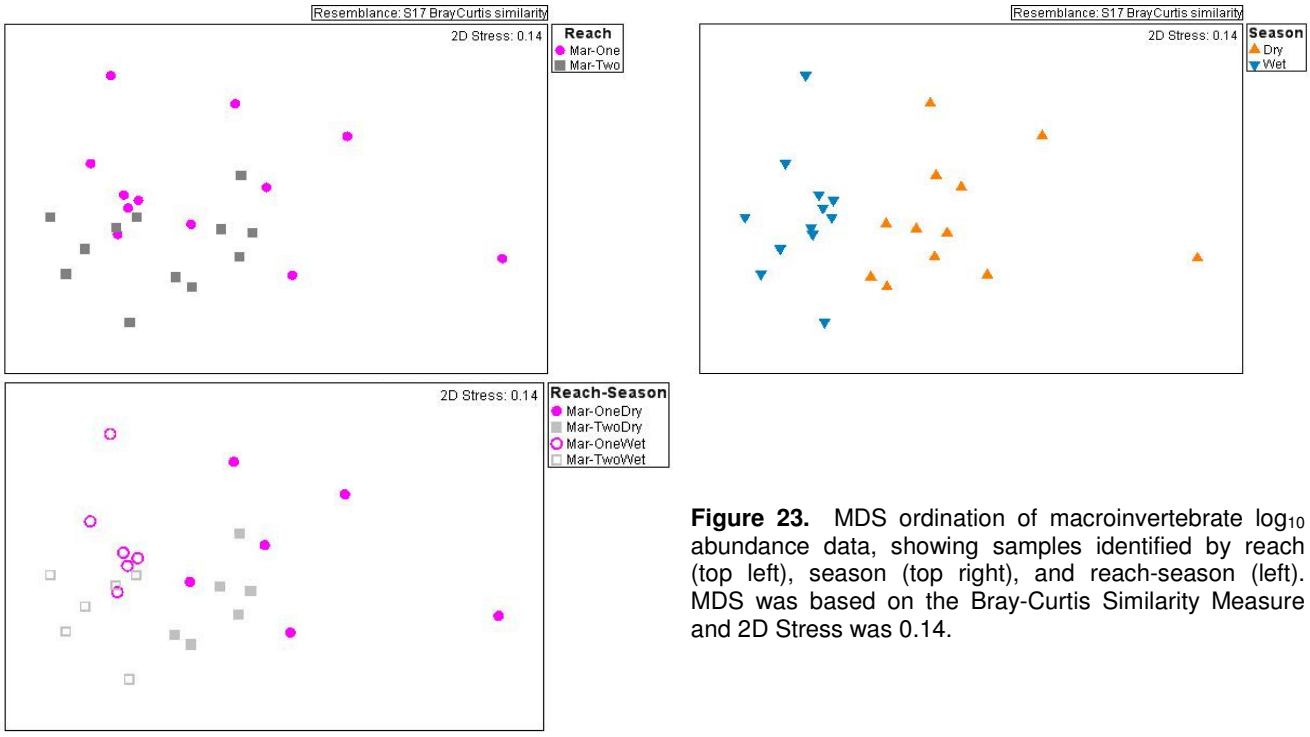



**Figure 23.** MDS ordination of macroinvertebrate $log_{10}$ abundance data, showing samples identified by reach (top left), season (top right), and reach-season (left). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.14.

### 3.4.4 Comparison of macroinvertebrate assemblages with Weeli Wolli Creek

Analyses were also completed using all macroinvertebrate $log_{10}$ abundance data recorded from Weeli Wolli Creek and Marillana Creek during October 2008 (dry season) and May 2009 (wet). Groupings within the macroinvertebrate ordination incorporating all data were less clear than within the water quality ordination (Figures 8 & 25). Firstly, there was no separation between systems (One-way ANOSIM; sample statistic = 0.01, significance of sample statistic p = 0.38), suggesting that on a broad scale the macroinvertebrate assemblages of Marillana Creek were similar to those from Weeli Wolli Creek in October 2008 and May 2009 (Figure 25). The consistent seasonal trend, however, was evident within the macroinvertebrate assemblages of Weeli Wolli and Marillana creeks, with a significant separation between seasons being found (Figure 25; Two-way crossed ANOSIM; sample statistic = 0.46, significance of sample statistic p = 0.0001). Overall, macroinvertebrate assemblages were also significantly separate amongst reaches, but some reaches were barely separable and recorded low R-values (Figure 25 & Table 11; Two-way crossed ANOSIM; sample statistic = 0.29, significance of sample statistic p = 0.0001). The greatest separation was between WW-Two and both Marillana Creek reaches (MAR-One, R=0.52; and MAR-Two, R=0.49; Table 11). There was considerable overlap in the

macroinvertebrate assemblages between a number of reaches, suggesting these reaches had similar faunal assemblages (Figure 25). The greatest similarity (i.e. lowest R-value) was between both Marillana reaches (R=0.11; Table 11). These reaches were also similar to the downstream Weeli Wolli reach, WW-Four (Table 11).

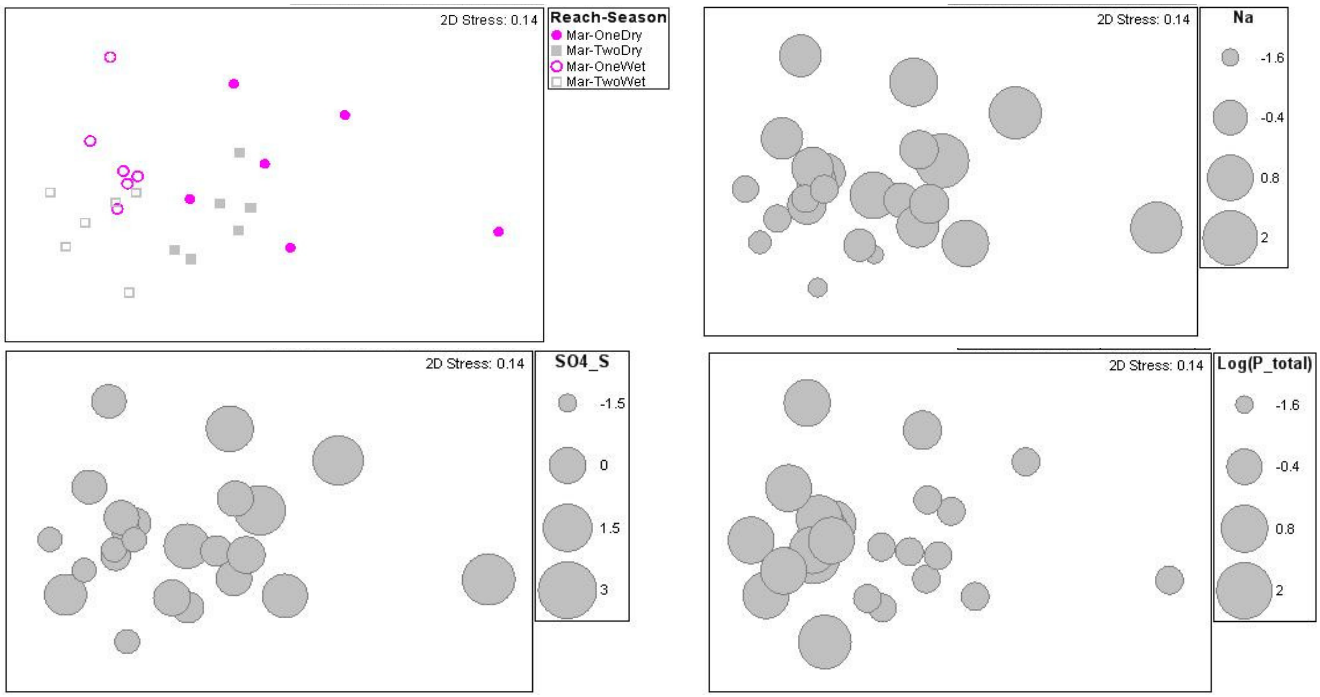



**Figure 24.** Bubble plots of water quality variables influencing the macroinvertebrate ordination, including sodium, sulphate and log total phosphorus.

**Table 11.** Pair-wise ANOSIM results of macroinvertebrate $log_{10}$ abundance data amongst reach, showing R-values (sample statistic)[18], * = groups significantly different.

| | *WW One* | *WW Two* | *WW Three* | *WW Four* | *MAR One* |
|---|---|---|---|---|---|
| **WW One** | | | | | |
| **WW Two** | 0.40* | | | | |
| **WW Three** | 0.47* | 0.21* | | | |
| **WW Four** | 0.24* | 0.38* | 0.18* | | |
| **MAR One** | 0.26* | 0.52* | 0..34* | 0.15* | |
| **MAR Two** | 0.41* | 0.49* | 0.31* | 0.14* | 0.11* |

[18] Sample statistic - R>0.75 = well separated groups, R>0.5 = groups overlapping but clearly different, and R>0.25 = groups barley separable.

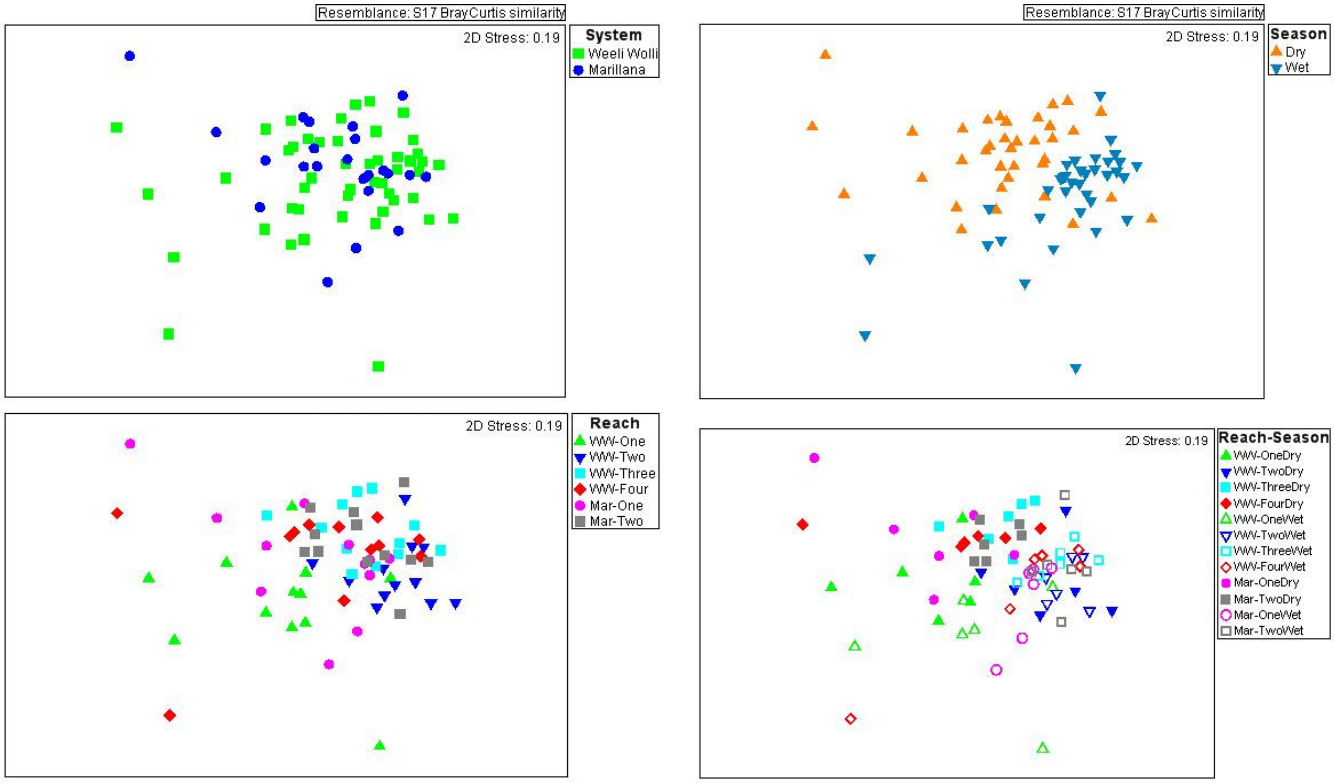



**Figure 25.** MDS ordination of macroinvertebrate log10 abundance data from Weeli Wolli Creek and Marillana Creek, showing samples identified by system (top left), season (top right), reach (bottom left), and reach-season (bottom right). MDS was based on the Bray-Curtis Similarity Measure and 2D Stress was 0.19.

## 3.5 Fish

### 3.5.1 Species richness

The fish fauna of the Pilbara is characterised by low species diversity but high levels of endemicity, with over 42% of species recorded restricted to the region (Unmack 2001, Allen *et al.* 2002). Masini (1988) found the relatively clear waters of permanent and semi-permanent waterbodies supported the best developed fish assemblages in the region. In a study of the biogeography of Australian fish fauna, Unmack (2001) recognised ten distinct freshwater fish biogeographic provinces, of which the Pilbara Province was one. This region was considered distinct because its fauna did not cluster with other drainages in multivariate (parsimony and UPGMA) analysis of fish distribution patterns (Unmack 2001).

Three of the eleven freshwater fish species known from the Fortescue River were recorded from Marillana Creek during October 2008 and May 2009. These were the spangled perch *Leiopotherapon unicolor*, Hyrtl's tandan (eel-tailed catfish) *Neosiluris hyrtlii*[19] (Plate 3), and western rainbowfish *Melanotaenia australis.* All species were collected from both reaches in each season (Table 11). These three fish were also the only species collected from Marillana Creek during previous regional surveys (WRM 2009b), and are the only species known from Weeli Wolli Creek (Streamtec 2004, WRM 2009a, 2010).

**Plate 3.** Hyrtl's tandan catfish, *Neosiluris hyrtlii* (photo taken and provided by Mark Allen ©.

### 3.5.2 Abundance

A total of 1008 freshwater fish were collected from Marillana Creek during the October 2008 surveys, and 1149 during May 2009 (Table 12). Western rainbowfish were the most abundant species collected from both reaches during both seasons (Table 12). A greater abundance of fish was recorded from the downstream reach (Reach Two).

**Table 12.** Total number of fish caught from Marillana Creek during the dry (Oct-08) and wet seasons (May-09).

| ***October 2008*** | | | | |
|---|---|---|---|---|
| | ***Rainbowfish*** | ***Perch*** | ***Catfish*** | ***Total*** |
| **Reach 1** | 360 | 12 | 4 | 376 |
| **Reach 2** | 526 | 16 | 90 | 632 |
| **Total** | **886** | **28** | **94** | **1008** |
| ***May 2009*** | | | | |
| | ***Rainbowfish*** | ***Perch*** | ***Catfish*** | ***Total*** |
| **Reach 1** | 494 | 14 | 19 | 527 |
| **Reach 2** | 511 | 55 | 56 | 622 |
| **Total** | **1005** | **69** | **75** | **1149** |

[19] Taxonomy of *N hyrtlii* in the Pilbara is currently under revision as genetic analysis suggests it is a different species from *N. hyrtlii* in the Kimberley and eastern Australia. Therefore, the name for this species may change in the future.

### 3.5.3 Length-frequency analysis

Breeding characteristics of fish species in the Pilbara, such as fecundity and the size at first maturity, vary between river systems and rainfall zone. Beesley (2006) found life history strategies of fish species in the Fortescue River lay between 'opportunistic' and 'periodic', reflecting the seasonal yet unpredictable nature of rainfall in the region.

**Western rainbowfish**

Breeding in western rainbowfish (*Melanotaenia australis*) occurs throughout the year, with multiple spawning bouts which take full advantage of the regions intermittent rainfall and streamflow (Beesley 2006). Morgan *et al.* (2002) captured small juveniles on most sampling occasions in the Fitzroy River. The size at first maturity varies between river systems, but western rainbowfish generally attain a maximum size of 110 mm TL[20] (Morgan *et al.* 2002).

Length-frequency plots of western rainbowfish from Marillana Creek show that individuals of all age-classes were present in the population, from juveniles and sub-adults to large adults (Figure 26). This suggests successful breeding and recruitment. A greater proportion of new recruits (< 30 mm SL[21]) were collected from both reaches during May 2009 following wet season rains (MAR-One = 38%; MAR-Two = 27%), than during the dry (MAR-One = 19%; MAR-Two = 11%; Figure 26). The majority of new recruits were recorded from the upper reach (MAR-One; Figure 26).

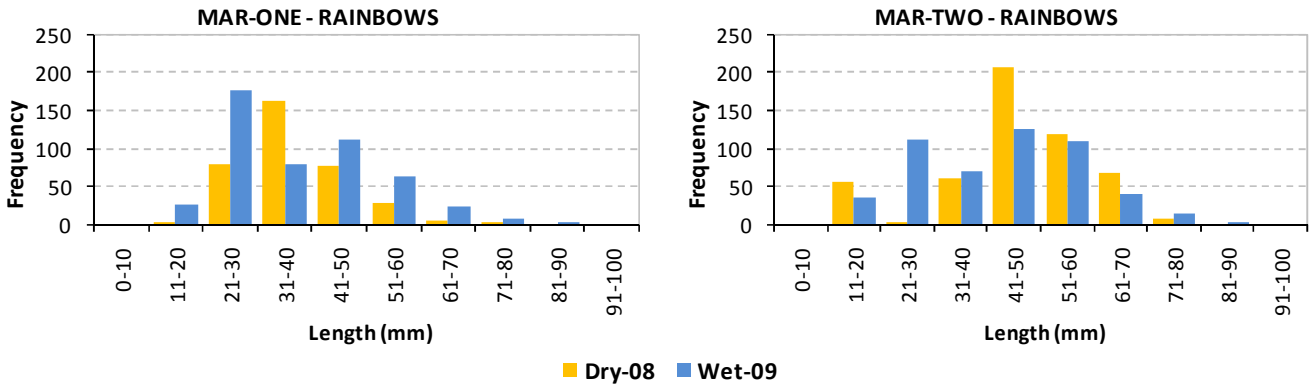



**Figure 26.** Length-frequency histograms for western rainbowfish collected from MAR-One (left) and MAR-Two (right) during the dry-08 and wet-09.

**Hyrtl's tandan catfish**

Very little is known of the breeding ecology of Hyrtl's tandan (*Neosiluris hyrtlii*). It is thought that individuals may mature in their first year at a size of approximately 135 mm TL for both sexes (Lake 1971, Bishop *et al.* 2001). Species of *Neosilurus* catfish usually attain a maximum size of only 200 mm however, *N. hyrtlii*, along with *N. ater*, can reach up to 400 mm TL (Lake 1971, Bishop *et al.* 2001). Breeding is thought to occur in the early wet season (Morgan *et al.* 2002, Bishop *et al.* 2001). It is at this time when initial flooding increases the

[20] TL = total length, measured from the tip of the snout to the tip of the longer lobe of the caudal fin.

[21] SL = standard length, measured from the tip of the snout to the posterior end of the last vertebra or to the posterior end of the midlateral portion of the hypural plate (i.e. this measurement excludes the length of the caudal fin). Standard length was measured in the current study.

area and diversity of aquatic habitat available, while also initiating increases in plankton and other foods (Bishop *et al.* 2001).

The greatest number of smaller Hyrtl's catfish (<70 mm SL) was recorded from the lower reach (MAR-Two) during the dry season (Figure 27). Few catfish were collected from MAR-One in either season, but those that were would be considered sub-adults to adults (Figure 27). Catfish of all age-classes were recorded from MAR-Two, including few juveniles, sub-adults, adults, and a number of larger sized adults (>150 mm SL; Figure 27).

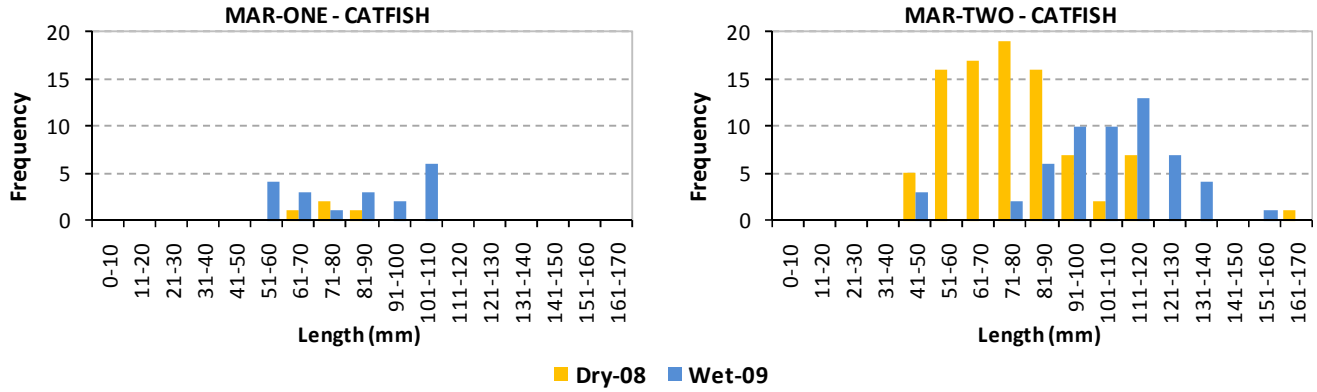



**Figure 27.** Length-frequency histograms for Hyrtl's tandan catfish collected from MAR-One (left) and MAR-Two (right) during the dry-08 and wet-09.

**Spangled perch**

Breeding in spangled perch (*Leiopotherapon unicolor*) of the Pilbara occurs during the summer wet season, between late November and March (Beesley 2006, Morgan *et al*. 2002). During this time, multiple spawning events are known to occur (Beesley 2006). In the Fitzroy River, Morgan *et al.* (2002) collected mature specimens in summer and larvae at the end of the wet season, indicating that spawning coincided with the flooding of the river. Spangled perch mature in their first year at approx. 58 mm TL for males and 78 mm TL for females. They reach a maximum size of 300 mm TL.

Length-frequency analysis of spangled perch captured from Marillana Creek showed that no juveniles (< 50 mm) were caught (Figure 28). This perhaps reflects the secretive nature of this species and its ability to quickly evade capture by hiding in snags and other cover. Further sampling of the creek should locate juveniles should they be present. Although adults (> 70 mm) were collected from both reaches during both seasons, no larger individuals were captured at the maximum size range (between 200 mm and 310 mm). The greatest number of spangled perch were recorded during the wet season at MAR-Two, and these were mostly adults, with only a few sub-adults recorded (50-70 mm SL; Figure 28).

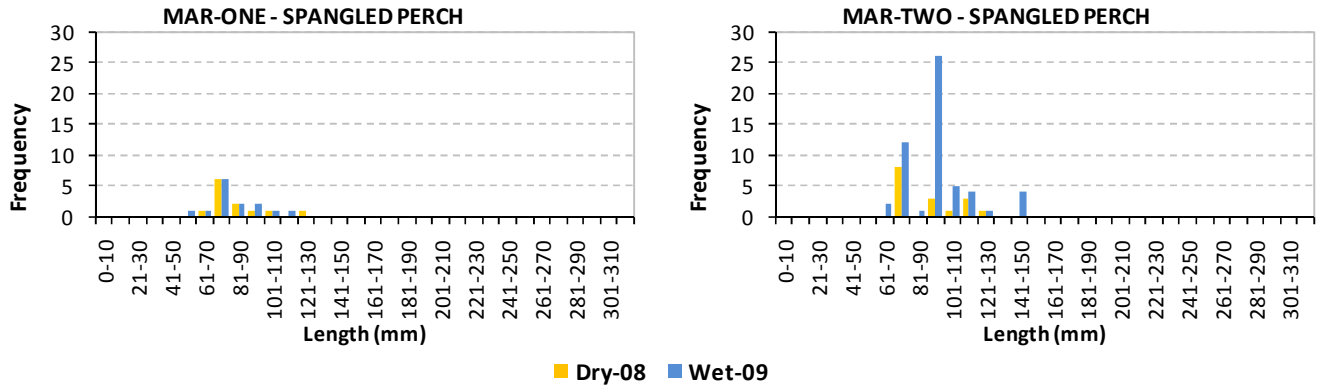



**Figure 28.** Length-frequency histograms for spangled perch collected from MAR-One (left) and MAR-Two (right) during the dry-08 and wet-09.

# 4 CONCLUSIONS

## 4.1 Water quality

The main water quality findings were:

- Super-saturated DO levels (>100%) were recorded from a number of sites along the creek in both seasons. These sites likely become anoxic overnight as respiration by plants, algae and fauna deplete DO. Super-saturated DO can also lead to fish bubble disease. One site in particular, MAR2-4 in October 2008, recorded exceptionally high DO levels (180%).
- Circum-neutral to slightly basic pH characteristic of Marillana Creek is not uncommon from similar waterbodies in the East Pilbara Region of W.A.
- All sites were fresh
- The high alkalinity levels recorded from all sites indicate that the buffering capacity of the waters of Marillana Creek is high
- The composition of major ions along Marillana Creek was typically dominated by sodium and hydrogen bicarbonate. This was similar to that reported from the lower end of Weeli Wolli Creek, downstream of the confluence with Marillana Creek
- Total nitrogen levels exceeded ANZECC/ARMCANZ (2000) guidelines at MAR2-1 and MAR2-2 in the dry season, and most sites during the wet. Total nitrogen levels were significantly higher from Reach Two. The cause of the elevated total nitrogen levels from the downstream Marillana reach is unknown, but may be coming from any number of potential sources, including pastoral activities and cattle stocking, local geology (i.e. soils or bedrock), and/or influence from Yandi discharge water and mining operations (see section 3.1.1). Potential sources for the increased total nitrogen from MAR-Two need to be investigated further before any conclusions can be drawn.
- Multivariate analyses showed that water quality was significantly different between reach and season. Dry season samples from Marillana Reach One formed the tightest group in the ordination, suggesting that samples within this group were most similar to each other, than any other group
- Using all water quality data collected from Weeli Wolli and Marillana Creek in October 2008 and May 2009, water quality was found to be significantly different between systems. Water quality was also significantly different amongst reach and season. During the dry season, Marillana Creek samples from both reaches grouped with Weeli Wolli Reach Four samples. This suggests that during the dry season, the water quality of Marillana Creek was similar to that recorded from the downstream Weeli Wolli reach (WW Reach Four). It appears that water quality of the downstream reach of Weeli Wolli Creek is influenced by Marillana Creek. During the wet season, WW-Four formed its own group, separate from Marillana Creek sites.

## 4.2 Microinvertebrates

The main microinvertebrate findings were:

- A total of 59 microinvertebrate taxa were recorded; 45 in October 2008 and 41 in May 2009

- The microinvertebrate fauna were typical of tropical systems reported elsewhere, with Branchionidae (Rotifera) being poorly represented, Lecanidae dominating the Rotifera, and the replacement of Daphniidae (Cladocera) with Chydoridae (Cladocera)
- Microinvertebrate taxa richness varied greatly between reach and season
- Using microinvertebrate data from Weeli Wolli Creek in the analysis, there was no significant difference in the average number of taxa between reach. There was, however, a significant difference between season , with a greater number of taxa being recorded in the dry season
- Multivariate analyses showed no significant difference in microinvertebrate assemblages between reach. While there did appear to be some separation of samples between season, groups were found to be barely separable. Dry season samples were significantly less variable than wet season samples
- The multivariate ordination incorporating all microinvertebrate abundance data recorded from Weeli Wolli and Marillana creeks during October 2008 and May 2009, showed no clear patterns. There was no significant separation between system, reach or season. The greatest similarity (i.e. lowest R-value and no significant difference) was between Marillana reaches One and Two. The greatest separation of microinvertebrate assemblages was between Weeli Wolli Reach One and Marillana Reach Two.

## 4.3 Hyporheic fauna

The main hyporheic fauna findings were:

- During the dry season, the vast majority of taxa collected in hyporheic samples were classified as stygoxene (72%) and do not have specialised adaptations for groundwater habitats. However, 5% of the taxa were classified as occasional hyporheos stygophiles, 5% were stygobites, and 9% were possible hyporheic taxa
- During the wet season, most taxa were stygoxene(81%), with 9% being considered hyporheos fauna (5% occasional hyporheos stygophiles, 2% stygobites, and 2% possible hyporheic taxa)
- Results from this study are similar to those reported previously in the Pilbara (Halse *et al.* 2002, WRM 2010), in that <20% of taxa collected in hyporheic habitats were entirely dependent on groundwater for their persistence as a species
- Hyporheos fauna were recorded from both reaches of Marillana Creek during both seasons. The greatest number of occurrences of hyporheos taxa was recorded from Reach Two in the wet season of May 2009, and the least from Reach One during the dry of October 2008
- Species considered to be restricted to the hyporheos were the stygobitic amphipod ?*Chydaekata* sp., possible hyporheos species Oligochaeta spp. and *Diacyclops* sp. (copepodites), and the occasional stygophiles Baetidae Genus 1 WA sp.1 (mayfly larvae), *Limbodessus occidentalis* and Dytiscidae spp. Larvae
- stygobitic amphipods collected from hyporheic samples were recorded as ?*Chydaekata* sp. because preliminary results from genetic analysis suggest that at least two species of stygal amphipod occur at Marillana Creek, including *Chydaekata* sp. and species D-Mar (Dr Terrie Finston, UWA, pers. comm.).

## 4.4 Macroinvertebrates

The main macroinvertebrate findings were:

- A total of 115 taxa of macroinvertebrates were recorded from the 12 riffle habitat sites along Marillana Creek during October 2008 and May 2009; 104 were recorded in October and 68 were recorded in May
- Taxa richness varied between reach and season, ranging from 23 taxa (MAR1-1 in the wet) to 55 (MAR 2-5 and MAR2-6 in the dry)
- Using macroinvertebrate data from Weeli Wolli Creek in the analysis, there was a significant difference in the average number of macroinvertebrate taxa between reach. Significantly lower taxa richness was recorded from WW Reach Two compared with all other reaches on Weeli Wolli and Marillana Creek. Across all reaches in Weeli Wolli and Marillana Creek, macroinvertebrate taxa richness was significantly greater in the dry than the wet season.
- The majority of taxa collected during October 2008 and May 2009 were common, ubiquitous species with distributions extending across Northern Australia (4%), Australasia (23%), and the world (cosmopolitan species; 5%). However, of interest was the collection of taxa endemic to Western Australia (1%) or, more specifically, the Pilbara region of Western Australia (3%). Taxa endemic to Western Australia included the mayfly Baetidae Genus 1 WA sp1 and the dragonfly *Austrogomphus gordoni*. Taxa with distributions restricted to the Pilbara region of Western Australia included the stygal amphipod *Chydaekata* sp., the dragonfly *Nannophlebia injabandi*, and the hydrophilid beetle *Laccobius billi*.
- A greater proportion of taxa endemic to the Pilbara were recorded from Marillana Creek during the wet season. No Western Australian endemic taxa were recorded from either reach during the dry season
- Multivariate analyses showed a distinct seasonal effect on macroinvertebrate assemblages of Marillana Creek. While there did appear to be some separation of samples based on reach, there was also some overlap, and analyses found the groups to be barely separable. This is likely due to the large variability evident within reaches, as well as similarities between reaches
- Analyses were also completed using all macroinvertebrate $\log_{10}$ abundance data recorded from Weeli Wolli Creek and Marillana Creek during October 2008 (dry season) and May 2009 (wet). There was no separation between system, indicating that at a broad scale the macroinvertebrate assemblages of Marillana Creek were similar to those from Weeli Wolli Creek in October 2008 and May 2009. The consistent seasonal trend, however, was still evident, with a significant separation between seasons being found. Overall, macroinvertebrate assemblages were also significantly separate amongst reaches, but some reaches were barely separable and recorded low R-values. The greatest separation was between WW-Two and both Marillana Creek reaches. The greatest similarity in macroinvertebrate assemblages was between both Marillana reaches. These reaches were also similar to the most downstream Weeli Wolli reach, WW-Four

## 4.5 Fish

The main fish findings were:

- Three of the eleven freshwater fish species known from the Fortescue River were recorded from Marillana Creek during October 2008 and May 2009; the spangled perch *Leiopotherapon unicolor*, Hyrtl's tandan (eel-tailed catfish) *Neosiluris hyrtlii*, and western rainbowfish *Melanotaenia australis*. These were the only species collected from Marillana Creek during previous regional surveys by the authors and are the only species known from Weeli Wolli Creek system
- A total of 1008 freshwater fish were collected during October 2008 and 1149 during May 2009. Western rainbowfish were the most abundant species collected from both reaches during both seasons. A greater abundance of fish was recorded from the downstream reach (Reach Two).
- Western rainbowfish of all age-classes were present in the population, from juveniles and sub-adults to large adults, suggesting successful breeding and recruitment. A greater proportion of new recruits (< 30 mm SL) were collected from both reaches during May 2009 following wet season rains. The majority of new recruits were recorded from the upper reach
- The greatest number of smaller Hyrtl's catfish (<70 mm SL) was recorded from the lower reach (MAR-Two) during the dry season. Few catfish were collected from MAR-One in either season, but those that were would be considered sub-adults to adults. Catfish of all age-classes were recorded from MAR-Two, including few juveniles, sub-adults, adults, and a number of larger sized adults
- No juvenile spangled perch (< 50 mm) were caught along Marillana Creek during the current study. This perhaps reflects the secretive nature of this species and its ability to quickly evade capture by hiding in snags and other cover. Further sampling of the creek should locate juveniles should they be present. Adults (> 70 mm) were collected from both reaches during both seasons, but no larger individuals were captured at the maximum size range (between 200 mm and 310 mm). The greatest number of spangled perch were recorded during the wet season at MAR-Two, and these were mostly adults, with only a few sub-adults recorded.

# 5 RECOMMENDATIONS

Recommendations for future monitoring include:

1. Continue monitoring in the same manner as documented here to detect any changes that may occur to the ecology of Marillana Creek as a result of increased discharge of dewatering water, and possible adverse conditions which may impact lower Weeli Wolli Creek
2. Future sampling should also include habitat assessments which can be compared with those taken along Weeli Wolli Creek
3. Establish Regional sites in Fortescue Marshes to ensure any cumulative impacts that may occur in the future do not adversely affect the marshes during times of connection
4. Deploy dissolved oxygen loggers for a period of 24 hours in pools with an abundance of algae to determine the extent of overnight DO depletion.

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# APPENDICES

# Appendix 1. Site photographs

For photographs of Weeli Wolli sites see WRM (2010).

## MARILLANA CREEK

## REACH ONE

**DRY 08** **WET 09**

**MAR1-1**

**MAR1-2**

**DRY 08** **WET 09**

**MAR1-3**

**MAR1-4**

**MAR1-5**

**DRY 08** **WET 09**

**MAR1-6**

**REACH TWO**

**DRY 08** **WET 09**

**MAR2-1**

**MAR2-2**

**DRY 08** **WET 09**

**MAR2-3**

**MAR2-4**

**MAR2-5**

**DRY 08**
**MAR2-6**

**WET 09**

# Appendix 2. ANZECC/ARMCANZ (2000) trigger values for the protection of aquatic systems in tropical northern Australia

**Table A2-1.** Default trigger values for some physical and chemical stressors for tropical Australia for slightly disturbed ecosystems (TP = total phosphorus; FRP = filterable reactive phosphorus; TN = total nitrogen; NOx = total nitrates/nitrites; NH4+ = ammonium). Data derived from trigger values supplied by Australian states and territories, for the Northern Territory and regions north of Carnarvon in the west and Rockhampton in the east (ANZECC/ARMCANZ 2000).

| | TP ($\mu g\ L^{-1}$) | FRP ($\mu g\ L^{-1}$) | TN ($\mu g\ L^{-1}$) | NOx ($\mu g\ L^{-1}$) | $NH_4^+$ ($\mu g\ L^{-1}$) | DO % saturation[f] | pH |
|---|---|---|---|---|---|---|---|
| **Aquatic Ecosystem** | | | | | | | |
| Upland River[e] | 10 | 5 | 150 | 30 | 6 | 90-120 | 6.0-7.5 |
| Lowland River[e] | 10 | 4 | 200-300[h] | 10[b] | 10 | 85-120 | 6.0-8.0 |
| Lakes & Reservoirs | 10 | 5 | 350[c] | 10[b] | 10 | 90-120 | 6.0-8.0 |
| Wetlands[3] | 10-50[g] | 5-25[g] | 350-1200[g] | 10 | 10 | 90[b]-120[b] | 6.0-8.0 |

b = Northern Territory values are 5µgL$^{-1}$ for $NO_x$, and <80 (lower limit) and >110% saturation (upper limit) for DO;
c = this value represents turbid lakes only. Clear lakes have much lower values;
e = no data available for tropical WA estuaries or rivers. A precautionary approach should be adopted when applying default trigger values to these systems;
f = dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability;
g = higher values are indicative of tropical WA river pools;
h = lower values from rivers draining rainforest catchments.

**Table A2-2.** Default trigger values for salinity and turbidity for the protection of aquatic ecosystems, applicable to tropical systems in Australia (ANZECC/ARMCANZ 2000).

| *Aquatic Ecosystem* | | *Comments* |
|---|---|---|
| ***Salinity*** | ***(µs/cm)*** | |
| **Aquatic Ecosystem** | | |
| Upland & lowland rivers | 20-250 | Conductivity in upland streams will vary depending on catchment geology. The fist flush may result in temporarily high values |
| Lakes, reservoirs & wetlands | 90-900 | Higher conductivities will occur during summer when water levels are reduced due to evaporation |
| ***Turbidity*** | ***(NTU)*** | |
| **Aquatic Ecosystem** | | |
| Upland & lowland rivers | 2-15 | Can depend on degree of catchment modification and seasonal rainfall runoff |
| Lakes, reservoirs & wetlands | 2-200 | Most deep lakes have low turbidity. However, shallow lakes have higher turbidity naturally due to wind-induced re-suspension of sediments. Wetlands vary greatly in turbidity depending on the general condition of the catchment, recent flow events and the water level in the wetland. |

# Appendix 3. Water quality data from October 2008 and May 2009.

For Weeli Wolli water quality data see WRM (2009).

**Table A3-1.** Water quality data from Marillana Creek, October 2008 (dry). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines.

| Reach | Site | pH | Temp (ºC) | EC (µS/cm) | DO (%) | DO (mg/L) |
|---|---|---|---|---|---|---|
| One | MAR1-1 | 7.76 | 25.1 | 983 | 56 | 4.4 |
| | MAR1-2 | 7.67 | 26.4 | 983 | 71 | 5.5 |
| | MAR1-3 | 7.98 | 25.3 | 1000 | 84 | 6.8 |
| | MAR1-4 | 7.83 | 25.7 | 1020 | 77 | 6.2 |
| | MAR1-5 | 7.98 | 26.2 | 1027 | 63 | 5.3 |
| | MAR1-6 | 7.66 | 27.8 | 1040 | 157 | 11.6 |
| Two | MAR2-1 | 8.06 | 30.6 | 927 | 147 | 10.7 |
| | MAR2-2 | 7.93 | 28.4 | 926 | 112 | 8.5 |
| | MAR2-3 | 8.26 | 29.3 | 907 | 165 | 12.4 |
| | MAR2-4 | 8.34 | 29.5 | 905 | 180 | 13.1 |
| | MAR2-5 | 7.75 | 25.9 | 942 | 79 | 6.3 |
| | MAR2-6 | 8.34 | 27.5 | 943 | 94 | 8.2 |

**Table A3-2.** Water quality data from Marillana Creek, May 2009 (wet). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines.

| Reach | Site | pH | Temp (ºC) | EC (µS/cm) | DO (%) | DO (mg/L) |
|---|---|---|---|---|---|---|
| One | MAR1-1 | 7.89 | 25.3 | 939 | 87 | 7.3 |
| | MAR1-2 | 7.86 | 23.8 | 985 | 105 | 9.2 |
| | MAR1-3 | 7.56 | 23.1 | 1000 | 44 | 3.9 |
| | MAR1-4 | 7.9 | 23 | 996 | 82 | 7.4 |
| | MAR1-5 | 8.01 | 22.3 | 1000 | 107 | 9.9 |
| | MAR1-6 | 7.89 | 23.9 | 1010 | 103 | 9.2 |
| Two | MAR2-1 | 8.06 | 24.8 | 987 | 122 | 10.7 |
| | MAR2-2 | 8.00 | 23.8 | 987 | 88 | 7.9 |
| | MAR2-3 | 8.60 | 19.8 | 963 | 133 | 11.5 |
| | MAR2-4 | 7.79 | 23.7 | 943 | 80 | 7.2 |
| | MAR2-5 | 7.70 | 24.8 | 939 | 60 | 5.1 |
| | MAR2-6 | 7.87 | 20.9 | 939 | 80 | 7.4 |

**Table A3-3.** Nutrient data from Marillana Creek, October 2008 (dry). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | N_NO3 | N_NH3 | Total N | Total P |
|---|---|---|---|---|---|
| One | MAR1-1 | 0.12 | 0.01 | 0.22 | 0.005 |
| | MAR1-2 | 0.03 | 0.005 | 0.1 | 0.005 |
| | MAR1-3 | 0.01 | 0.005 | 0.27 | 0.01 |
| | MAR1-4 | 0.01 | 0.005 | 0.07 | 0.005 |
| | MAR1-5 | 0.01 | 0.005 | 0.05 | 0.005 |
| | MAR1-6 | 0.01 | 0.005 | 0.09 | 0.005 |
| Two | MAR2-1 | 1.3 | 0.005 | 1.8 | 0.005 |
| | MAR2-2 | 0.84 | 0.005 | 1.2 | 0.005 |
| | MAR2-3 | 0.08 | 0.005 | 0.17 | 0.005 |
| | MAR2-4 | 0.03 | 0.005 | 0.1 | 0.005 |
| | MAR2-5 | 0.15 | 0.005 | 0.24 | 0.005 |
| | MAR2-6 | 0.04 | 0.03 | 0.16 | 0.005 |

**Table A3-4.** Nutrient data from Marillana Creek, May 2009 (wet). Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | N_NO3 | N_NH3 | Total N | Total P |
|---|---|---|---|---|---|
| One | MAR1-1 | 0.42 | 0.005 | 0.68 | 0.04 |
| | MAR1-2 | 0.17 | 0.01 | 0.35 | 0.02 |
| | MAR1-3 | 0.02 | 0.005 | 0.15 | 0.02 |
| | MAR1-4 | 0.07 | 0.005 | 0.16 | 0.03 |
| | MAR1-5 | 0.01 | 0.01 | 0.07 | 0.02 |
| | MAR1-6 | 0.01 | 0.01 | 0.18 | 0.02 |
| Two | MAR2-1 | 1 | 0.005 | 1.4 | 0.04 |
| | MAR2-2 | 0.61 | 0.005 | 1.00 | 0.02 |
| | MAR2-3 | 0.37 | 0.005 | 0.74 | 0.02 |
| | MAR2-4 | 0.45 | 0.005 | 0.59 | 0.02 |
| | MAR2-5 | 0.12 | 0.005 | 0.24 | 0.02 |
| | MAR2-6 | 0.08 | 0.005 | 0.22 | 0.02 |

**Table A3-5.** Ionic composition data collected from Marillana Creek in October 2008 (dry). All values are mg/L.

| Reach | Site | Na | K | Ca | Mg | Cl | CO3 | HCO3 | SO4_S | Alkalinity | Hardness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 92.1 | 7.9 | 50 | 46.9 | 138 | 0.5 | 323 | 63.2 | 265 | 320 |
| | MAR1-2 | 92 | 7.7 | 49.3 | 46.4 | 143 | 0.5 | 311 | 62.8 | 255 | 310 |
| | MAR1-3 | 93.9 | 7.8 | 50.8 | 47.2 | 145 | 0.5 | 342 | 64.2 | 280 | 320 |
| | MAR1-4 | 102 | 7.6 | 52.8 | 49.6 | 153 | 0.5 | 329 | 67.3 | 270 | 340 |
| | MAR1-5 | 99.1 | 7.9 | 51.7 | 49.5 | 162 | 0.5 | 336 | 66.9 | 275 | 330 |
| | MAR1-6 | 98.2 | 7.5 | 52.7 | 49.3 | 144 | 0.5 | 342 | 68.5 | 280 | 330 |
| Two | MAR2-1 | 67.6 | 8.2 | 54.9 | 54.7 | 102 | 0.5 | 384 | 54.9 | 315 | 360 |
| | MAR2-2 | 76.7 | 8.2 | 50.6 | 53.8 | 99 | 0.5 | 366 | 57.6 | 300 | 350 |
| | MAR2-3 | 79 | 7.5 | 49.1 | 47.6 | 107 | 0.5 | 366 | 54.5 | 300 | 320 |
| | MAR2-4 | 86.4 | 7.9 | 46.8 | 50 | 113 | 0.5 | 366 | 56.9 | 300 | 320 |
| | MAR2-5 | 82.7 | 7.5 | 52.1 | 50.1 | 120 | 0.5 | 354 | 57.2 | 290 | 340 |
| | MAR2-6 | 83.7 | 7.5 | 51.4 | 50.6 | 125 | 0.5 | 342 | 58 | 280 | 340 |

**Table A3-6.** Ionic composition data collected from Marillana Creek in May 2009 (wet). All values are mg/L.

| Reach | Site | Na | K | Ca | Mg | Cl | CO3 | HCO3 | SO4_S | Alkalinity | Hardness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 82.7 | 7.3 | 45.6 | 45.3 | 111 | 0.5 | 311 | 53.7 | 255 | 300 |
| | MAR1-2 | 83.4 | 7.3 | 45.8 | 44.9 | 122 | 0.5 | 317 | 54.1 | 260 | 300 |
| | MAR1-3 | 86.3 | 7.3 | 48.1 | 45.5 | 129 | 0.5 | 323 | 56.1 | 265 | 310 |
| | MAR1-4 | 83.3 | 7.1 | 47.9 | 44.7 | 129 | 0.5 | 323 | 53 | 265 | 300 |
| | MAR1-5 | 86.1 | 7.1 | 47.7 | 45.5 | 124 | 0.5 | 323 | 56.5 | 265 | 310 |
| | MAR1-6 | 85.9 | 7.1 | 46.9 | 44.8 | 114 | 0.5 | 317 | 56.4 | 260 | 300 |
| Two | MAR2-1 | 67.9 | 7.7 | 52 | 51.2 | 100 | 0.5 | 366 | 51.7 | 300 | 340 |
| | MAR2-2 | 69.9 | 7.3 | 48.5 | 52.2 | 102 | 0.5 | 366 | 60.8 | 300 | 340 |
| | MAR2-3 | 72.3 | 7.4 | 48.3 | 50.5 | 99 | 0.5 | 305 | 51.6 | 280 | 330 |
| | MAR2-4 | 73.2 | 7.2 | 48.7 | 51.3 | 100 | 0.5 | 342 | 51.8 | 280 | 330 |
| | MAR2-5 | 73.1 | 7.3 | 50 | 48.5 | 104 | 0.5 | 336 | 51.5 | 275 | 320 |
| | MAR2-6 | 73.6 | 7.4 | 49.9 | 48.2 | 105 | 0.5 | 329 | 51.7 | 270 | 320 |

**Table A3-7.** Metals data collected from Marillana Creek in October 2008. Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | Al | As | B | Ba | Cd | Co | Cr | Cu | Fe | Mn | Mo | Ni | Pb | Se | U | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 0.0025 | 0.0005 | 0.36 | 0.036 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0025 | 0.0025 |
| | MAR1-2 | 0.0025 | 0.0005 | 0.34 | 0.035 | 0.0002 | 0.0025 | 0.0005 | 0.001 | 0.027 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0025 | 0.0025 |
| | MAR1-3 | 0.0025 | 0.0005 | 0.36 | 0.034 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0025 | 0.0025 |
| | MAR1-4 | 0.0025 | 0.0005 | 0.36 | 0.036 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0014 | 0.0025 | 0.0025 |
| | MAR1-5 | 0.0025 | 0.0005 | 0.35 | 0.033 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0012 | 0.0025 | 0.0025 |
| | MAR1-6 | 0.0025 | 0.0005 | 0.35 | 0.035 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.024 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.0025 | 0.0025 |
| Two | MAR2-1 | 0.0025 | 0.0005 | 0.31 | 0.013 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0025 | 0.0025 |
| | MAR2-2 | 0.0025 | 0.0005 | 0.35 | 0.027 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.0025 | 0.0025 |
| | MAR2-3 | 0.0025 | 0.0005 | 0.32 | 0.028 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0018 | 0.0025 | 0.0025 |
| | MAR2-4 | 0.0025 | 0.0005 | 0.34 | 0.024 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0015 | 0.005 | 0.0025 |
| | MAR2-5 | 0.0025 | 0.0005 | 0.3 | 0.035 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0021 | 0.0025 | 0.0025 |
| | MAR2-6 | 0.0025 | 0.0005 | 0.3 | 0.033 | 0.00005 | 0.0025 | 0.0005 | 0.001 | 0.01 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0023 | 0.0025 | 0.0025 |

**Table A3-8.** Metals data collected from Weeli Wolli Creek, May 2009. Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines. All values are mg/L.

| Reach | Site | Al | As | B | Ba | Cd | Co | Cr | Cu | Fe | Mn | Mo | Ni | Pb | Se | U | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| One | MAR1-1 | 0.028 | 0.0005 | 0.32 | 0.051 | 0.00005 | 0.0025 | 0.0008 | 0.0007 | 0.014 | 0.004 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0042 | 0.006 |
| | MAR1-2 | 0.0025 | 0.0005 | 0.3 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.00005 | 0.055 | 0.007 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0038 | 0.006 |
| | MAR1-3 | 0.0025 | 0.0005 | 0.29 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.0002 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0042 | 0.004 |
| | MAR1-4 | 0.0025 | 0.0005 | 0.29 | 0.051 | 0.00005 | 0.0025 | 0.0005 | 0.0003 | 0.018 | 0.005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0035 | 0.004 |
| | MAR1-5 | 0.0025 | 0.0005 | 0.3 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.0002 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0011 | 0.0042 | 0.003 |
| | MAR1-6 | 0.026 | 0.0005 | 0.28 | 0.049 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0012 | 0.0044 | 0.006 |
| Two | MAR2-1 | 0.0025 | 0.0005 | 0.27 | 0.032 | 0.00005 | 0.0025 | 0.0005 | 0.00005 | 0.015 | 0.005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0009 | 0.0016 | 0.004 |
| | MAR2-2 | 0.007 | 0.0005 | 0.31 | 0.042 | 0.00005 | 0.0025 | 0.0005 | 0.0001 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0012 | 0.0046 | 0.004 |
| | MAR2-3 | 0.0025 | 0.0005 | 0.25 | 0.047 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0014 | 0.004 | 0.005 |
| | MAR2-4 | 0.0025 | 0.0005 | 0.25 | 0.048 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.001 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0015 | 0.0043 | 0.005 |
| | MAR2-5 | 0.0025 | 0.0005 | 0.25 | 0.052 | 0.00005 | 0.0025 | 0.0005 | 0.0004 | 0.0025 | 0.0005 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.003 | 0.004 |
| | MAR2-6 | 0.022 | 0.0005 | 0.26 | 0.055 | 0.00005 | 0.0025 | 0.0009 | 0.0007 | 0.02 | 0.02 | 0.0005 | 0.0005 | 0.00005 | 0.0005 | 0.0016 | 0.0025 | 0.008 |

# Appendix 4. Microinvertebrate data from October 2008 and May 2009.

**Table A4-1.** Dry season, October 2008.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **PROTISTA** | | | | | | | | | | | | | | |
| **Ciliophora** | | *Didinium* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| | | *Euplotes* sp. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Rhizopoda** | | | | | | | | | | | | | | |
| | **Arcellidae** | *Arcella discoides* | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 |
| | | *Arcella* sp. [med., transp., domed] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Arcella* sp. [sm., brn] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Centropyxidae** | *Centropyxis aculeata* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 |
| | | *Centropyxis ecornis* | 2 | 3 | 2 | 2 | 3 | 2 | 1 | 1 | 2 | 2 | 2 | 1 |
| | | *Centropyxis* sp [med.] | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | | *Centropyxis* sp [sm, elongate] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | *Centropyxis* sp [tiny] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | **Cyclopyxidae** | *Cyclopyxis* sp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Difflugiidae** | *Difflugia elegans* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | | *Difflugia gramen* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Euglyphidae** | *Euglypha* sp. | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Lesquereusiidae** | *Lesquereusia spiralis* | 2 | 2 | 1 | 0 | 2 | 2 | 0 | 0 | 1 | 2 | 1 | 2 |
| | | *Netzelia tuberculata* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **ROTIFERA** | | | | | | | | | | | | | | |
| **Bdelloidea** | | | | | | | | | | | | | | |
| | | indet. bdelloid [v. sm.] | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Monogononta** | | | | | | | | | | | | | | |
| | **Atrochidae** | *Cupelopagis vorax* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Epiphanidae** | *Microcodides* cf. *chlaena* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Euchlanidae** | *Euchlanis* sp. | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | *Tripleuchlanis plicata* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| | **Lecanidae** | *Lecane bulla* | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| | | *Lecane curvicornis* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* cf. *elsa* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Lecane ludwigii* | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane luna* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* (*M.*) a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| | | *Lecane* (*M.*) b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | **Lepadellidae** | *Colurella* sp. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | *Lepadella* sp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Mytillinidae** | *Mytilinia ventralis* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Notommatidae** | *Eosphora anthadis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | | *Notommata copeus* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Notommata* sp. | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **COPEPODA** | | | | | | | | | | | | | | |
| **Cyclopoida** | | | | | | | | | | | | | | |
| | | *?Tropocyclops* sp. | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | ?*Microcyclops* [late copepodite only] | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | cyclopoid copepodites | 0 | 0 | 0 | 2 | 2 | 1 | 2 | 2 | 3 | 2 | 1 | 1 |
| | | cyclopoid nauplii | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 2 | 2 | 1 | 1 | 0 |
| | | | | | | | | | | | | | | |
| **CLADOCERA** | | | | | | | | | | | | | | |
| | **Chydoridae** | *Armatalona macrocopa* | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 2 |
| | | *Alona rigidicaudis* | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Alona* cf. *verrucosa* | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Ephemeroporus barroisi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **OSTRACODA** | | | | | | | | | | | | | | |
| | | *Diacypris* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | *Limnocythere* sp. | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 |
| | | juv. ostracods, indet. | 0 | 2 | 1 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 1 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **9** | **8** | **8** | **9** | **11** | **5** | **10** | **8** | **19** | **16** | **7** | **6** |

**Table A4-2.** Wet season, May 2009.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **PROTISTA** | | | | | | | | | | | | | | |
| **Rhizopoda** | | | | | | | | | | | | | | |
| | **Arcellidae** | *Arcella discoides* | 2 | 1 | 2 | 3 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 |
| | **Centropyxidae** | *Centropyxis aculeata* | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| | | *Centropyxis ecornis* | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Centropyxis* sp [med.] | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Centropyxis* sp [tiny] | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Difflugiidae** | *Difflugia* [sm, ovoid] | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Euglyphidae** | *Euglypha* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Lesquereusiidae** | *Lesquereusia modesta* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lesquereusia spiralis* | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Netzelia tuberculata* | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Trinematidae** | *Trinema* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **ROTIFERA** | | | | | | | | | | | | | | |
| **Bdelloidea** | | indet. bdelloid [sm.] | 0 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | indet. bdelloid [tiny] | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Monogononta** | | | | | | | | | | | | | | |
| | **Brachionidae** | *Keratella tropica* | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Dicranophoridae** | *Dicranophorus sp.* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Epiphanidae** | *Microcodides* cf. *chlaena* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Euchlanidae** | *Euchlanis incisa* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Euchlanis* sp. | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tripleuchlanis plicata* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Lecanidae** | *Lecane batillifer* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane bulla* | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane lunaris* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* cf. *thalera* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* (*M.*) a | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Lecane* (*M.*) b | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Lepadellidae** | *Colurella* sp. | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Notommatidae** | *Cephalodella* cf. *forficula* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Notommata copeus* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Trichocercidae** | *Trichocerca* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Trichotriidae** | *Macrochaetus* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **COPEPODA** | | | | | | | | | | | | | | |
| **Cyclopoida** | | | | | | | | | | | | | | |
| | | *?Tropocyclops* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Thermocyclops decipiens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | cyclopoid copepodites | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| | | cyclopoid nauplii | 0 | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **CLADOCERA** | | | | | | | | | | | | | | |
| | **Chydoridae** | *Alona rigidicaudis* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | *Alona* cf. *verrucosa* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Chydorus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Karualona karua* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Daphniidae** | *Ceriodaphnia cornuta* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **OSTRACODA** | | | | | | | | | | | | | | |
| | | *Limnocythere* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | juv. ostracods, indet. | 0 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **4** | **6** | **20** | **18** | **1** | **0** | **6** | **2** | **1** | **2** | **1** | **3** |

# Appendix 5. Hyporheic data from October 2008 and May 2009.

**Table A5-1.** Dry season, October 2008.

| | | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Species* | *CAT* | *MAR1-1dry* | *MAR1-2dry* | *MAR1-3dry* | *MAR1-4dry* | *MAR1-5dry* | *MAR1-6dry* | *MAR2-1dry* | *MAR2-2dry* | *MAR2-3dry* | *MAR2-4dry* | *MAR2-5dry* | *MAR2-6dry* |
| **ANNELIDA** | | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | **P** | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| **CRUSTACEA** | | | | | | | | | | | | | | | |
| **Amphipoda** | | | | | | | | | | | | | | | |
| **Crangonyctoid** | **Paramelitidae** | *?Chydaekata* sp. | **S** | 0 | 4 | 0 | 0 | 0 | 0 | 6 | 4 | 0 | 5 | 24 | 4 |
| | | | | | | | | | | | | | | | |
| **Copepoda** | | | | | | | | | | | | | | | |
| **Cyclopoida** | **Cyclopodidae** | *Microcyclops varicans* | **X** | 0 | 6 | 0 | 0 | 3 | 8 | 0 | 0 | 3 | 2 | 0 | 0 |
| | | *Diacyclops* sp. [copepodites] | **P** | | | | 3 | | | | | | | | |
| | | Cyclopodidae: copepodites/males | **X** | 0 | 10 | 1 | 9 | 7 | 15 | 0 | 1 | 3 | 5 | 0 | 2 |
| | | | | | | | | | | | | | | | |
| **ARACHNIDA** | | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | **U** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | | |
| **COLLEMBOLLA** | | Collembolla spp. | **X** | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| **INSECTA** | | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Baetidae** | *Baetidae Genus 1 WA sp.1* | **O** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | | | | | | | | | | | | | | | |
| **COLEOPTERA** | **Hydrophilidae** | Hydrophilidae spp. | **U** | 0 | 6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 |
| | **Scirtidae** | *Scirtidae* sp. (L) | **X** | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 14 | 0 |
| | | | | | | | | | | | | | | | |
| **DIPTERA** | | Diptera instar spp. | **X** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| | **Chironomidae** | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Chironominae | *Paratendipes "K1"* | **X** | 0 | 36 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Cryptochironomus griseidorsum* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Polypedilum sp.* | **X** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tanytarsus sp.* | **X** | 0 | 6 | 4 | 0 | 0 | 6 | 0 | 0 | 0 | 1 | 0 | 0 |
| | Orthocladiinae | Unknow n genus (WW08) | **X** | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Tanypodinae | *Paramerina sp.* | **X** | 0 | 22 | 1 | 1 | 0 | 9 | 0 | 0 | 0 | 4 | 3 | 6 |
| | | *Procladius sp.* | **X** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | **Ceratopogonidae** | Ceratopogoniinae spp. | **X** | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 0 |
| | | Ceratopogoniinae spp. (P) | **X** | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | Dasyheilenae | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| | | | | | | | | | | | | | | | |
| **LEPIDOPTERA** | **Pyralidae** | Nymphulinae spp. | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 |
| | | | | | | | | | | | | | | | |
| | | **TAXA RICHNESS** | | **0** | **13** | **4** | **3** | **3** | **5** | **3** | **3** | **2** | **13** | **6** | **7** |

**Table A5-2.** Wet season, May 2009.

| | | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class/Order | Family | Species | CAT | MAR1-1wet | MAR1-2wet | MAR1-3wet | MAR1-4wet | MAR1-5wet | MAR1-6wet | MAR2-1wet | MAR2-2wet | MAR2-3wet | MAR2-4wet | MAR2-5wet | MAR2-6wet |
| **CNIDARIA** | | | | | | | | | | | | | | | |
| **HYDROZOA** | **Hydridae** | *Hydra* sp. | **X** | 0 | 2 | 0 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| **NEMATODA** | | Nematoda spp. | **U** | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ANNELIDA** | | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | **P** | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **GASTROPODA** | | | | | | | | | | | | | | | |
| | **Lymnaeidae** | *Austropeplea lessoni* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **CRUSTACEA** | | | | | | | | | | | | | | | |
| **AMPHIPODA** | | | | | | | | | | | | | | | |
| **Crangonyctoid** | **Paramelitidae** | *?Chydaekata* sp. | **S** | 1 | 2 | 3 | 2 | 3 | 2 | 4 | 3 | 4 | 3 | 3 | 0 |
| **COPEPODA** | | | | | | | | | | | | | | | |
| **Cyclopoida** | **Cyclopodidae** | Cyclopidae: copepodites/males | **U** | 0 | 4 | 9 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| | | *Ectocyclops phaleratus* | **X** | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Microcyclops varicans* | **X** | 0 | 4 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| **ARACHNIDA** | | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | **U** | 0 | 2 | 2 | 0 | 2 | 1 | 2 | 2 | 2 | 0 | 2 | 0 |
| | | Oribatida spp. | **U** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| **COLLEMBELA** | | Collembolla spp. | **X** | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | **Entomobryoidea** | Entomobryoidea spp. | **X** | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 |
| | | Poduroidea spp. | **X** | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **INSECTA** | | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Baetidae** | *Genus 1 WA sp. 1* | **O** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 1 |
| | **Caenidae** | *Tasmanacoenis arcuata* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 3 |
| **COLEOPTERA** | **Dytiscidae** | Dytiscidae spp. (L) | **O** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Limbodessus occidentalis* | **O** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Platynectes decempunctatus* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Elmidae** | *Austrolimnius sp. (L)* | **U** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Hydraenidae** | *Hydraena sp.* | **X** | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | **Hydrophilidae** | Hydrophilidae spp. (L) | **U** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | *Enochrus sp. (L)* | **X** | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 2 | 2 | 0 |
| | | *Enochrus mastersii* | **X** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Helochares sp. (L)* | **X** | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 1 | 0 | 2 | 0 |
| | | *Laccobius sp. (L)* | **X** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class/Order | Family | Species | CAT | MAR1-1wet | MAR1-2wet | MAR1-3wet | MAR1-4wet | MAR1-5wet | MAR1-6wet | MAR2-1wet | MAR2-2wet | MAR2-3wet | MAR2-4wet | MAR2-5wet | MAR2-6wet |
| | | *Paranacaena sp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Sternolophus sp. (L)* | X | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Hygrobidae** | *Hygrobia spp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | **Scirtidae** | *Scirtidae sp. (L)* | X | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 2 | 4 |
| | | | | | | | | | | | | | | | |
| **HEMIPTERA** | **Hebridae** | *Hebrus axillaris* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | | |
| **ODONATA** | | | | | | | | | | | | | | | |
| **Anisoptera** | | Anisoptera sp. (imm) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| **Zygoptera** | | Zygoptera sp. (imm) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | | | | | | | | | | | | | | |
| **DIPTERA** | **Chironomidae** | | | | | | | | | | | | | | |
| | Chironominae | *Paratendipes "K1"* | X | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | | *Cryptochironomus griseidorsum* | X | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tanytarsus sp.* | X | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | WWTS5 | X | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 |
| | Orthocladiinae | *Rheocricotopus sp.* | X | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Cricotopus albitarsis* | X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Thienemanniella sp.* | X | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Corynonoeura sp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | Unknown genus (WW08) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| | Tanypodinae | *Paramerina sp.* | X | 6 | 64 | 1 | 0 | 36 | 0 | 26 | 6 | 32 | 1 | 34 | 15 |
| | | *Thienemannimyia sp.* | X | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Nilotanypus sp.* | X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | | *Larsia ?albiceps* | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Ceratopogonidae** | Ceratopogonidae (P) | X | 0 | 0 | 2 | 0 | 1 | 2 | 2 | 0 | 2 | 0 | 2 | 0 |
| | | Ceratopogoninae sp. | X | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 3 | 2 | 3 | 2 |
| | | Dasyheleinae sp. | X | 2 | 3 | 3 | 2 | 1 | 2 | 2 | 0 | 2 | 2 | 3 | 2 |
| | | Forcipomyiinae sp. | X | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Dolichopodidae** | Dolichopodidae spp. | X | 2 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | **Ephydridae** | Ephydridae spp. | X | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Simuliidae** | Simuliidae spp. | X | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Syrphidae** | Syrphidae spp. | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Thaumaleidae** | Thaumaleidae spp. | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | **Tipulidae** | Tipulidae spp. | X | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| **TRICHOPTERA** | **Hydropsychidae** | *Cheumatopsyche sp.* | X | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | **Lepidoptera** | Lepidoptera spp. (imm) | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| | **Philpotomidae** | *Chimarra uranka* | X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | | | | | | | | | | | | | | |
| | | **Taxa richness** | | **16** | **15** | **19** | **6** | **15** | **13** | **20** | **7** | **20** | **8** | **17** | **22** |

# Appendix 6. Macoinvertebrate data from October 2008 and May 2009.

**Table A6-1.** October 2008.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **CNIDARIA** | | | | | | | | | | | | | | |
| **Hydrozoa** | | *Hydra* sp. | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 |
| **ANNELIDA** | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | 3 | 0 | 2 | 0 | 1 | 4 | 0 | 0 | 3 | 3 | 2 | 3 |
| **MOLLUSCA** | | | | | | | | | | | | | | |
| **GASTROPODA** | **Ancylidae** | *Ferissa petterdi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Lymnaeidae** | *Austropeplea lessoni* | 0 | 2 | 0 | 3 | 3 | 4 | 1 | 2 | 3 | 2 | 2 | 2 |
| | **Planorbidae** | *Gyraulus hesperus* | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 2 | 2 | 2 | 0 | 2 |
| **ARACHNIDA** | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | 3 | 0 | 0 | 4 | 2 | 0 | 2 | 4 | 3 | 3 | 4 | 3 |
| **ORIBATIDA** | | Oribatida spp. | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| **INSECTA** | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Caenidae** | Caenidae spp. (imm.) | 0 | 0 | 0 | 3 | 0 | 2 | 2 | 0 | 0 | 3 | 0 | 0 |
| | | *Tasmanocoenis arcuata* | 4 | 2 | 3 | 3 | 2 | 2 | 2 | 0 | 3 | 4 | 2 | 3 |
| | **Baetidae** | Baetidae spp. (imm.) | 0 | 0 | 0 | 4 | 3 | 2 | 2 | 0 | 0 | 0 | 4 | 0 |
| | | *Baetidae Genus 1 WA sp.1* | 4 | 1 | 3 | 4 | 2 | 0 | 4 | 4 | 3 | 4 | 4 | 4 |
| | | *Cloeon* sp. | 0 | 0 | 0 | 0 | 4 | 3 | 0 | 0 | 0 | 4 | 0 | 0 |
| **ODONATA** | | | | | | | | | | | | | | |
| **Anisoptera** | | Anisoptera spp.(imm) | 2 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 2 | 2 | 0 |
| | **Libellulidae** | Libellulidae spp. (imm.) | 1 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 2 |
| | | *Diplacodes haematodes* | 2 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 0 | 2 |
| | | *Nannophlebia injabandi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | | *Orthetrum caledonicum* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | *Zyxomma elgneri* | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| **HEMIPTERA** | **Belostomatidae** | *Diplonychus eques* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Corixidae** | Corixidae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Gerridae** | Gerridae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Limnogonus fossarum gilguy* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | *Rhagadotarsus anomolus* | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Hebridae** | Hebridae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 0 |
| | | *Hebrus axillaris* | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| | **Nepidae** | *Laccotrephes tristis* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Naucoridae** | *Naucoris subopacus* | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| | **Notonectidae** | *Anisops* sp. (F) | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Pleidae** | *Paraplea brunni* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Velidae** | Veliidae spp.(imm.) | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | *Microvelia australiensis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **COLEOPTERA** | **Dytiscidae** | *Platynectes* sp. (L) | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | *Platynectes decempunctatus var decemp.* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 0 |
| | | *Tiporus tambreyi* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Elmidae** | *Austrolimnius* sp. (A) | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | *Austrolimnius* sp. (L) | 0 | 0 | 0 | 3 | 0 | 1 | 1 | 2 | 3 | 0 | 2 | 1 |
| | **Gyrinidae** | *Aulonogyrus strigosus* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Aulonogyrus/Macrogyrus* sp. (L) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| | | *Dineatus australis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | **Hydraenidae** | *Hydraena sp.* | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | **Hydrophilidae** | *Berosus* sp. (L) | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 3 | 0 | 0 |
| | | *Berosus dallasae* | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Coelostoma sp.* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 |
| | | *Helochares* sp. (L) | 2 | 2 | 1 | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | 2 |
| | | *Helochares tatei* | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 0 | 1 |
| | | *Laccobius bili* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Paracymus pygmaeus* | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Sternolophus* sp. (L) | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Hydrochidae** | *Hydrochus* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 2 |
| | **Scirtidae** | Scirtidae spp. (L) | 2 | 2 | 0 | 3 | 0 | 1 | 0 | 1 | 2 | 0 | 2 | 1 |
| **DIPTERA** | **Chironomidae** | Chironomidae spp. (P) | 2 | 2 | 3 | 4 | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 3 |
| | | *Paramerina sp.* | 2 | 1 | 0 | 3 | 3 | 0 | 0 | 0 | 2 | 2 | 3 | 3 |
| | | *Thienemannimyia sp.* | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 2 | 3 | 3 | 2 | 3 |
| | | *Nilotanypus sp.* | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 1 |
| | | *Larsia ?albiceps* | 2 | 2 | 2 | 2 | 3 | 0 | 2 | 2 | 3 | 1 | 3 | 3 |
| | | *Procladius sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | *Ablabesmyia hilli* | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 1 |
| | | *Rheocricotopus sp.* | 3 | 2 | 2 | 3 | 0 | 0 | 3 | 2 | 1 | 2 | 3 | 1 |
| | | *nr. Parametriocnemus* | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Cricotopus albitarsis* | 2 | 2 | 3 | 0 | 0 | 0 | 3 | 3 | 2 | 3 | 4 | 3 |
| | | *Thienemanniella sp.* | 3 | 1 | 1 | 3 | 2 | 0 | 3 | 3 | 2 | 2 | 4 | 2 |
| | | *Corynonoeura sp.* | 2 | 1 | 3 | 4 | 3 | 0 | 2 | 0 | 0 | 1 | 3 | 3 |
| | | *Paratendipes "K1"* | 0 | 3 | 1 | 3 | 2 | 0 | 2 | 1 | 0 | 1 | 0 | 0 |
| | | *Chironomus sp.* | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | *Cryptochironomus griseidorsum* | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 0 | 1 | 0 | 2 | 2 |
| | | *Polypedilum nubifer* | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | *Dicrotendipes sp1* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| | | *Dicrotendipes sp2* | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 3 | 0 |
| | | *Cladopelma curtivala* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| | | *Polypedilum watsoni* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | | *Paracladopelma sp "M1"* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | *Polypedilum sp.* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 |
| | | WWC17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| | | *Tanytarsus sp.* | 1 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 3 |
| | | *Paratanytarsus sp.* | 0 | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 0 |
| | | *Cladotanytarsus sp.* | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | WWTS5 | 1 | 2 | 2 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 |
| | **Ceratopogonidae** | Ceratopogoniinae spp. | 2 | 2 | 3 | 3 | 4 | 2 | 2 | 1 | 2 | 2 | 3 | 3 |
| | | Dasyheilenae spp. | 3 | 2 | 0 | 3 | 4 | 2 | 0 | 4 | 3 | 4 | 2 | 0 |
| | | Forcypomiinae spp. | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 2 | 0 |
| | | Ceratopogonidae spp. (P) | 0 | 2 | 2 | 3 | 1 | 2 | 0 | 2 | 2 | 2 | 2 | 2 |
| | **Culicidae** | *Anopheles* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | Culicidae spp. (P) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Dolichopidae** | Dolichopodidae spp. | 3 | 0 | 2 | 3 | 2 | 0 | 2 | 2 | 2 | 2 | 2 | 2 |
| | **Ephydridae** | Ephydridae spp. | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 1 | 1 |
| | **Simuliidae** | Simulidae spp (P) | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 0 | 2 |
| | | Simulidae spp. | 3 | 3 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 | 2 | 2 |
| | **Stratiomyidae** | Stratiomyidae spp. | 0 | 2 | 0 | 0 | 0 | 2 | 1 | 0 | 3 | 0 | 2 | 1 |
| | **Tabanidae** | Tabanidae spp. | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 1 | 0 |
| | **Tipulidae** | Tipulidae spp. | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TRICHOPTERA** | | Trichoptera spp. (P) | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 1 |
| | **Ecnomidae** | *Ecnomus* sp. | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 2 |
| | **Hydropsychidae** | *Cheumatopsyche wellsae (spAV11)* | 4 | 3 | 2 | 4 | 2 | 1 | 4 | 4 | 4 | 4 | 5 | 4 |
| | **Hydroptilidae** | *Hellyethira* sp | 0 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 3 | 1 |
| | **Orthotrichidae** | *Orthotrichia spp.* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Leptoceridae** | Oecetis spp. | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| | | *Triaenodes spp.* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Triplectides australis* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Triplectides ciskus seductus* | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 1 |
| | **Philopotamidae** | Philopotamidae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | *Chimmara* sp. | 4 | 3 | 1 | 3 | 0 | 0 | 4 | 3 | 3 | 3 | 2 | 3 |
| **LEPIDOPTERA** | **Pyralidae** | *Nymphulinae cf sp. 3* | 2 | 3 | 3 | 3 | 3 | 0 | 2 | 3 | 2 | 3 | 0 | 2 |
| | | *Nymphulinae cf sp. 37* | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 3 | 0 | 0 |
| | | Nymphulinae spp. (imm.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 3 | 0 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **35** | **40** | **36** | **46** | **33** | **34** | **40** | **31** | **47** | **47** | **52** | **52** |

**Table A6-2.** May 2009.

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Class/Order* | *Family* | *Taxa* | *MAR1-1* | *MAR1-2* | *MAR1-3* | *MAR1-4* | *MAR1-5* | *MAR1-6* | *MAR2-1* | *MAR2-2* | *MAR2-3* | *MAR2-4* | *MAR2-5* | *MAR2-6* |
| **ANNELIDA** | | | | | | | | | | | | | | |
| **OLIGOCHAETA** | | Oligochaeta spp. | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 1 | 2 | 0 |
| | | | | | | | | | | | | | | |
| **MOLLUSCA** | | | | | | | | | | | | | | |
| **GASTROPODA** | **Planorbidae** | *Gyraulus hesperus* | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 0 | 0 | 0 |
| | **Ancylidae** | *Ferrissia petterdi* | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **CRUSTACEA** | | | | | | | | | | | | | | |
| **AMPHIPODA** | **Paramelitidae** | *?Chydaekata* sp. | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **ARACHNIDA** | | | | | | | | | | | | | | |
| **ACARINA** | | Hydracarina spp. | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 2 | 2 | 3 | 4 | 4 |
| **ORIBATIDA** | | Oribatidae spp. | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | |
| **INSECTA** | | | | | | | | | | | | | | |
| **EPHEMEROPTERA** | **Baetidae** | Baetidae spp (dam) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | | *Genus 1 WA sp. 1* | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 5 | 5 | 5 | 4 | 4 |
| | **Caenidae** | *Tasmanacoensis arcutata* | 2 | 4 | 4 | 2 | 2 | 3 | 1 | 0 | 2 | 3 | 0 | 4 |
| **ODONATA** | | | | | | | | | | | | | | |
| **Anisoptera** | | Anisoptera spp. (imm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Aeshnidae** | Aeshnidae spp. (imm) | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Gomphidae** | *Austrogomphus gordoni* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Libellulidae** | *Diplacodes haematodes* | 0 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Nannophlebia injabandi* | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 |
| **Zygoptera** | **Coenagrionidae** | Coenagrionidae spp. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **HEMIPTERA** | **Gerridae** | *Limnogonus fossarum gilguy* | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 1 |
| | **Mesoveliidae** | *Mesoveliidae spp. (imm)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Naucoridae** | *Naucoris subopacus* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **COLEOPTERA** | **Dytiscidae** | *Platynectes decempunctatus var decem.* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Platynectes* sp. (L) | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Tiporus centralis* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Elmidae** | *Austrolimnius* sp (A) | 0 | 0 | 2 | 3 | 3 | 2 | 1 | 1 | 0 | 2 | 0 | 1 |
| | | *Austrolimnius* sp. (L) | 0 | 0 | 1 | 3 | 4 | 3 | 2 | 2 | 0 | 2 | 2 | 0 |
| | **Gyrinidae** | *Aulonogyrus strigosus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Dineutus australis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | **Hydrophilidae** | Hydrophilidae spp. (L) | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 0 | 1 |
| | | *Berosus dallasae* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | *Helochares tatei* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Helochares* sp. (L) | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| | **Scirtidae** | Scirtidae spp. (L) | 2 | 0 | 0 | 2 | 0 | 1 | 0 | 3 | 3 | 2 | 3 | 3 |
| **DIPTERA** | **Ceratopogonidae** | Ceratopogoniinae spp. | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 3 | 2 | 2 |
| | | Dasyheleinae spp. | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Forcipomyiinae spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

| | | | Reach One | | | | | | Reach Two | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MAR1-1 | MAR1-2 | MAR1-3 | MAR1-4 | MAR1-5 | MAR1-6 | MAR2-1 | MAR2-2 | MAR2-3 | MAR2-4 | MAR2-5 | MAR2-6 |
| | **Chironomidae** | Chironomidae spp. (P) | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 0 | 0 | 0 |
| | | *Paramerina sp.* | 0 | 2 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 2 |
| | | *Thienemannimyia sp.* | 1 | 3 | 1 | 2 | 2 | 1 | 0 | 1 | 2 | 3 | 2 | 3 |
| | | *Nilotanypus sp.* | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 0 | 2 | 1 | 2 |
| | | *Larsia ?albiceps* | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 0 | 3 |
| | | *Procladius sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | *Ablabesmyia hilli* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *Rheocricotopus sp.* | 3 | 3 | 0 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 |
| | | *Cricotopus albitarsis* | 3 | 2 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 3 |
| | | *Thienemanniella sp.* | 3 | 2 | 0 | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
| | | *Corynonoeura sp.* | 1 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | *Paracladopelma "K2"* | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Paratendipes "K1"* | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| | | *Cryptochironomus griseidorsum* | 0 | 2 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| | | *Dicrotendipes sp1* | 2 | 2 | 3 | 3 | 3 | 2 | 0 | 0 | 1 | 0 | 2 | 2 |
| | | *Dicrotendipes sp2* | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 2 | 2 |
| | | *Tanytarsus sp.* | 2 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 1 |
| | | *Cladotanytarsus sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | | WWTS5 | 2 | 2 | 0 | 2 | 0 | 0 | 2 | 1 | 2 | 2 | 2 | 2 |
| | **Dolichopodidae** | Dolichopodidae spp. | 0 | 3 | 0 | 2 | 2 | 3 | 2 | 0 | 2 | 1 | 0 | 0 |
| | **Simulidae** | Simulidae spp. | 3 | 4 | 1 | 3 | 3 | 4 | 3 | 3 | 4 | 3 | 2 | 2 |
| | | Simuliidae sp (P) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 |
| | **Syrphidae** | Syrphidae spp. | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Tabanidae** | Tabanidae spp. | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 |
| | **Tanyderidae** | Tanyderidae spp. | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TRICHOPTERA** | **Ecnomidae** | *Ecnomus sp.* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Hydroptilidae** | Hydroptilidae sp (imm) | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *Hellyethira sp.* | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | **Hydropsychidae** | *Cheumatopsyche wellsae* | 4 | 4 | 1 | 4 | 4 | 0 | 5 | 5 | 0 | 4 | 4 | 4 |
| | **Leptoceridae** | *Oecetis sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | *Triplectides ciuskus seductus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Philopotamidae** | *Chimarra* sp. | 3 | 4 | 0 | 3 | 3 | 0 | 4 | 3 | 0 | 3 | 3 | 3 |
| **LEPIDOPTERA** | **Nymphulinae** | *Nymphulinae sp. 3* | 3 | 4 | 3 | 4 | 4 | 4 | 0 | 3 | 3 | 3 | 3 | 4 |
| | | *Nymphulinae sp. 18* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 2 |
| | | *Nymphulinae sp. 37* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 |
| | | | | | | | | | | | | | | |
| | | **Taxa richness** | **23** | **26** | **32** | **30** | **29** | **26** | **27** | **23** | **30** | **26** | **25** | **33** |