internal report **357**

Little billabongs in space and time: Preliminary methods and results from a study of the development of seasonal pools of the Magela Creek, NT Australia

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LITTLE BILLABONGS IN SPACE AND TIME;

PRELIMINARY METHODS AND RESULTS FROM A STUDY OF THE DEVELOPMENT OF SEASONAL POOLS OF THE MAGELA CREEK, NT AUSTRALIA.

January 2001

By Clint McCullough

eriss PhD Scholarship holder.

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Plate 1 Looking upstream from study site 2 at beginning of sampling, early August 2000. Magela Creek almost ceased flowing, pools newly born.

Plate 2 Looking upstream from study site 2 at end of sampling, late September 2000. Pool nearing extinction waiting for relieve with the onset of the Monsoons.

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SYNOPSIS

The environmental characteristics of the pools of the Magela Creek in the Dry Season appears to be such that they fall somewhere between the 2 extremes of the Creek in its flowing state, and of its catchment billabongs. This is not surprising with the pools simply representing smaller and more ephemeral billabongs; smaller-scale analogies of the more prominent billabongs of this system in both space and time.

The results of this study have also compared well with the results of a previous study of Magela Creek pools, with noted differences suggesting that there are longitudinal changes in both pool chemistry and morphology occurring along the Creek.

INTRODUCTION

This Internal Report is the first of a series to be produced every six months describing the findings of the PhD scholarship *project 'Ecological effects of Magnesium sulphate in Magela Creek, NT'* for the previous 6 months. It is intended that the contents of this report will then be revised, peer-reviewed and added to macroinvertebrate data to form a Supervising Scientist Report (SSR) and eventually a published paper.

The concentration of this report is on univariate descriptive analyses of the environmental characteristics of the Magela Creek pools as the Creek ceases to flow, through to their extinction. Multivariate analysis have largely been excluded for environmental data due to the paucity of their sample number (the emphasis of the study being on macroinvertebrate communities) and also due to time constraints. A more complete presentation and interpretation of these data will follow later this year in a Supervising Scientist Report (SSR) and in a published paper (journal as yet unknown)

All data files related to this project are stored on the following network path: Projects on 'Makuk'/Biolmon/$MgSO_4$. Therefore, no specific metadata filepaths will be given when a project aspect is noted.

Study sites

The location of this study was in the strongly seasonal mid-upper reaches of the Magela Creek, largely contained in the World Heritage listed Kakadu National Park, Northern Territory of Australia (Figure 1) (Press et al 1995).

The highly seasonal weather pattern of this tropical area results in months of an extremely high incidence of rainfall (the 'Wet Season', or 'Gudjweg'), followed by months of very little to nil rainfall (the 'Dry Season', in particular the Aboriginal season of 'Wurrung'). This strong seasonality causes a great change in the physical environment for aquatic inhabitants of the river at the reaches of the study site, frequently resulting in a complete loss of water from shallow pools, with a resulting complete extinction of their aquatic fauna which is unable to migrate to a new water body.

Study site pools were selected in July during the dry season of 2000 in the upper-middle reaches of the Magela Creek. These ranged in distance from around 2 km – 4 km up the Magela Creek from the downstream confluence of the Georgetown Creek.

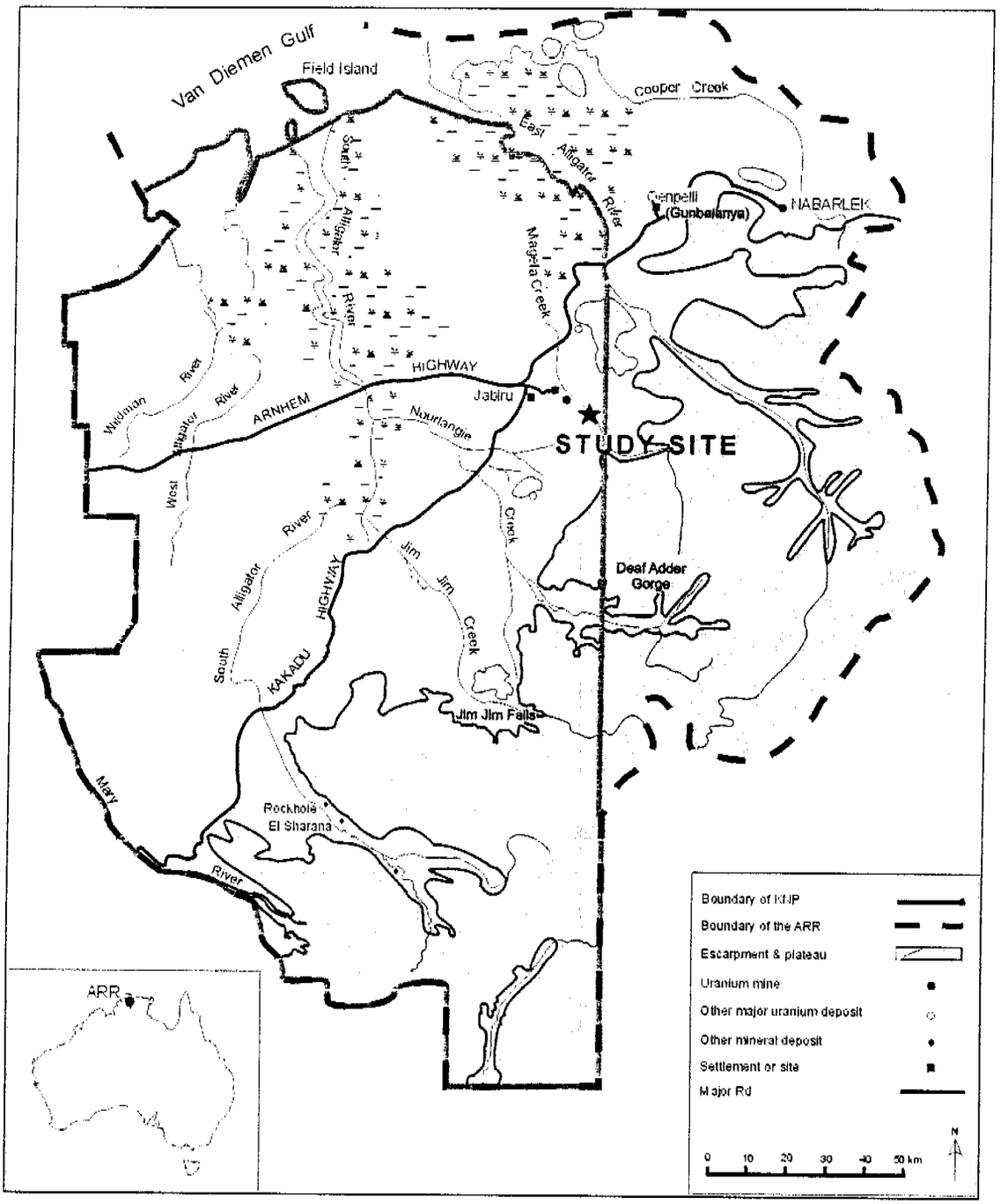

Figure 1 Study site location in Kakadu National Park in the Northern Territory of Australia.

METHODS

All data analysis was made on a PC with the software packages Minitab (Minitab Inc. 1998), and SigmaPlot (SPSS Inc. 2000).

Macroinvertebrates

Field sampling

The macroinvertebrate sampling protocol closely followed that of Jones (1995), with the exception of the use of an electric benthic sampler (Figure 2, Plate 3) after Brooks (1994), and a smaller substrate sample diameter of 0.0625 m^2 (c.f. 0.1256 m^2) being used to collect macroinvertebrate samples from semi-random locations within each pool.

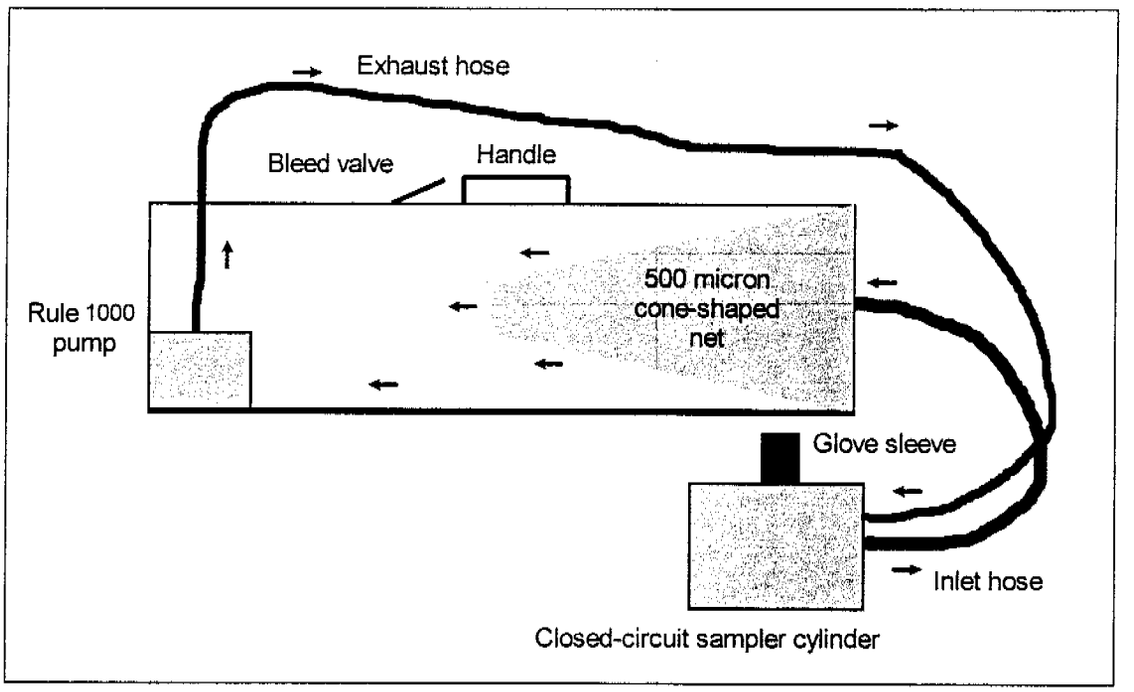

Figure 2 Cross-section of design of benthic macroinvertebrate sampler used in the study.

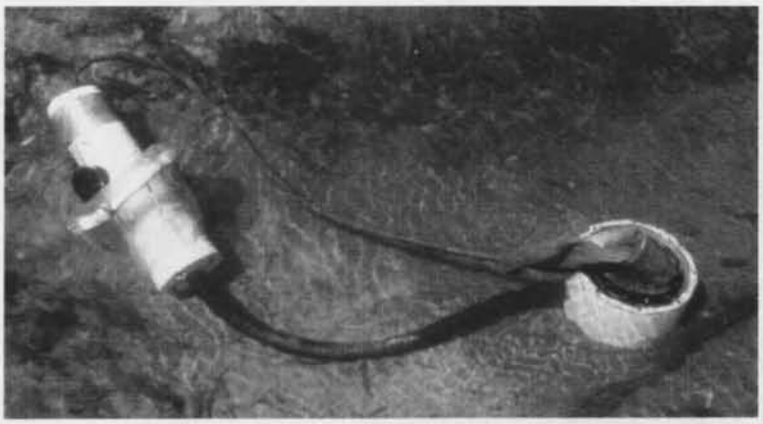

Plate 3 Benthic sampler device in pool.

Pools were selected to be of *c.* 50 m^3 in volume, and of an initial water column depth greater than 0.5 m. All pools selected were flowing, although most ceased to flow very soon after. Initial sampling design called for 25 pools in 5 clusters of 3 close pools each (each cluster separated by approximately 100 m). However, there was significant reductions and other changes made to this original design as follows, due to recognition of an unrealistic original sampling regime load. For the initial sampling of the pools in their lotic state, 6 replicate samples were taken from each second pool of the original 25 along a longitudinal sequence (consequently a total of 6 * 12 = 72 samples were taken). However, for the next 2 temporal sampling occasions, 6 replicates were then taken from 3 pools from each site (including pools sampled on the first occasion) giving a total of (6 * 15) 90 samples for the next 2 sampling occasion thereafter. This sampling regime therefore failed to deliver data for pools sampled on the 2nd and third occasions, but not on the first. Pool data collected is therefore summarised as follows (Table 1).

Table 1 Pool data collected

Site	Old pool name	New pool name	1st	2nd	3rd
	1	1		√	√
1	2	2	√	√	√
	4	3	√	√	√
	1	1	√	√	√
2	3	2	√	√	√
	5	3	√	√	√
	2	1	√	√	√
3	4	2	√	√	√
	5	3		√	√
	1	1	√	√	√
4	3	2	√	√	√

	5	3	√	√	√
	2	1	√	√	√
5	4	2	√	√	√
	5	3		√	√

Note: √ indicates full macroinvertebrate data collected for this session.

Macroinvertebrates were collected in 3 temporally-spaced sampling sessions, with a time interval of 3 weeks in between each session. All samples throughout the experiment were taken from a standardised depth of *c.* 200 mm; (this depth maintained throughout sampling). Sample sediments were agitated by hand for 120 seconds, to a depth of approximately 50 mm whilst the sample was taken. Sample mesh used in the sampler was 500 µm.

When complete, each sample was emptied from the removable benthic sampler filter and rinsed through another 500 µm sieve to remove further inorganic debris. The remaining macroinvertebrate and substrate material were then rinsed and stored with 80% ethyl alcohol into 100 ml plastic bottles for transport back to the lab.

Laboratory processing

Following entry of all samples into the Section's Microsoft Access macroinvertebrate sample registry, samples were rinsed again through 1,000 µm and 500 µm sieves nested in reach other under tap water to further remove fine debris and remove the coarser fraction.

Animals were then sorted from surrounding debris and identified to taxonomic level based on the following rationale. Where animals were difficult to key (e.g. due to larval instars being too small of size, or external damage to animals), and the ecological differences between these lower levels did not justify the extra effort, these animals were only keyed to the higher taxonomic levels such as order e.g. orders Collembola and sub-order Oribatida and remaining Acariformes. With animals groups where keying was relatively simple and reliable, and/ or significant differences in ecological were suspected, keying was to genus or even species in some cases e.g. *Tasmanocoenis* spp. and *Austrogomphus mjobergi.*

Limits were also placed upon taxonomic resolution by the macroinvertebrate database used for data storage, with some lower levels of taxa being unable to be recorded e.g. the genus *Aedes* was recorded at the higher taxonomic level of Culicidae.

The following taxonomic levels and keys used in this study were as follows;

Mites (order: Acariformes) were separated into oribatid mites and remaining suborder members via Harvey & Growns (1998).

Caddisfly larvae (order: Trichoptera) were identified to genus level in most cases via St. Clair (1997, 2000), and Wells (1985, 1991, 1997) with Helicopsyche larvae identified to species level via Johanson (1995) and Wells (1991).

Beetle larvae (order: Coleoptera) were sorted to family level in the cases of the Dytiscidae and Corixidae, and species in the cases of the genus Elmidae (Glaister 1991, 1999).

Mayflies (order: Ephemeroptera) were sorted to family level in the cases of the Leptophlebiidae and Baetidae, and genus in the cases of the family Caenidae (Suter 1996, 1999).

Two-winged flies (order: Diptera) were sorted to family level in the cases of the Ceratopogonidae and Culicidae, and genus in the cases of the family Chironomidae (Cranston 1991).

Dragonflies (order: Anisoptera) were sorted to family level in the cases of the Corduliidae, and species in the cases of the family Gomphidae via Hawking (1993).

Molluscs were identified to genus level via Smith (1996).

Decapod crustaceans were identified to family level using Horwitz (1995).

In addition to these specialised keys, the general keys of Williams (1980) were also used as an accessory aid.

Water chemistry

A single water sample was taken of the flowing state of the Creek from Site 2 immediately before sampling on the first occasion for the following parameters using a variety of single-parameter instruments. These data were used to represent the state of all pools in the flowing Creek at this time.

- Dissolved oxygen (mg/l).
- Conductivity (µS/cm).
- pH (pH units).
- Temperature (°C).

Single water samples of environmental factors in each pool were taken for both second and third sampling sessions prior to disturbance using a 'Horiba U10 water checker' multi-parameter meter, of the following parameters.

- Dissolved oxygen (mg/l).
- Turbidity (Nephelometric Turbidity Units, NTU*).

- pH (pH units).
- Temperature (°C).
- Conductivity (µS/cm).

* It should be noted that the Horiba U10 Water Checker fails to deliver an established NTU measurement based on its non-standard turbidity probe design, this specifically being due to the Water Checker using an optical receptor set at 30° rather than at the Standard Methods 2130 B. approved angle of 90° +/- 30° (i.e. 60° – 120°) (APHA et al 1998).

In many cases, samples for water column turbidity were also taken immediately after sampling had finished at a pool site.

The following parameters were measured in the laboratory from returned samples.

- Organic fractions (TOC, combustible Fine Particulate Organic Matter (FPOM) calibration samples and combustible Coarse Particulate Organic Matter (CPOM)).
- Chlorophyll pigments a, b, and c.

Effect of low buffered waters on field measured pH

A small experiment was also carried out to determine what effect that the extremely low buffering capacity of test waters may have on measured pH; especially if high equilibrium times were not being realised.

Various (100% - 2%) dilutions of pH 4.01 buffer were produced from freshly prepared stock solution (APHA et al 1998). A laboratory pH meter then analysed each sample, and a note was made of the pH recorded at various time interval.. No mixing devices were used at this time. Finally, the specific conductance of the sample was measured.

Organic fractions

3 different forms of organic matter were measured. These included; Total Organic Carbon (TOC) in the water column, combustible Fine Particulate Organic Matter (FPOM) less the Ultrafine Particulate Organic Matter (UPOM) fraction, and Coarse Particulate Organic Matter (CPOM). All carbon samples were stored in either 2% nitric-acid rinsed glass McCartney bottles or in 2% nitric-acid rinsed high-density polypropylene plastic containers (Speers & leGras 1997) and frozen until analysis.

For this study, similar to standardised organic fraction sizes (Table 2), the following fractions and definitions were used (Minshall 1996) (Table 3).

Table 2 Standardised organic fractions

Fraction	Less than	Greater than
DOM	0.45 μm	*
FPOM	1,000 μm	0.45 μm
CPOM	*	1,000 μm

Table 3 Fractions used in this study

Fraction	Less than	Greater than
DOM	0.45 μm	*
FPOM	500 μm	0.45 μm
CPOM	*	1,000 μm

Single samples of pool water were taken for later laboratory analysis of the pool's DOC content (total of 20 replicates) from around its margin in 60 ml 2% nitric-acid rinsed high-density polypropylene plastic containers (Speers & leGras 1997).

Following the 2 minutes of macroinvertebrate sampling, the turbidity of filtrate water in the sampler head was measured by inserting the probe of a 'Horiba Water Checker U-10' portable multiparameter meter. Although the Nephelometric Turbidity measuring design of the Horiba does not meet this method's accepted criteria (APHA et al 1998), it still enabled a rapid analysis to be made of the turbidity. c.f. Jones (1995), these filtrate turbidity data were then used as a surrogate for the finer fractions of organic matter (DOC). A sample of filtrate (total of 19 replicates) of 1 l was then removed from the sampler head into a 2% Nitric acid-rinsed high-density polypropylene bottles from random samples for the analysis of its FPOM content, in order to calibrate and validate the correlation between turbidity and FPOM in these samples.

Fine particulate organic matter (FPOM)

Combustible FPOM was determined by filtering the 1 l benthic sampler filtrate samples through 'Whatman' brand ultra-fine glass fibre paper (GFC) filter disc of approximately 0.45 μm pore size. This material was dried for 24 hours at 105 °C, weighed and then ashed (due to the expected presence of significant amounts of inorganic sand) for 24 hours at 550 °C, and then weighed again. The difference with the sample weights was then determined, given the mass of carbon, which had been present in the sample (c.f. Dostine et al. 1992a).

Normally, aluminium containers are ashed prior to samples being placed in them as there is though to be a layer of oil on their surface which is lost during the ashing process. A sample of 10 GFC discs and 10 aluminium pie dishes were therefore also taken through the same

drying and ashing process to assess if they displayed significant weight loss that may confound results of FPOM and CPOM; being weighed immediately after drying and then immediately following ashing.

Coarse particulate organic matter (CPOM)

CPOM was collected in the same samples as those for macroinvertebrates, and was then processed following sorting of macroinvertebrates from this waste debris. The mass of this material was determined by combustion following drying and weighing as per FPOM.

Pool volumes and surface area

Pool dimension data was collected following final macroinvertebrate collection by measuring maximum pool width (2 x r_1), longest length (2 x r_2) and greatest pool depths (r_3) dimensions. At least 10 random spot depths were also collected and averaged to provide an average pool depth.

Pool surface area calculations were calculated as for an ellipse i.e.

Equation 1 Pool surface area = $r_1 r_2 r_3$

Pool volume calculations were made by treating the pool volume as half an ellipsoid i.e.

Equation 2 Pool volume = $(1/2) \times 4/3 \pi r_1 r_2 r_3$

After (Korn & Korn 1968).

Phytoplanktonic algae biomass

Field collection

A week after the final macroinvertebrate collection 0.5 l of mid-column water was collected from the centre of a pool into a jar, placed into an ice slurry, and then brought back to the laboratory in a darkened chilly-bin.

Laboratory processing

Processing and analysis of phytoplanktonic algae closely followed the recommendations of Steineman and Lamberti (1996) and Franson et al (1998). All processing took place under low-light conditions to reduce light induced chlorophyll degradation (APHA et al 1998).

Each water sample was promptly filtered through 'Whatman' brand ultra-fine glass fibre paper (GFC) filter disc of approximately 0.45 μm pore size. Typically 3 discs were required due to clogging of the filter pores with the amount of organic material being filtered with unused discs being added to samples to maintain this total where were filter discs had been required. The resulting filtered material and filter disc were then placed into 40 ml of a 90% acetone/ water mixture in a 60 ml high-density polypropylene bottle, shaken and then refrigerated at 4 °C for 24 hours.

Samples were then finely ground in a 'Janke & Kunkel Ultra-Turrax T25' tissue macerator at 24,000 RPM for 10 minutes, replaced into a refrigerator fridge at 4 °C, and left for a further 24 hours.

Following further removal of chlorophyll into solution, the sample bottles were centrifuged at 1,200 RPM for 15 minutes at 4 °C in a refrigerated 'MSE Coolspin' centrifuge to clarify.

3 ml of clear sample was then analysed for discrete spectral absorption in a 'Perkin Elmer Lamba 2' Scanning UV/Visible Spectrophotometer at the following wavelengths.

Table 4 Chlorophyll sample wavelengths spectrophometrically analysed

Wavelength (nm)	Rationale
630	Chlorophyll *c* absorption peak
645	Chlorophyll *b* absorption peak
664	Chlorophyll *a* absorption peak
750	Turbidity control wavelength

Calculations to convert these sample concentration values to study pool concentrations were then followed after APHA et al (1998).

Inter-pool and Groundwater flow

Field collection

Potential for interchange of $MgSO_4$ solute between pools through groundwater flow during pool spiking experiments to follow was determined by spiking a pool downstream of the Ranger discharge site (e.g. near bankside biomonitoring site 009) with a known concentration of both Rhodamine B and Magnesium sulphate (approximately 10 ppb and $3.3x10^{-04}$ mol. l^{-1} respectively) during September 2000.

Adjacent pools, especially those downstream of the treated pool, were then immediately sampled for Magnesium ions and Rhodamine B fluorescence to establish baseline chemistry conditions and also as blanks for fluorometer calibration. Samples from the spiked and adjacent pools were then sampled again the next morning following time to permit even mixing of solutes. Thereafter samples were taken approximately twice each week, to determine changes in these parameters due to an interchange of water between pools.

As a control, a black 75 l tub of Magela Creek water placed on the bankside, partially filled with typical billabong sediment and exposed to similar environmental conditions e.g. thermochroic effects and photic levels. This waterbody was also sampled approximately twice a week for degradation of dye (measured as a loss of concentration). 'Millipore' filtered reagent water was added at these times to maintain the water volume lost to evaporative losses. This control body was stolen in October brining the experimental data collection to an early close.

Laboratory processing

60 ml samples were returned for laboratory analysis in 2% nitric acid-rinsed high-density polyethylene bottle and placed in 4 °C cold storage in a dark refrigerator to reduce chemical degradation until analysis. Concentrations of Rhodamine B and Magnesium ion concentrations are still to be made via fluoroscopy and High-Pressure Liquid Chromatography (HPLC) respectively.

Rate of pool water level drop

Star pickets were placed in a single deep pool for each cluster of 5 pools with their tops at the surface with the change in water surface height (i.e. extent of water level drop) from this datum measured approximately every 3 –7 days.

RESULTS

Macroinvertebrates

Due to the incompletion of macroinvertebrate sorting data entry and analysis, no results will be presented at this stage.

Water chemistry measurements

All environmental data from pool sampling has now been collected, analysed and entered, pending the final analysis of CPOM samples following the completion of macroinvertebrate sorting.

Temperature

Although also likely to be confounded an artefact of differing sampling times in the day, pool temperatures varied notably both between sampling times, and also between sampling sites (Figure 3).

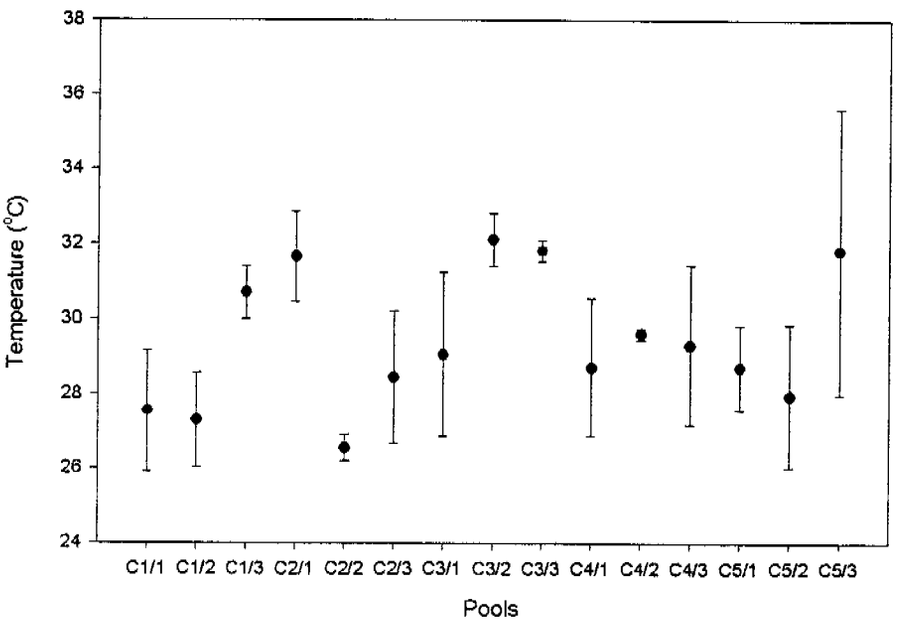

Figure 3 Temperature (°C) results for all 3 sampling sessions (n = 3). Error bars indicate standard deviations.

Even given confounding effects of pool sampling at inconsistent times of the day, in almost all cases pool temperatures increased over the study period, in one case reaching a maximum of 34.5 ^{o}C in the uppermost study pool which had a wide, shallow and sun-exposed riffle feeding into it (Figure 4).

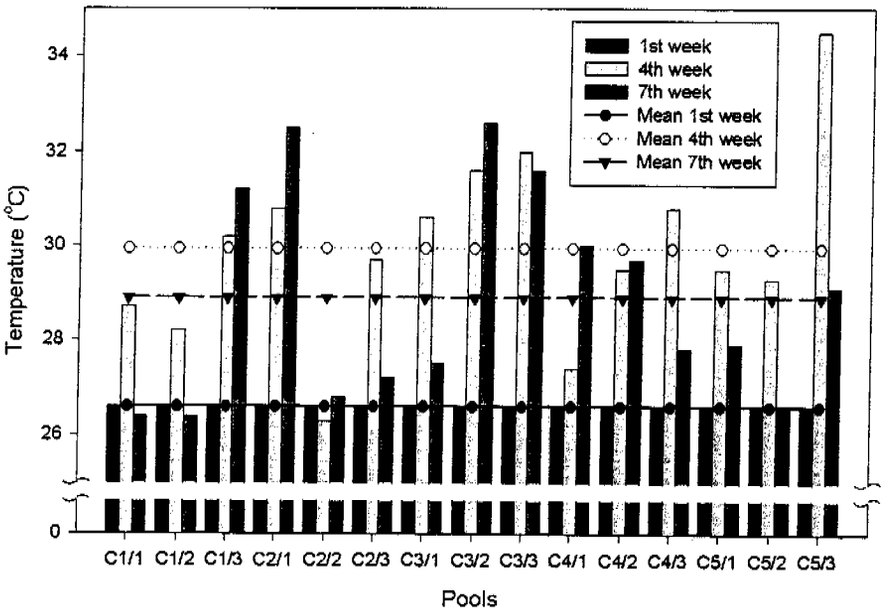

Figure 4 Changing temperature values of pool water column through time. Consecutive sampling weeks were approximately 21 days apart.

Surprisingly, 7th week temperatures (third and final sampling session) were not always higher than 4th week (second sampling session) temperatures. In fact 4th week temperatures were on average 1 ^{o}C warmer (29.9 ^{o}C versus 28.9 ^{o}C of the final week), with a mean value being expected to remove most confounding error due to sampling time differences. Although all the data for this parameter arrived from a single collection point at Site 2, a one-way ANOVA based on a pooled standard deviation identified the pools of the first sampling session as having a highly significantly lower water temperature than those of later sampling sessions ($n = 15$, $df = 44$, $p < 0.001$).

Dissolved oxygen

Dissolved oxygen was also variable between and within sites, and there appeared to be no trend in these data (Figure 5). However, significant confounding due to diurnally dynamic rates of photosynthesis and respiration by benthic and pelagic algae, atmospheric reaeration coefficients and biochemical and biological demand are likely to confuse any such patterns when only spot measurements are taken.

Of all chlorophyll pigment concentrations suspected as being predictors to turbidity, a best-subsets multiple linear regression identified chlorophyll a alone as being the only significant contributor ($r^2 = 0.468$, n = 15).

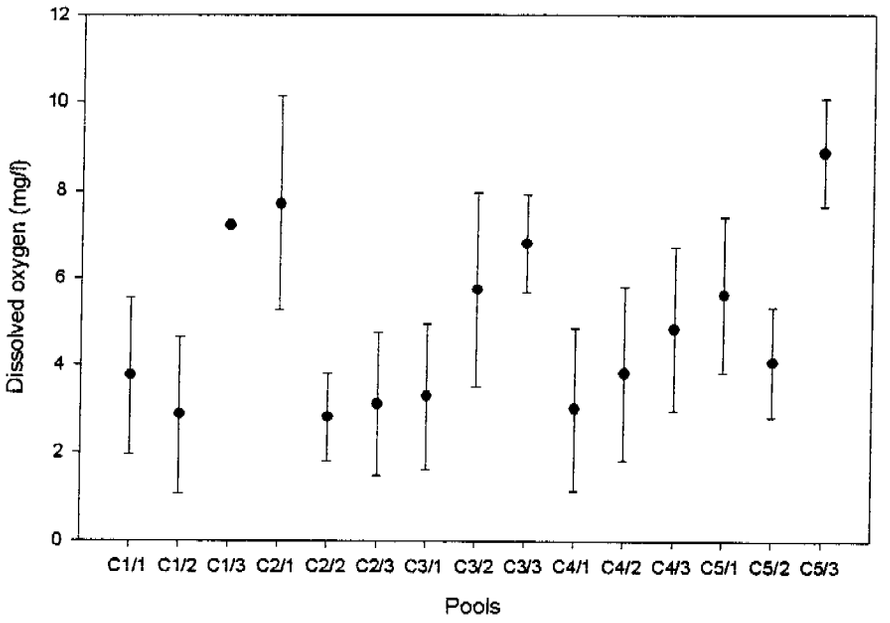

Figure 5 Dissolved oxygen (DO) results for all 3 sampling sessions (n = 3). Error bars indicate standard deviations.

In general, however, there was an overall trend for dissolved oxygen values of decreasing oxygen saturation in the water column of the pools through time (Figure 6). Again although all the data for this parameter arrived from a single collection point at Site 2, a one-way ANOVA based on a pooled standard deviation identified the pools of the first sampling session as having a significantly higher oxygen saturation than later sampling sessions (n = 15, df = 44, $p < 0.001$).

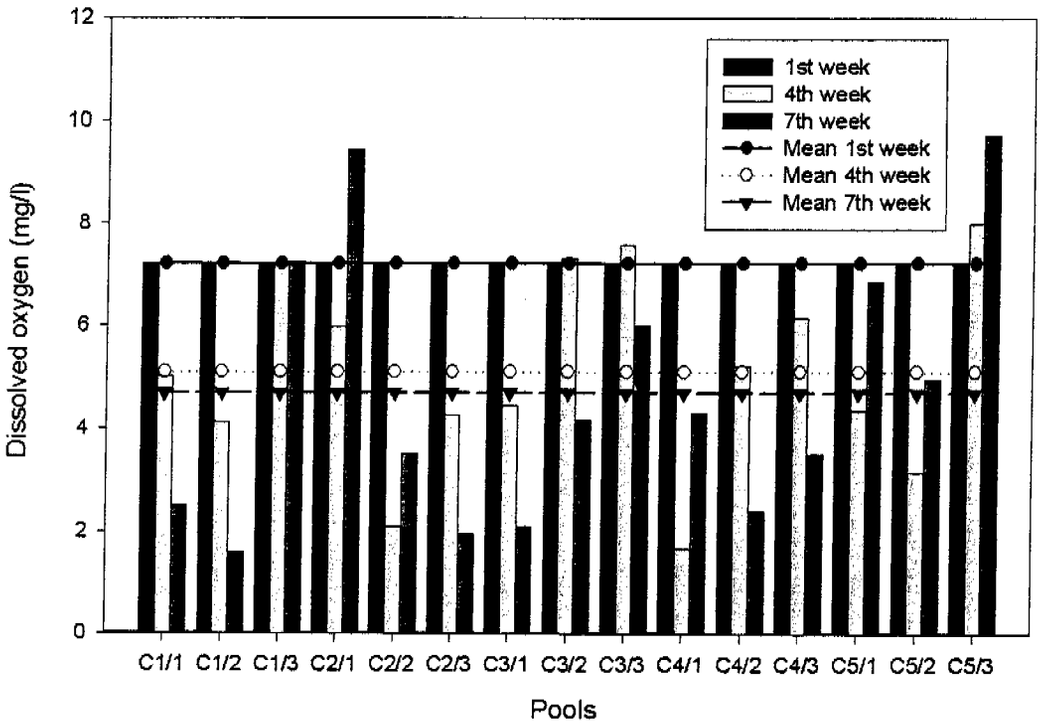

Figure 6 Changing dissolved oxygen values of pool water column through time. Consecutive sampling weeks were approximately 21 days apart.

Total organic carbon

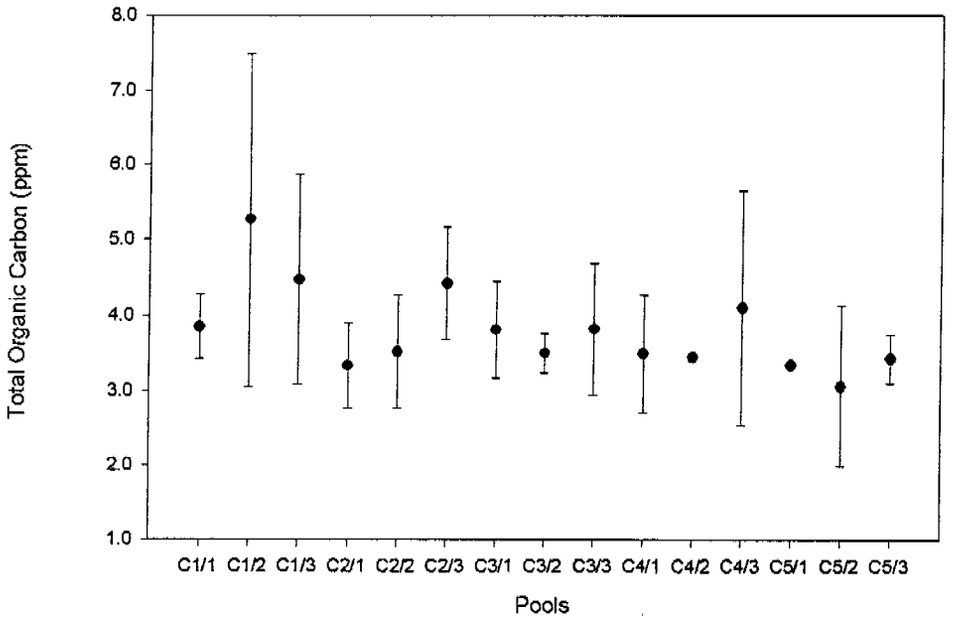

Figure 7 Total Organic Carbon (TOC) results for last 2 sampling sessions (n = 2). Error bars indicate standard deviations. Note: only single data results for pools 4/2 and 5/1.

Water column TOC increased in all pools from the 4th to the 7th week's samples, with the 7th week values for TOC on average 1.1 ppm greater (4.4 ppm versus 3.3 ppm) than those of the final week (Figure 8). Based on previous work in this area, it is expected that the greater component of organic carbon in the water of the pool would be in the form of DOC (Chris leGras et al in prep.).

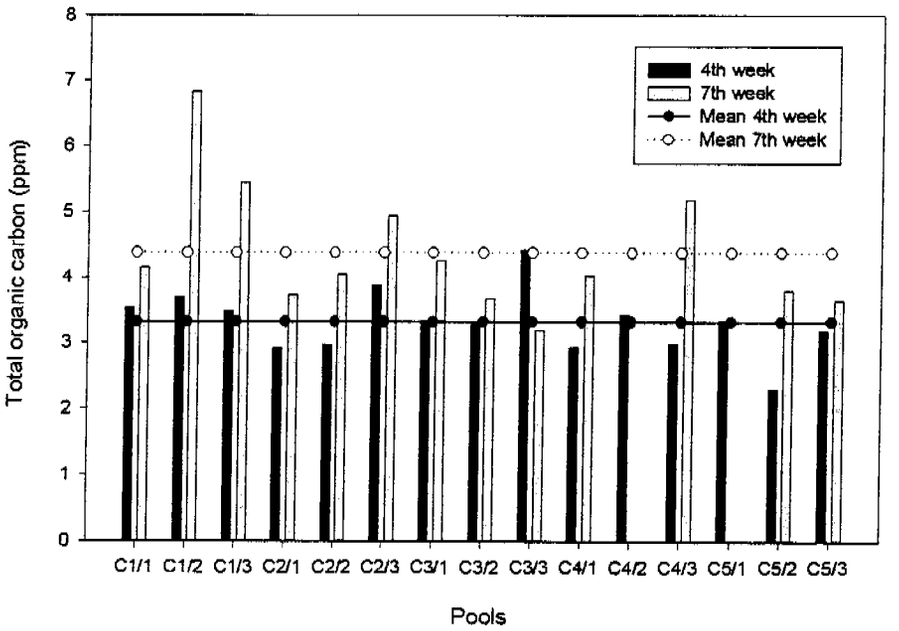

Figure 8 Changing total organic carbon values of pool water column through time. Consecutive sampling weeks were approximately 14 days apart. Note: only single data results for pools 4/2 and 5/1.

A one-way ANOVA based on a pooled standard deviation identified the pools of the 7th and final sampling session as having a significantly higher TOC than the previous sampling session ($n = 13$, $df = 27$, $p < 0.001$).

pH

In general, pool pH showed notable variation, however all recorded values were less than pH 7.0 (acidic) (Figure 9).

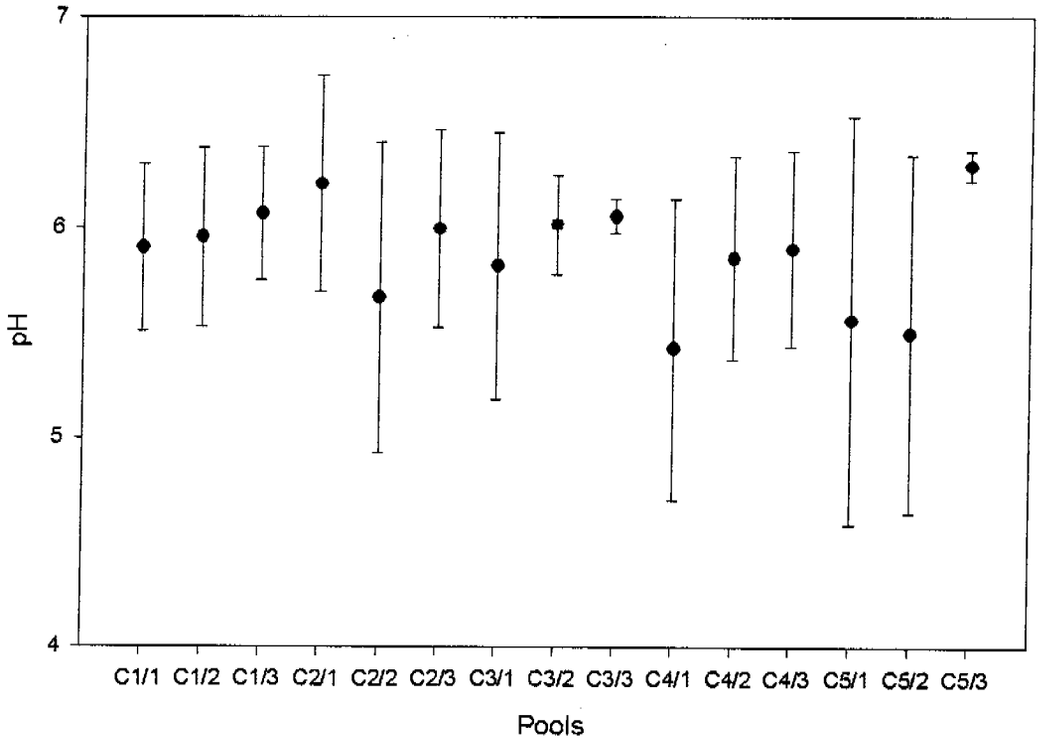

Figure 9 Pool water pH for all 3 sampling sessions (n = 3). Error bars indicate standard deviations.

A one-way ANOVA based on a pooled standard deviation identified the pools of the 2nd sampling session as having a significantly higher pH than the other sampling sessions ($n = 13$, $df = 44$, $p < 0.001$) (Figure 10).

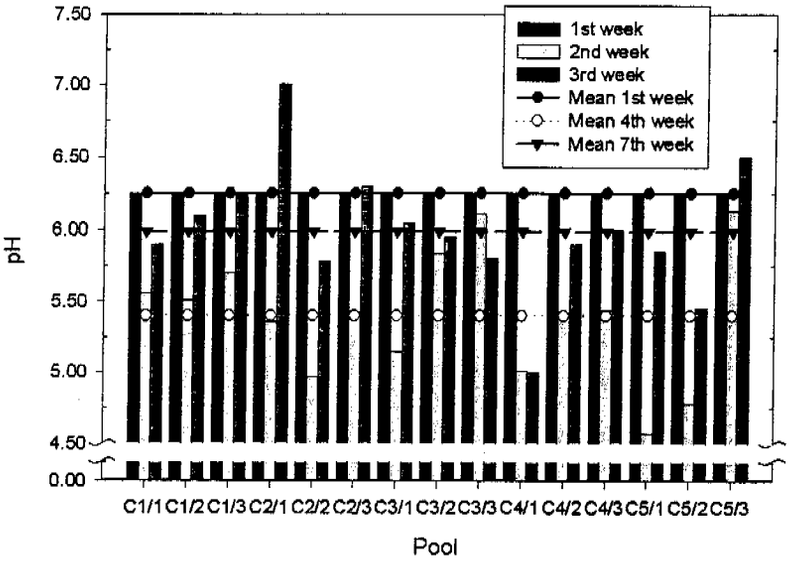

Figure 10 Changing pH of pool water column through time. Consecutive sampling weeks were approximately 21 days apart.

Specific conductance

As typical of the Alligator Rivers Region area, specific conductance was low in all pools (< 35 µS/cm) (Figure 11).

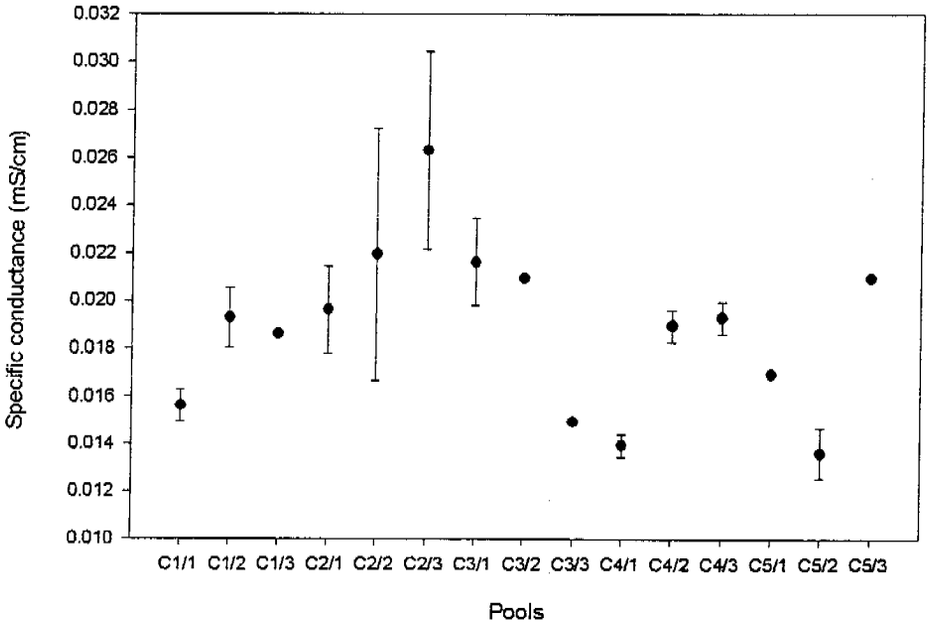

Figure 11 Pool water specific conductance for all 3 sampling sessions (n = 3). Error bars indicate standard deviations.

Mean pool water specific conductance increased over time, from 0.014 μS/cm to 0.016 μS/cm and then finally to 0.027 μS/cm (Figure 12). Specific conductances of the 7th week were significantly greater than those of previous weeks ($n = 13$, $df = 44$, $p < 0.001$).

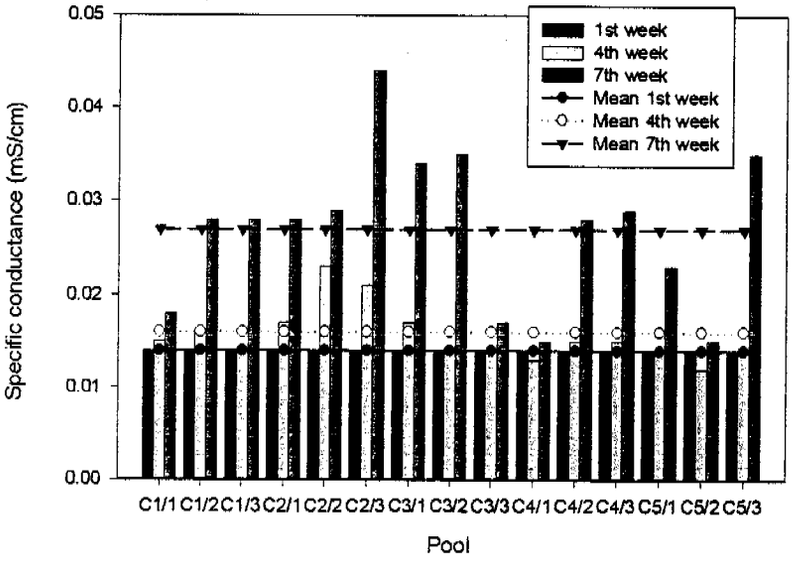

Figure 12 Changing specific conductance of pool water through time. Consecutive sampling weeks were approximately 21 days apart.

Turbidity

For most pools, turbidity was not particularly variable (Figure 13).

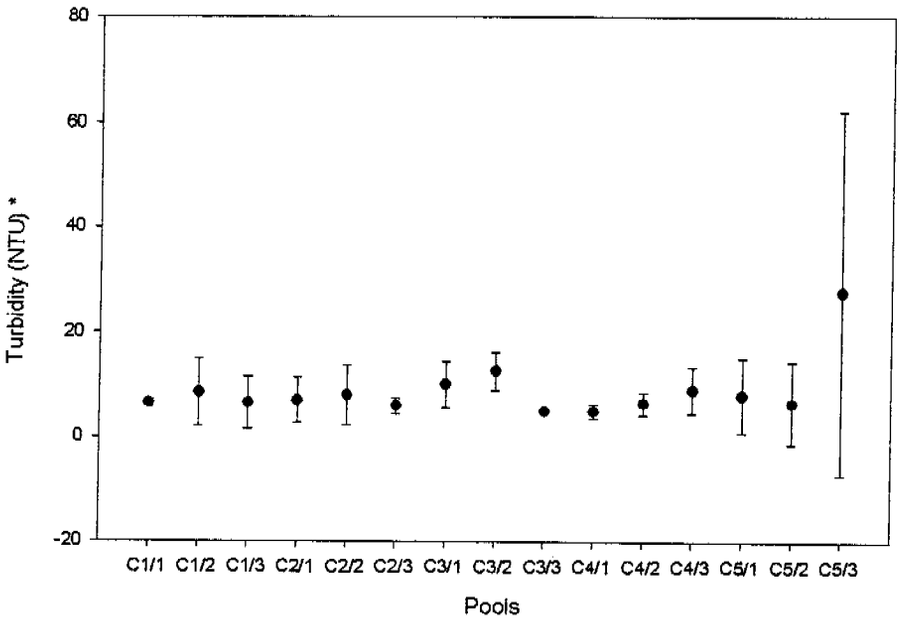

Figure 13 Pool water turbidity prior to macroinvertebrate sampling for last 2 sampling sessions. Error bars indicate standard deviations (n = 3). * Note that the turbidity instrument technology used is not by a Standard Method (APHA et al 1998).

In the 7th week, the uppermost pool (5/3), greatly increased its water column turbidity (Figure 14), and a very high chlorophyll a concentration was also recorded shortly after (Figure 26). Turbidity was found to be strongly positively correlated with water column chlorophyll a concentration (r = 0.81) (Figure 15).

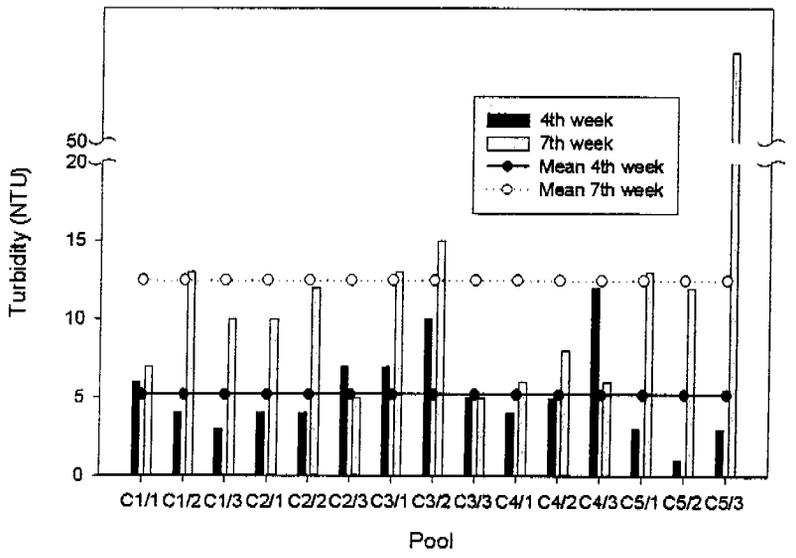

Figure 14 Changing turbidity of pool water through time. Consecutive sampling weeks were approximately 21 days apart.

Organic fractions

Fine particulate organic matter (FPOM)

Prior to FPOM analysis, pools with extremely high outlier chlorophyll a results were excluded from the FPOM/ CPOM regression due to their FPOM estimates thought to have been confounded by the high turbidity resulting from the algal biomass of these waters. This was confirmed with a stepwise multiple regression (Appendix A). Of all chlorophyll pigment concentrations suspected as being predictors to turbidity, chlorophyll a was identified as the only significant contributor (r^2 = 65.08, t = 4.92, n = 15) (Figure 15). Sample data for the third replicate of the third sampling session of the uppermost pool (5/3/3) was therefore not included in this FPOM analysis due to its extremely high chlorophyll a value (66.73) correlating strongly and therefore thought to have contributed to a very high pool turbidity (117 NTU, Figure 13).

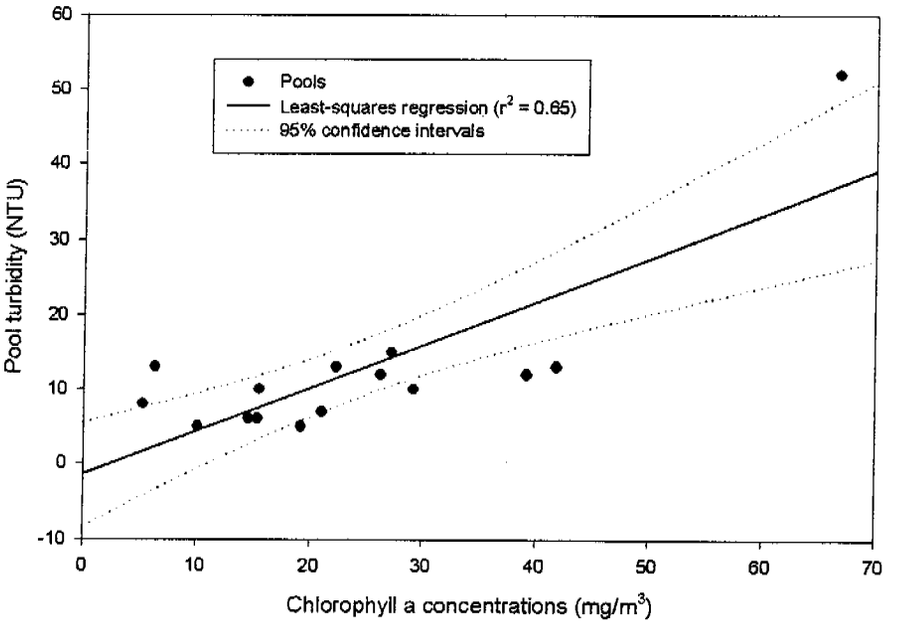

Figure 15 95% confidence intervals and least-squares regression for chlorophyll a concentration over turbidity. Regression line equation: y = 0.58x –1.41 (n = 15).

FPOM appeared to generally increase in pools over time (Figure 16) although, as denoted by the error bars, it remained notably variable, or 'patchy' across the sample pool.

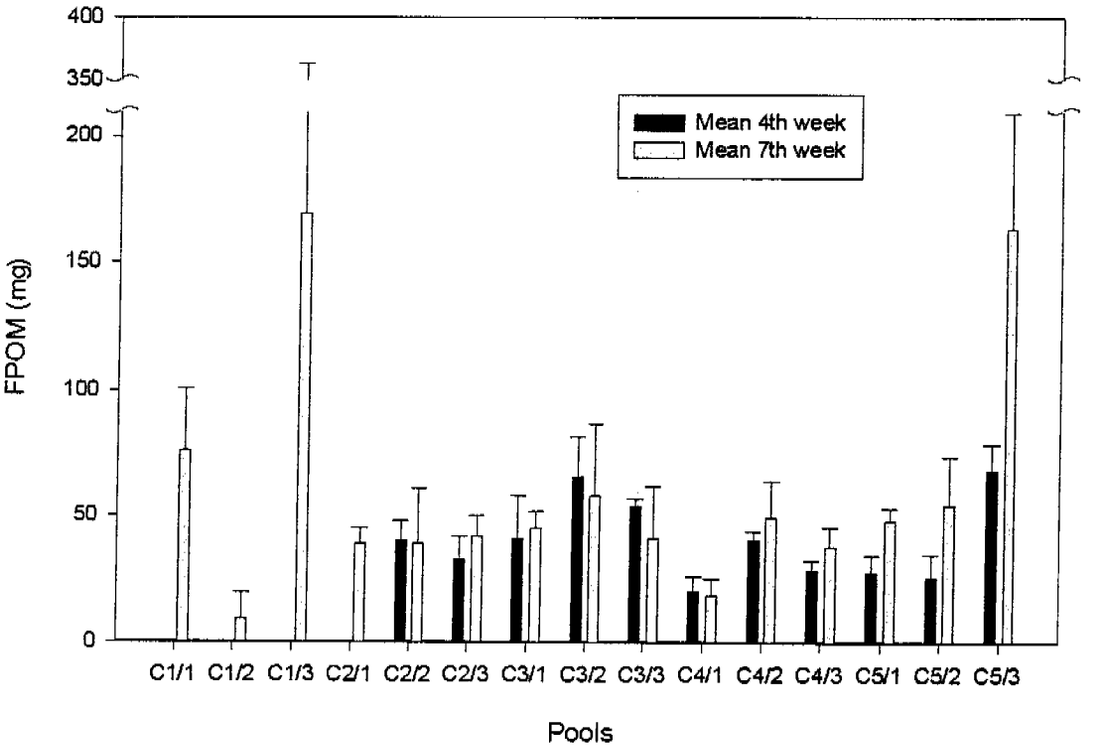

Figure 16 Changing FPOM of pool samples through time. Consecutive sampling weeks were approximately 14 days apart. Note: data for the 7th week are absent from samples 1/1 though to 2/1. Error bars indicate standard deviations (n = 2).

There was no significant difference between FPOM samples of the sampling sessions of week 4 and week 7 ($n = 29$, $df = 69$, $p = 0.064$).

The methodology for determining the masses of FPOM (as suspended matter) was validated by the results of Figure 17 and Figure 18 where an extremely low mass of sample filter and container loss was displayed.

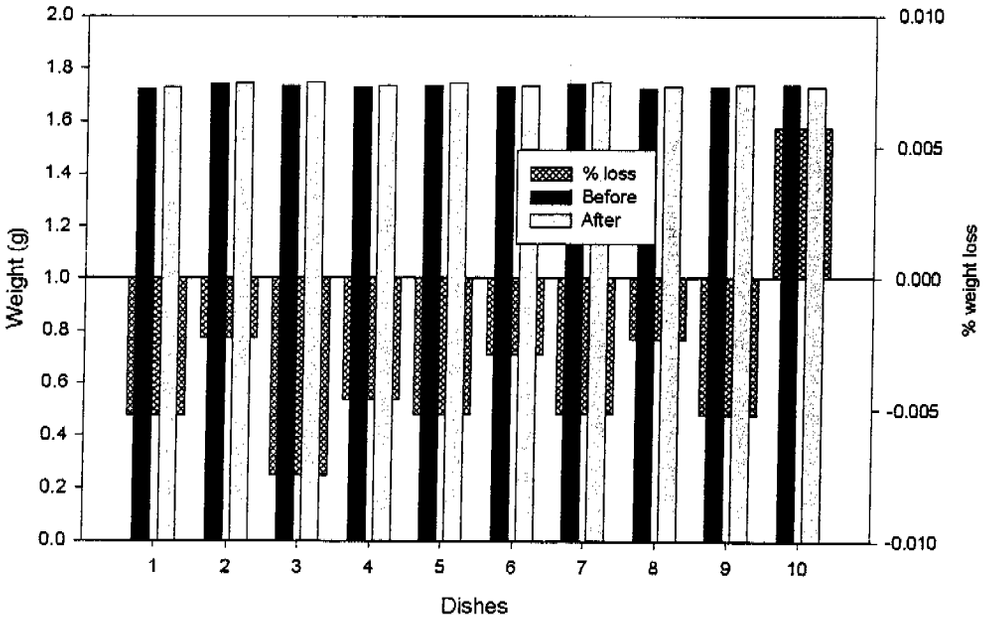

Figure 17 Weight loss for aluminium dishes following drying at 105 °C for 24 hours, and then ashing at 550 °C for 24 hours.

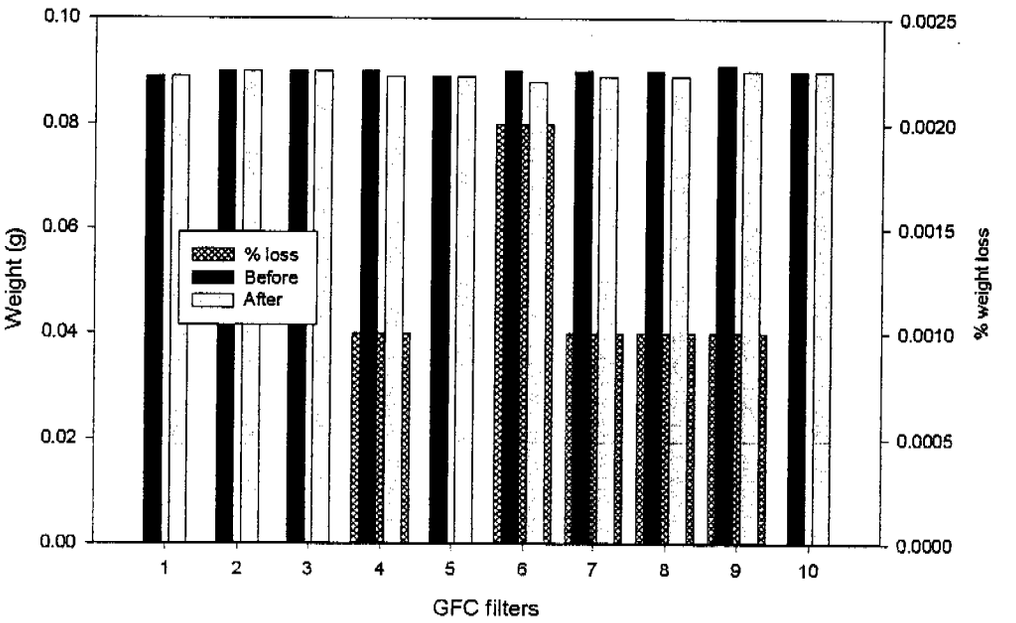

Figure 18 Weight loss for 'Whatman' glass fibre ('GFC') discs following drying at 105 °C for 24 hours, and then ashing at 550 °C for 24 hours.

There was an extremely strong linear correlation of FPOM (as measured by suspended sediment) with the field surrogate response of turbidity (Figure 19)

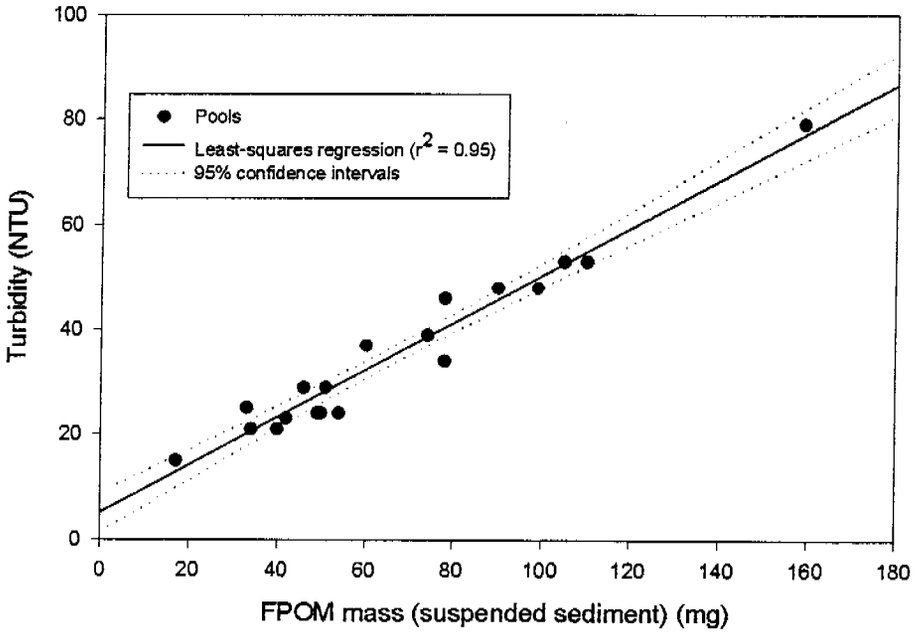

Figure 19 95% confidence intervals and least-squares regression for turbidity over FPOM. Regression line equation: y = 1.602x + 14.173 (n = 19).

Coarse particulate organic matter (CPOM)

There is currently few data on CPOM available from this project at this stage to allow for a notable discussion of this variable here.

However, surprisingly there appears to be no strong relationship between CPOM and FPOM mass (Figure 20).

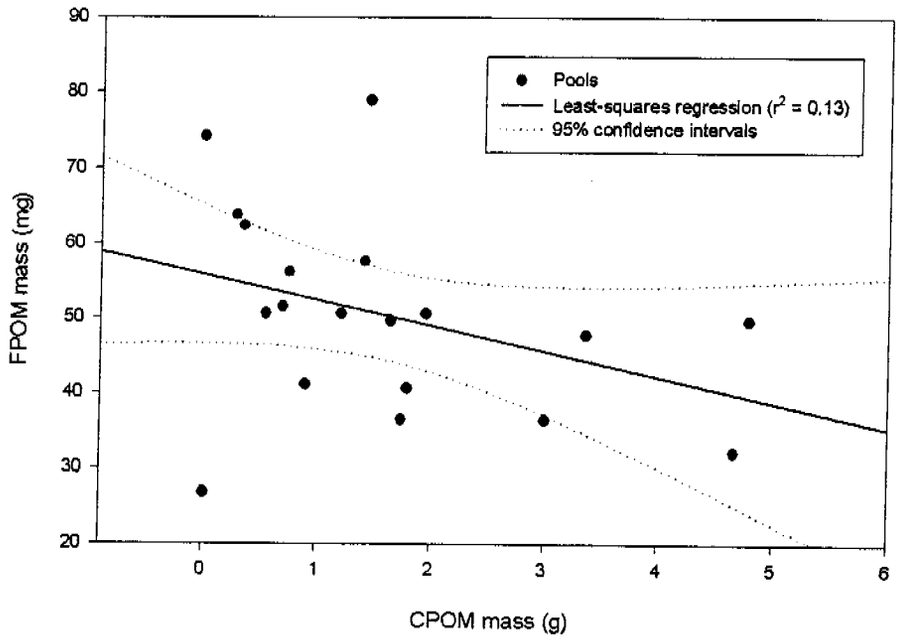

Figure 20 95% confidence intervals and least-squares regression for FPOM over CPOM. Regression line equation: y = 58.185 - 2.952 (n = 19).

Effect of low buffered waters on field measured pH

As expected, there was a very significant linear relationship between buffer concentration and specific conductance (r^2 = 0.99, Figure 21). Initial buffer concentrations demonstrate an extremely high specific conductance relative to typical natural waters of this region which are around 15 – 30 µS/cm in flowing systems (Hart & McGregor 1985, Klessa 2000).

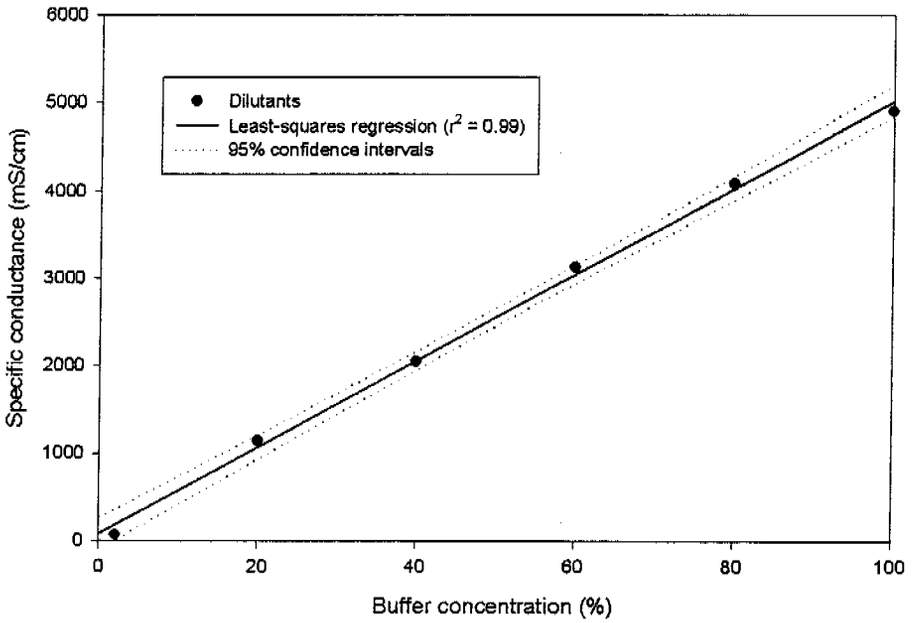

Figure 21 95% confidence intervals and least-squares regression for specific conductance over pH buffer 4.01 (APHA et al 1998) concentration. Regression line equation: y = 49.31 x + 79.82 (n = 6).

Although final equilibrium of the pH results for 100% buffer concentration is notably higher than for other buffer strengths (Figure 22), this is most likely simply a result of the dependence of this buffers value on the concentration of it's single constituent (APHA et al 1998), and is therefore an artefact academic to the primary focus of the experiment.

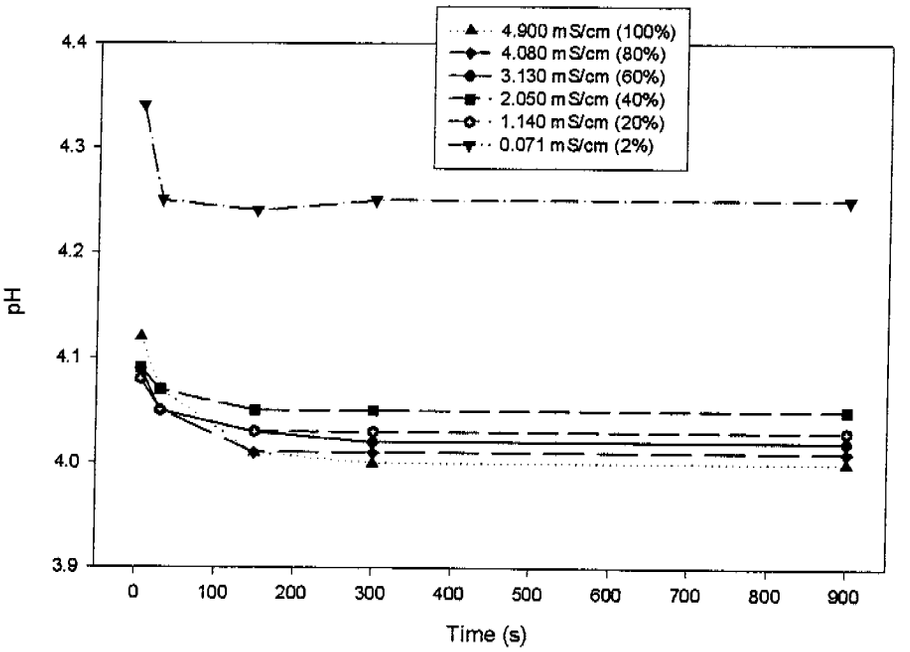

Figure 22 Effect of buffer concentration on equilibrium times of pH readings. Values in parentheses are percentage dilution of standard 4.01 pH buffer (APHA et al 1998).

In all concentrations pH equilibrium appeared to be reached by 300 s (5 minutes), with results at only 150 s (2 ½ minutes) very closely estimating this value. Equilibrium time was notably quicker for the sample of highest specific conductance (4,900 µS/cm), occurring within 30 s.

Lowest buffer specific conductance was still notably higher than these typical values encountered in the field, but appeared to give such very similar equilibration times to higher values that an extrapolation of these equilibrium times to that of lower field values would appear reasonable.

Pool volumes and surface area

Given the range of pools available for this study, final pool volume varied greater than was initially planned, ranging in size from 103.56 m^3 to 1.74 m^3 (Figure 23).

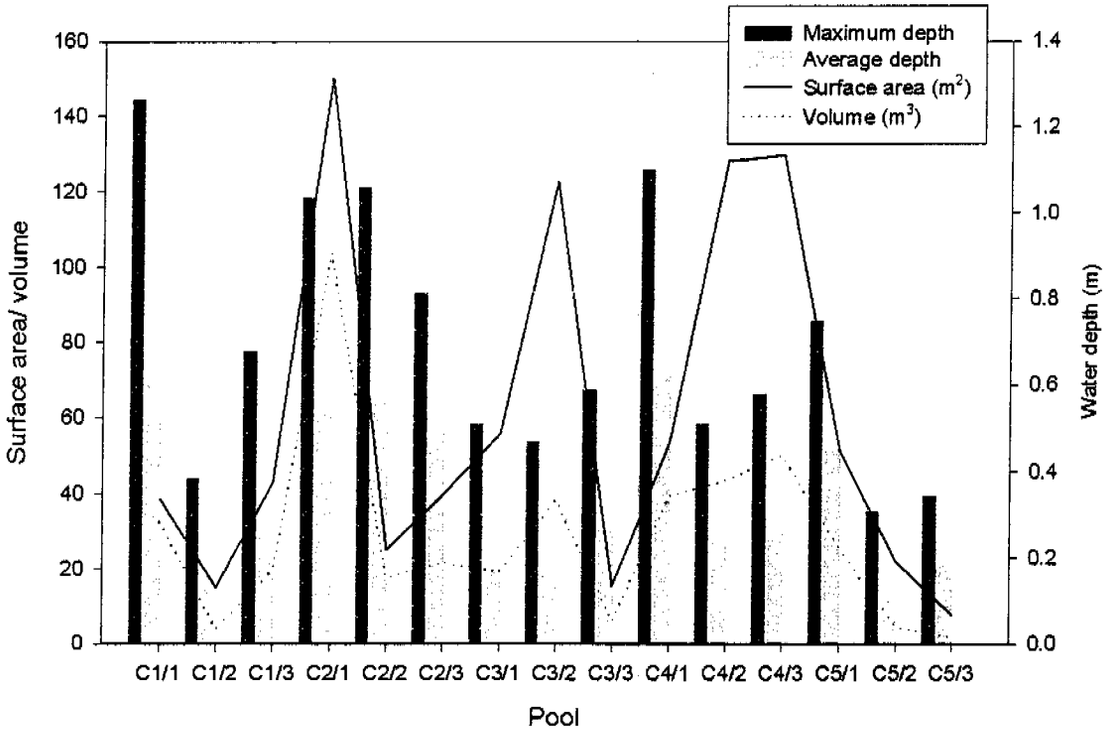

Figure 23 Synopsis of study pool morphology.

There was a strong, positive relationship between pool volume, as calculated by the half-ellipsoid model (Equation 2), and surface area (r = 0.86) as calculated by a geometric oval model (Equation 1) (Figure 24).

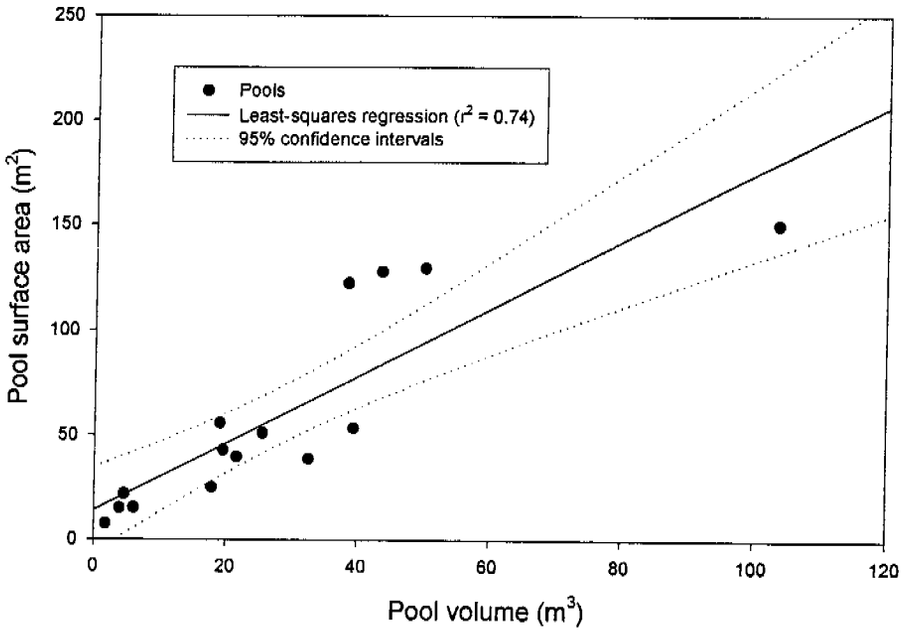

Figure 24 95% confidence intervals and least-squares regression for pool volume over pool surface area. Regression line equation: y = 2.1129x - 7.9398 (n = 15).

There was also an extremely strong, positive relationship between maximum pool depth and average pool depth (r = 0.93) (Figure 25).

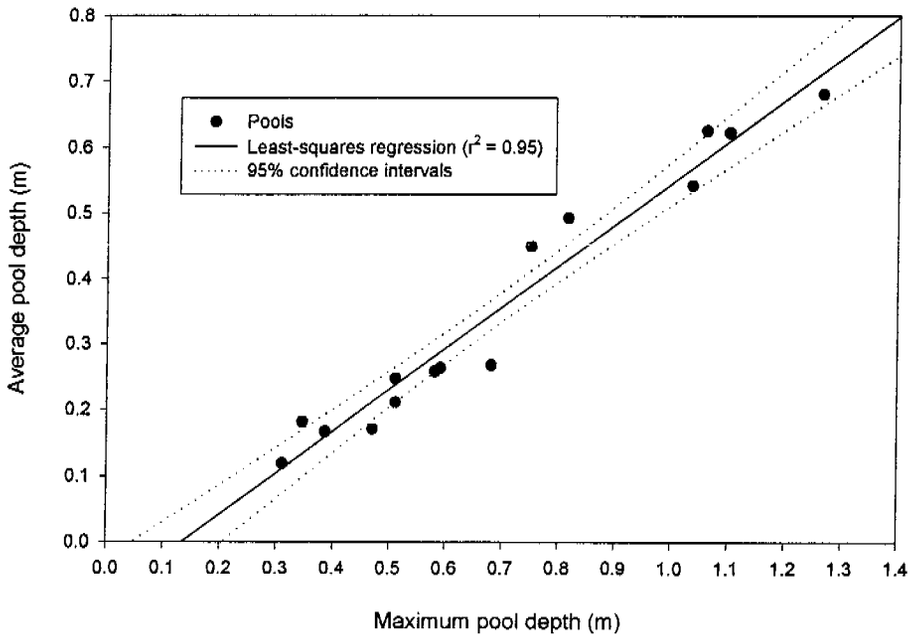

Figure 25 95% confidence intervals and least-squares regression for pool volume over pool surface area. Regression line equation: y = 0.6300x – 0.836 (n = 15).

Mean pool volume was 28.44 m^3, with a standard deviation of 25.78 m^3, pool surface area was 59.73 m^2 with a standard deviation of 47.94 m^2, mean average pool depth was 0.35 m with a standard deviation of 0.19 m and mean maximum pool depth was 0.55 m with a standard deviation of 0.29m.

Phytoplanktonic algae biomass

Chlorophyll a values from pools in the 7th sampling week compare well with those of Magela Creek catchment billabongs near the end of the dry season (Hart & McGregory 1985) (Figure 26). Chlorophyll a was the dominant photosynthetic pigment in most of the pools. No comparison is able to be made with the Magela Creek in its flowing state as, as is typical of many flowing waters, values of this parameter are usually insignificant therein and have not been calculated (Klessa 2000).

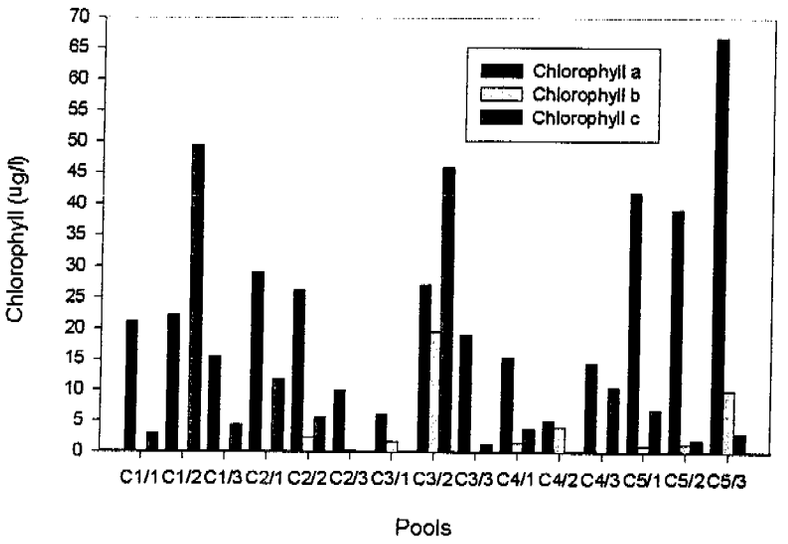

Figure 26 Chlorophyll a, b and c results respectively for sampling a week following final macroinvertebrate sampling of pools.

Inter-pool and Groundwater flow

Samples are currently still under storage in cool and darkened conditions awaiting Analytical Laboratory HPLC equipment to be readied and calibrated, for when other project samples are required to be analysed and for when staff time to assist in training becomes available.

Rate of pool water level drop.

There did not appear to be any trend in which pools ceased flow in the Dry Season (Table 5).

Table 5 Time to cease flow for each study pool.

Site	Days to cease flow
C1/1	0
C1/2	0
C1/3	50
C2/1	12
C2/2	12
C2/3	0
C3/1	0
C3/2	0
C3/3	12
C4/1	5
C4/2	12
C4/3	5
C5/1	5
C5/2	0
C5/3	0

Rate of pool drop was lowest early in the dry season soon after flow ceased, and then increased throughout the dry season, reaching a peak rate in late October; from 4.5 mm/day (Site 4) to 7.3 mm/day (Site 2) (Figure 27).

In general, once they had ceased flow, lower reach pools dried out faster than uppermost pools.

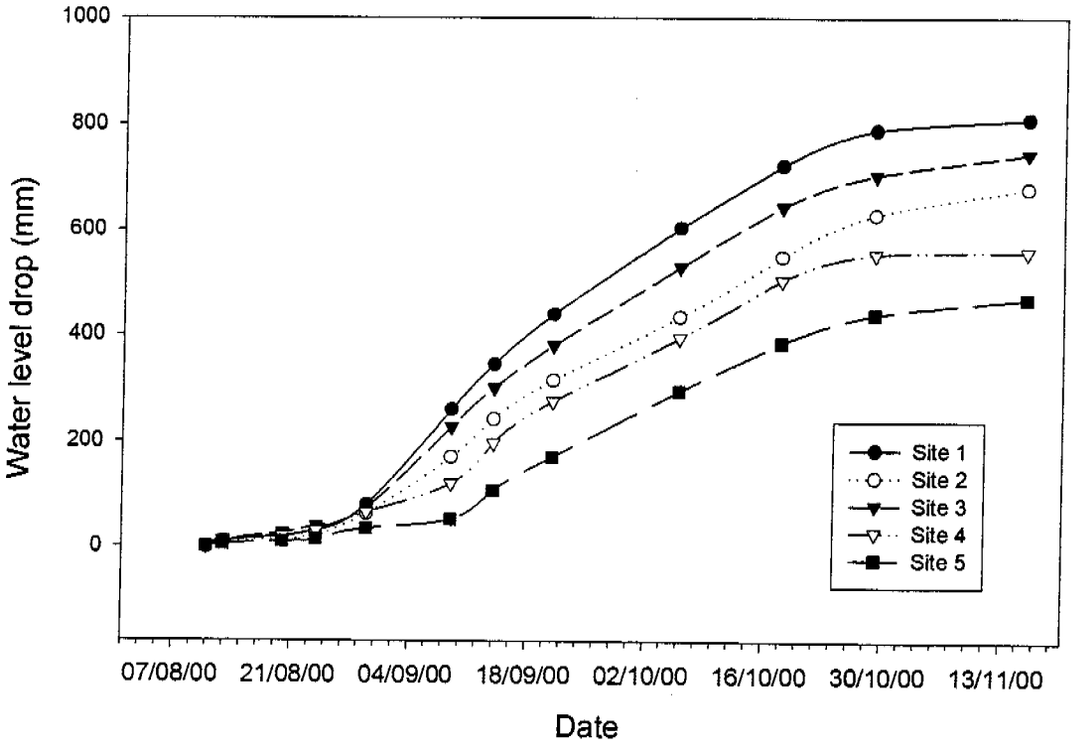

Figure 27 Rate of pool water level drop following cessation of flow (n = 15).

DISCUSSION

Macroinvertebrates

Macroinvertebrate collection is now complete and laboratory sorting and data entry is nearing its final stages. Contrary to expectations, community structure appears to be more diverse in the last stages of pool life (third sampling session), and resembles that of a typical lentic system. This is characterised by a dominance of chironomid and ceratopogonid larvae, although *Tasmanocoenis* and *Wundacaenis* mayfly larvae also continued to appear though to the final sampling sessions.

As note of interest, caenid mayflies believed to be *Tasmanocoenis* were observed to be flying 17th of January 2001 (pers. obs.) and may well be the adults of populations observed during sampling in the Magela Creek in the course of this project.

Water chemistry measurements

Data on water chemistry of the Magela system during the dry season when it is not flowing is in a paucity. To the knowledge of the author, this project represents only the second work that eriss has produced studying the chemistry of the Creek during this stage of its annual cycle. This, however, is typical of the highly seasonal Top End Northern Territory waterways for which monitoring is usually only concerned with the wet season chemistry when pollution discharges predominantly occur as a result of excess surface waters accumulating. As a consequence of this no comparisons can be drawn of the results of this study with those of equivalent waterways within a similar geography and geology. Instead, as a comparison chemistry results will be analysed in light of the Magela Creek in its flowing stages, baselines of such characterised by Klessa (2000), of a previous study oriented towards the fish communities of the Magela Pools during a single year (Woodland & Ward 1992) and of the Magela Creek's catchment billabongs (Hart & McGregory 1985).

Water temperature

Differences between sites may however be more real as a consequence of the notably different degree riparian canopy enclosure above different pools (pers. obs.), offering some a greater degree of shading, or shading at different times of the day. This was further tested by a correlation analysis of the variables total organic carbon (TOC) and mean water temperature via a Pearson correlation matrix; TOC acting as a surrogate for overhead canopy closure

density. This analysis, however, suggested a slightly negative, yet statistically insignificant relationship ($r = -0.22$, $p = 0.417$, $n = 15$).

Magela Creek water temperatures have not been measured with the Creek in its flowing state (Klessa 2000), with this parameter being of little value for monitoring purposes. It is though that catchment billabongs become thermally stratified during the heat of the day, and destratify overnight as a result of their greater depths (Hart & McGregor 1982). Due to the small maximum and mean depths of pools (Figure 23) this is not likely, and instead entire water column pool water temperatures is likely to be rather homogenous, and in the range of that expected for catchment billabongs water surfaces (Hart & McGregor 1982). The pool temperatures of this study also compare well with those encountered in a previous study of the Magela Creek pools (Woodland & Ward 1992).

Dissolved oxygen

Generally Magela Creek catchment billabongs have shown a well-saturated oxygen profile for their first 0.5 – 1.0 m depths, then followed by a marked reduction in oxygen saturation with increasing depth indicating a marked column stratification (Hart & McGrgor 1982). The oxygen values recorded at the surface of the pools compare well with the highly saturated values obtained from catchment billabongs.

Oxygen tensions of pools of the previous study also compared well; with a large range of values encountered, from very low to almost saturation. As already noted, a number of abiotic factors including depth, sun and wind exposure, etc. is likely to contribute to this large range. There is no available data for oxygen saturations of the Magela Creek under flowing conditions (Chris leGras, pers. Comm).

There is likely to also be much higher levels of mixing in the shallow drying pools, meaning that the surface sediments of these smaller systems, unlike those of the larger waterbodies, are also likely to be strongly oxidising.

Total organic carbon

TOC levels encountered in this study are typical of previous findings for this area for streams at their first days of flushing at the beginning of the Wet Season, but higher than the TOC values of those same streams at later flows (Chris leGras et al in prep.) (Figure 7). There is no published data on either the flowing Magela Creek or billabongs in its catchment to allow for a comparison with these waterbodies (Hart & McGregory 1985, Klessa 2000).

TOC contributions are expected to mainly be encountered through leaf-fall into pools, and bacterial and fungal decomposition leading to the formation of organic acids.

pH

Pool pH mean and range was similar to that of both the Magela Creek during flow (Klessa 2000) and also of Magela Creek catchment billabongs (Hart & McGregor 1982). Specific conductances of pools when first sampled were slightly lower than that of the flowing Magela Creek mean when flowing (14 µS/cm versus flowing values of 18 µS/cm) although this increased over time as was expected through decomposition of organic contributions to the pools, evaporation of dilutant and a likely increasing significance of groundwater inputs typically of greater conductivity than surface waters.

Surprisingly, pool pH was lowest in the 4th week, rather than the 7th week as was expected through concentration of solutes and development of organic acids by decaying vegetation (Figure 10). However, pH also showed no obvious temporal trends in a previous study of Creek pools (Woodland & Ward 1992) although the range encountered was notably more acidic than that of this previous work (4.57 – 7.01 compared to 5.3 – 7.7).

Specific conductance

By the 4th week, specific conductance was higher than the mean of 18 µS/cm that is normally encountered in the flowing Magela Creek (Klessa 2000). The highest values that the pools attained, however, are still slightly less than those of the Magela Creek catchment billabongs following early-Wet Season flushing (Hart & McGregory 1985).

Conductivity of pools in a previous study was notably higher, with values of 62 µS/cm to 22 µS/cm cited, compared to this study's range of a highest of 44 µS/cm and a lowest of 12 µS/cm (Woodland & Ward 1992).

Increasing contributions to the specific conductance of pool waters are thought to be the same as for those for billabongs; an increase in solute concentration as evaporation progresses, and intrusion of saline groundwaters.

Turbidity

Values were higher than those of the baseflow of the Magela Creek, which were recorded at a mean of 6 NTU (Klessa 2000), but they are unable to be compared with those of both catchment billabongs and previous study of Magela Creek pools due to the difference in method used there (secchi disk) (Hart & McGregory 1985).

Not surprisingly increases in turbidity occurred throughout the Dry Season, and these are thought to be due to an increase in algal biomass as nutrient limitation is overcome, as was also noted by a corresponding increase in specific conductance over this time (Figure 12).

Effect of low buffered waters on field measured pH

Although executed after field measurements had been taken, the potential implications of the extremely low conductivity values being encountered may have had repercussions on the credibility of data collected in this project, and also on methodologies proposed for the following bioassaying project. However, pH equilibrium time was only slightly greater in the low specific conductance sample tested (70.8 µS/cm) over that of the high specific conductance sample (4,900 µS/cm) by 60 seconds.

The results of this small laboratory experiment suggest that if a pH sampling protocol with no pH probe mixing realises at least 1 ½ minutes to allow for equilibration (notably less with a mixer attached such as the Ecosystem Protection's new Hydrolab Quanta™ multi-parameter meter) no erroneous measurement collections due to a failure to reach equilibrium values are likely to occur.

Organic fractions

Fine particulate organic matter (FPOM)

The extremely strong linear correlation of FPOM (as measured by suspended sediment) (Figure 19) with its field surrogate of turbidity validated this method which has been used previously in the Magela Creek (Jones 1995). This previous work, however, both failed to validate this choice of surrogate measure, and also failed to quantify actual typical benthic FPOM biomasses.

However, in some cases there appeared to be a trend in replicate turbidities, with later turbidity samples in a given pool sometimes having a higher result than previous. This may be due to a general increasing pool water column turbidity caused by our activities confounding benthic FPOM turbidity results. This was assessed in the field (APPENDIX 1) where it was felt that, although frequently turbidity increases were noted, they were not of the same magnitude as were turbidity readings in the sampler head resulting from benthic FPOM, and thus their influence on FPOM results was though to be minor.

It is likely that the confounding effects of increasing pool water column turbidity was exarcebated in the final sampling session where water volumes were lowest, and mean water column turbidities and FPOM loadings were highest.

Coarse particulate organic matter (CPOM)

Data collection and analysis is still progressing with CPOM, and this variable will therefore be discussed in a later report as the current data pool is insufficient at this time.

Pool volumes and surface area

The extremely strong positive relationship between pool maximum depth and pool average depth (both as determined by field-measurements) supports the use of a symmetrical geometric shape as a simple model of pool morphology (Equation 1, Equation 2).

Not surprisingly, as they were both based upon geometric models, pool volume and pool surface area were also extremely well correlated (Figure 24).

Study pool volume was over a somewhat greater range than was originally expected, with volumes from m^3 to m^3. Due to the unexpectedly low availability of pools that would last through the drying study period, however, this could not be avoided. Maximum depths were in the range noted in the previous study noting pool morphology, although pool volume was approximately twice as large (Woodland & ward 1992). This is likely to be due to the location of the previous study's pools a few kilometres further downstream in the Magela Creek bed; with the transition to fewer but larger pools being noted during the preparation of this study and leading to work being executed much further up the mainstem than was originally envisaged.

Phytoplanktonic algae biomass

As already noted, the high chlorophyll *a* results for the third and final sampling session of the uppermost pool (66.73, Figure 26) appeared to cause a very high pool turbidity (117 NTU, Figure 13) in the uppermost pool (5/3). Given the rate and order at which pools dried out it is not a surprise that such a high algal biomass would be encountered in this pool which is also one the oldest, having ceased flow early on in the season and thus had the longest amount of time in which a community could develop.

Chlorophyll a biomass does not appear to have been driven by the nutrient status of pool waters, with a regression of chlorophyll *a* over giving an r^2 of only 0.022.

Unlike the previous work, pool chlorophyll *a* of this study ranged 6mg/l to 67 mg/l compared to 6 mg/l to 178 mg/l. Chlorophyll *b* values were much lower, ranging from 0 mg/l to 20 mg/l, and chlorophyll *c* values were much higher than those of the previous study; up to 49 mg/l compared to less than 7 mg/l (Woodland & ward 1992).

Inter-pool and groundwater flow.

No analysis has yet been carried out for groundwater flow data between seasonal pools. This data will be presented and discussed in the next Internal Report in this series.

Rate of pool water level drop.

As fits with general understanding, pool water loss was highest in the lowermost pools, and least in the uppermost pools (Figure 27). Only a single site (Site 3) failed to fit this paradigm, drying up slower than the site below it; this difference may have been contributed to by the differences in sun-exposure which pools typically experienced based on their differing riparian characteristics, as also for water temperature (Figure 3).

Pool water loss, in the cooler part of the Dry Season ('Wurrgeng') was initially very slow, becoming increasingly rapid as the Dry Season progressed into its hotter and less humid phases ('Gurrung') and finally beginning to taper off as air humidity increased again and occasional rainfall occurred in the Pre-Monsoon build-up season ('Gunumeleng').

All study pools were dry and extinct by the beginning of the Wet Season (unpublished data), with their macroinvertebrate communities either dead or being expected to have migrated to more stable sites where possible. Fish communities in shallow near-extinct pools were seen to be heavily predated upon by piscivorous water fowl such as black-necked stork (*Ephippiorhynchus asiaticus*), straw-necked ibis (*Threskiornis spinicollis*) and the great egret (*Egretta alba*), leading to a complete loss of their fish communities before pool drying had completed. This loss has also previously been noted by Woodland & Ward (1992).

SUMMARY

Multivariate analysis of environmental data was limited both by time and sample number; the latter significantly reducing analysis power. For example, multiple regression analyses generally require 10 – 20 data points for variable being included in the analysis (Helsel & Hirsch 1992). This is not surprising given that the design of the project targeted the greater effort at macroinvertebrate sampling for the purposes of both baseline information for a better understanding of pool community structure for next year's mesocosm bioassay study, and as a pilot study for the methodology expected to be used in same proposed project.

However, it would appear that the environmental characteristics of the pools of the Magela Creek in the Dry Season is such that they fall somewhere between the 2 extremes of the Creek in its flowing state (Klessa 2000), and of its catchment billabongs (Hart & McGregory 1985). This is not surprising with the pools simply representing smaller and more ephemeral billabongs; smaller-scale analogies of the more prominent billabongs of this system in both space and time.

The results of this study also compare well to the results of the previous study of Magela Creek pools (Woodland & ward 1992), with noted differences suggesting that there are longitudinal changes in pool chemistry and morphology occurring along the Creek.

Following on from this analysis of environmental data, and the findings that they represent an intermediate type between the flowing Magela Creek and its catchment billabongs; what will be particularly interesting, is do the macroinvertebrate communities continue this analogy?

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APPENDICES

Appendix 1

Table 6 Raw data for environmental parameters of pool. Note: - indicates an absent data value.

Reg. Code	Date	Sites		Chemistry							Mean FPOM (mg)	Chlorophyll		
		Old Location	New Location	TOC (ppm)	Temperature °C	DO (mg/l)	Conductivity (mS/cm)	pH	Turbidity (before)	Turbidity (after)		Chlorophyll a (µg/l)	Chlorophyll b (µg/l)	Chlorophyll c (µg/l)
950	08/09	C1/1	C1/1	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
951	08/09	C1/2	C1/2	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
952	08/09	C1/4	C1/3	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
953	08/09	C2/1	C2/1	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
954	08/09	C2/3	C2/2	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
955	08/09	C2/5	C2/3	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
956	08/09	C3/2	C3/1	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
957	08/09	C3/4	C3/2	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
958	08/09	C3/5	C3/3	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
959	08/09	C4/1	C4/1	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
960	08/09	C4/3	C4/2	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
961	08/09	C4/5	C4/3	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
962	08/09	C5/2	C5/1	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
963	08/09	C5/4	C5/2	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
964	08/09	C5/5	C5/3	-	26.6	7.21	0.014	6.25	-	-	-	-	-	-
965	08/31	C1/1	C1/1	3.6	28.7	5.02	0.015	5.56	6	-	-	-	-	-
966	08/31	C1/2	C1/2	3.7	28.2	4.12	0.016	5.51	4	-	-	-	-	-
967	08/31	C1/4	C1/3	3.5	30.2	7.18	0.014	5.70	3	-	-	-	-	-
968	08/31	C2/1	C2/1	2.9	30.8	5.98	0.017	5.36	4	-	-	-	-	-
969	09/01	C2/3	C2/2	3.0	26.3	2.10	0.023	4.97	4	12	40.3	-	-	-
970	09/01	C2/5	C2/3	3.9	29.7	4.25	0.021	5.43	7	10	32.5	-	-	-

971	09/01	C3/2	C3/1	3.3	30.6	4.45	0.017	5.15	7	-	41.1	-	-	-
972	09/01	C3/4	C3/2	3.3	31.6	7.30	0.014	5.84	10	20	65.8	-	-	-
973	09/01	C3/5	C3/3	4.4	32.0	7.57	0.014	6.11	5	12	54.1	-	-	-
974	09/02	C4/1	C4/1	2.9	27.4	1.68	0.013	5.01	4	6	20.3	-	-	-
975	09/02	C43	C4/2	3.4	29.5	5.21	0.015	5.41	5	5	40.4	-	-	-
976	09/02	C4/5	C4/3	3.0	30.8	6.16	0.015	5.44	12	7	28.3	-	-	-
977	09/02	C5/2	C5/1	3.3	29.5	4.35	0.014	4.57	3	6	27.6	-	-	-
978	09/02	C5/4	C5/2	2.3	29.3	3.16	0.012	4.78	1	9	25.5	-	-	-
979	09/02	C5/5	C5/3	3.2	34.5	8.00	0.014	6.13	3	-	68.4	-	-	-
980	09/21	C1/1	C1/1	4.2	26.4	2.50	0.018	5.90	7	52	76.1	21.0	-1.0	3.1
981	09/21	C1/2	C1/2	6.8	26.4	1.60	0.028	6.10	13	-	9.4	22.3	-0.4	49.4
982	09/21	C1/4	C1/3	5.5	31.2	7.24	0.028	6.25	10	-	169.1	15.5	0.0	4.5
983	09/21	C2/1	C2/1	3.7	32.5	9.42	0.028	7.01	10	-	39.1	29.2	-1.1	11.8
984	09/21	C2/3	C2/2	4.1	26.8	3.50	0.029	5.78	12	23	39.0	26.2	2.5	5.7
985	09/22	C2/5	C2/3	4.9	27.2	1.95	0.044	6.30	5	12	41.9	10.1	0.3	-3.3
986	09/22	C3/2	C3/1	4.3	27.5	2.10	0.034	6.05	13	-	45.1	6.3	1.8	-0.8
987	09/22	C3/4	C3/2	3.7	32.6	4.15	0.035	5.95	15	-	58.2	27.2	19.5	45.9
988	09/22	C3/5	C3/3	3.2	31.6	6.00	0.017	5.80	5	-	40.9	19.1	0.1	1.4
989	09/22	C4/1	C4/1	4.0	30.0	4.30	0.015	5.00	6	-	18.2	15.3	1.6	3.9
990	09/22	C43	C4/2	-	29.7	2.40	0.028	5.90	8	-	49.2	5.2	4.1	-3.2
990	09/24	C4/5	C4/3	5.2	27.8	3.50	0.029	6.00	6	6	37.9	14.5	-0.2	10.5
992	09/24	C5/2	C5/1	-	27.9	6.87	0.023	5.85	13	-	48.2	41.8	1.2	6.9
993	09/25	C5/4	C5/2	3.8	26.6	4.95	0.015	5.45	12	-	54.5	39.1	1.5	2.0
994	09/25	C5/5	C5/3	3.7	29.1	9.71	0.035	6.50	52	148	163.1	66.7	10.1	3.1

Appendix 2

Table 7 Pool water surface height data

Location	Water surface height drop (mm)									
	09/08/00	22/08/00	28/08/00	07/09/00	12/09/00	19/09/00	04/10/00	16/10/00	27/10/00	14/11/00
C1/1	0	31	80	260	345	440	605	723	790	810
C2/2	0	22	63	170	242	315	435	550	630	680
C3/1	0	39	74	227	300	380	530	645	705	745
C4/1	0	30	65	120	196	275	395	505	555	560
C5/1	0	14	35	52	107	170	295	385	440	470

Appendix 3

Table 8 Buffer concentration effects on specific conductance

% buffer	Buffer volume	Dilutant volume	Specific Conductance	pH				
				5	30	150	300	900
100	200	0	4,900	4.12	4.07	4.01	4.00	4.00
80	160	40	4,080	4.09	4.05	4.01	4.01	4.01
60	120	80	3,130	4.09	4.05	4.03	4.02	4.02
40	80	120	2,050	4.09	4.07	4.05	4.05	4.05
20	40	160	1,140	4.08	4.05	4.03	4.03	4.03
2	4	196	71	4.34	4.25	4.24	4.25	4.25

Appendix 4

Table 9 FPOM calibration from surrogate turbidity data

Start mass (mg)	End Mass (mg)	Turbidity (NTU)	Mass diff. (mg)
2.155	2.102	110	53
2.103	2.069	78	34
2.131	2.083	99	48
2.12	2.074	78	46
2.192	2.155	60	37
2.068	2.044	49	24
2.104	2.075	51	29
2.073	2.049	54	24
2.129	2.09	74	39
2.058	2.035	42	23
2.14	2.087	105	53
2.134	2.086	90	48
2.071	2.047	50	24
2.068	2.043	33	25
2.057	2.036	34	21
2.033	2.018	17	15
2.081	2.052	46	29
2.058	2.037	40	21
2.228	2.149	159	79
	Average	35.37 NTU	66.79 mg
	Standard Dev.	15.87 NTU	34.34 mg

Appendix 5

Table 10 Pool final week morphology data.

Site	Maximum width (m)	Maximum length (m)	Surface area (m^2)	Maximum depth (m)	Average depth (m)	Volume (m^3)
C1/1	5.00	9.82	38.56	1.265	0.68	32.52
C1/2	2.40	7.97	15.02	0.385	0.17	3.86
C1/3	3.60	15.20	42.98	0.680	0.27	19.48
C2/1	9.10	21.00	150.09	1.035	0.54	103.56
C2/2	4.24	7.54	25.11	1.060	0.63	17.74
C2/3	4.65	10.87	39.70	0.815	0.49	21.57
C3/1	3.40	20.90	55.81	0.510	0.21	18.98
C3/2	8.85	17.60	122.33	0.470	0.17	38.33
C3/3	3.20	6.05	15.21	0.590	0.26	5.98
C4/1	5.25	13.00	53.60	1.100	0.62	39.31
C4/2	5.60	29.05	127.77	0.510	0.25	43.44
C4/3	6.70	24.60	129.45	0.580	0.26	50.05
C5/1	5.20	12.50	51.05	0.750	0.45	25.53
C5/2	2.70	10.25	21.74	0.310	0.12	4.49
C5/3	2.05	4.70	7.57	0.345	0.18	1.74

Appendix 6

Minitab best subsets regression for Chlorophyll a

Response is Ca

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13 cases used 2 cases contain missing values.

                                        S   S M A
                                        p   u a v
                                        e   r x . V
                                        c   f . d o
                                        C   A d e l
                                        o T r e p u
             Adj.                       n O e p t m p
Vars  R-Sq   R-Sq    C-p          s     d C a t h e H

   1  12.1    4.1    0.8     15.166       X
   1  11.4    3.4    0.9     15.224           X
   2  28.2   13.8    1.0     14.376       X   X
   2  23.1    7.8    1.6     14.873       X     X
   3  38.1   17.4    1.9     14.071       X   X X
   3  34.4   12.5    2.3     14.483       X         X X
   4  45.8   18.6    3.0     13.969       X   X X     X
   4  45.4   18.0    3.1     14.022       X X X     X
   5  54.6   22.2    4.1     13.660     X X X X     X
   5  52.4   18.4    4.3     13.994     X X X     X X
   6  55.0   10.1    6.0     14.688     X X X X     X X
   6  55.0    9.9    6.0     14.699     X X X X X X
   7  55.1    0.0    8.0     16.080     X X X X X X X
```
