

Water Quality of the Roper River 2012-2016



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Tufa formation on the upper Roper River at Elsey National Park (Simon Townsend)

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Summary

This report summarises water quality data collected under a number of different programs between 2008 and 2016 with a focus on dry season water quality.

In particular, the report aims to explore

1. Longitudinal (downstream) changes in dry season water quality
2. Temporal changes in dry season water quality between the early to late dry season
3. Inter-annual differences in dry season water quality
4. Spatial and temporal variations in diurnal patterns of water quality over the dry season
5. Relationship of water quality and discharge over one wet season

During the dry season flows in the Roper River and its tributaries are primarily sourced from the Tindall Limestone aquifer in the Daly Basin in the north and the Georgina Basin in the south that enter the river in the upper parts of the catchment. Dry season discharge in the Roper River is a mixture of these two water types. Surface water inputs from tributaries in the lower reaches are negligible.

Dry season water quality varies longitudinally along a downstream gradient. The groundwater inflows in the upper part of the catchment are the main determinant of water quality. Electrical conductivity is high (1000-1500 $\mu\text{S}/\text{cm}$) with alkaline pH (and high water clarity (<5 NTU)). Both EC and pH increase in the upper catchment with distance downstream due to groundwater inflows of limestone origin. The groundwater also provides substantial nitrate inputs into the system, leading to high NO_3 concentrations of 0.050 to 0.300 mg/L in the upper catchment. Downstream of the groundwater inputs NO_3 concentrations decrease quickly to less than 0.010 mg/L as NO_3 is taken up by aquatic plants and algae and is not replenished, while soluble phosphorus concentrations are low (<0.010 -0.050 mg/L) and tend to show an opposite trend with higher concentrations found in the lower Roper River.

Water Quality during the dry-to-wet transition can be significantly impacted by storm runoff events. A 2014 event caused hypoxia (very low DO) and a fish kill in the lower reaches of the river.

Wet season water quality is turbid with over 300 NTU during peak storm events, has lower conductivity due to rainfall-runoff (200-1000 NTU) and lower pH (6.9-8.0), and varies over the season and during storm events.

1 Background and Study Aims

With increasing development in the Roper River region demand for water is growing. The Tindall aquifer, which supplies base flows in the Roper River in the dry season, is also the region's main source of domestic drinking water, water for stock and the irrigation of crops, including forestry. A draft Water Allocation Plan has been developed for the Mataranka Tindal aquifer (WRD 2011, under review) to regulate the conflicting demands for water and ensure sufficient water is available for environmental flows to maintain good water quality and sustain the river's biota. Beneficial Uses have been declared for groundwater in the Katherine-Mataranka area, which includes the upper catchment of the Roper River. The declared groundwater uses are raw water for drinking, agriculture and industrial purposes (DENR 2016). Currently, there are no beneficial uses declared for surface water in the catchment.

Regular water quality monitoring has been conducted in the Roper River catchment in accordance with the draft water allocation plan since 2013. In addition, water quality monitoring occurred opportunistically in the past, and as part of distinct projects. This report summarises water quality data collected under a number of different programs since 2008. Some of the data has been reported previously in project-related reports (Zaar 2009, Kerle 2014, Kerle and Cruickshank 2014).

The aim of this report is to summarise the water quality data collected under four different monitoring programs that have been conducted within the Roper river catchment between 2012 and 2016. A detailed description of the programs is provided in section 3.

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2 Catchment Description

The Roper River catchment comprises an area of approximately 80,000 km² in the north-east of the Northern Territory (Figure 1). It extends from about 70 km north of the community of Bulman on the Southern Arnhem Plateau (13° S) to 30 km south of Daly Waters (16.7° S). The western catchment boundary runs between Katherine and Mataranka, extending to just east of Top Springs in the south towards the Gulf of Carpentaria. The Roper River drains into the Limmen Bight in the Gulf of Carpentaria.

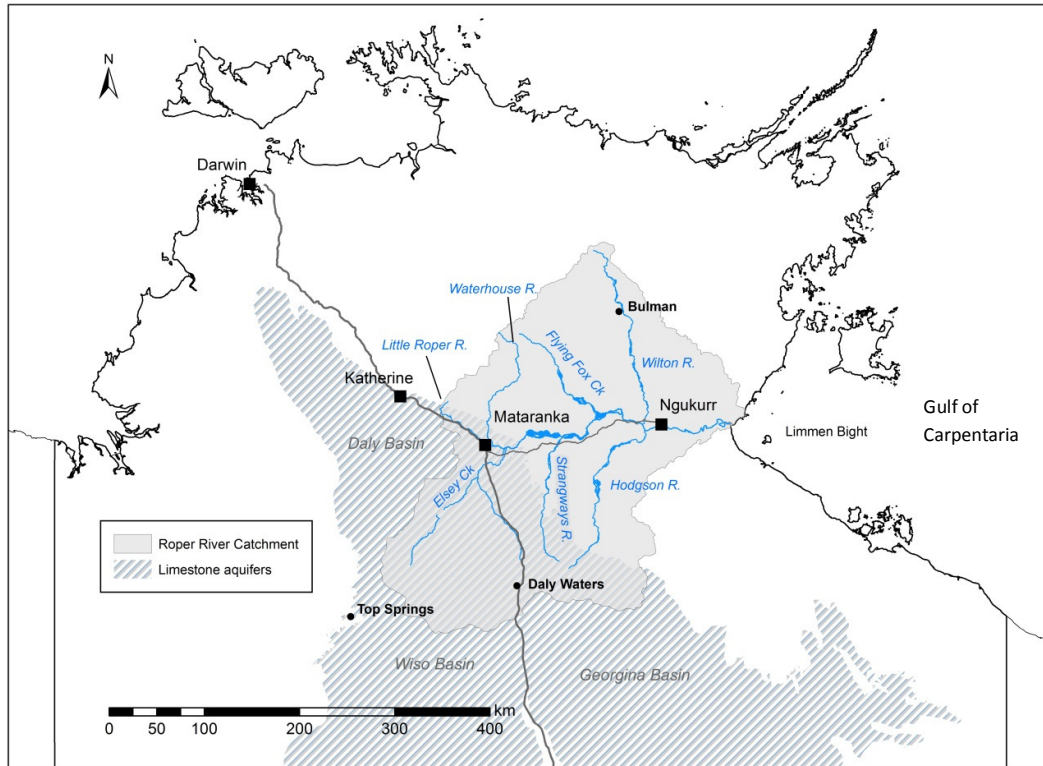


Figure 1. Location of Limestone aquifers and Roper River catchment

The catchment is of low relief with elevations in the northern catchments of the Waterhouse and Wilton Rivers ranging from 200 to 350 m AHD in central Arnhem Land and 200 to 250 m AHD in the southern catchment of the Strangways and Hodgson Rivers. The Roper River itself is a lowland river with an elevation of 120m AHD at its start near Mataranka.

Eucalyptus woodland is the dominant native vegetation type in the catchment with smaller areas of *Melaleuca* woodland and some tussock grassland (NVIS 2007). The wetter northern parts of the catchment also contain areas of *Eucalyptus* open forest.

The region is sparsely populated. The largest settlements in the catchment are the town of Mataranka in the west and the Aboriginal community of Ngukurr in the east. The major land uses in the catchment are traditional indigenous uses and grazing under natural vegetation (LUMP 2008). More recently, some large forestry projects have been established in the Mataranka area.

The Roper River area has a wet-dry monsoonal climate. Mean annual rainfall ranges from 1100 mm in the north to approximately 600 mm in the south. The vast majority of rainfall (> 90%) occurs during the wet season (November to April) when convective storms, cyclones and monsoonal conditions occur. The extended dry season lasts from May and October with very little rainfall occurring during this time. Figure 2 shows the long-term rainfall and flow patterns in the upper and middle reaches of the river.

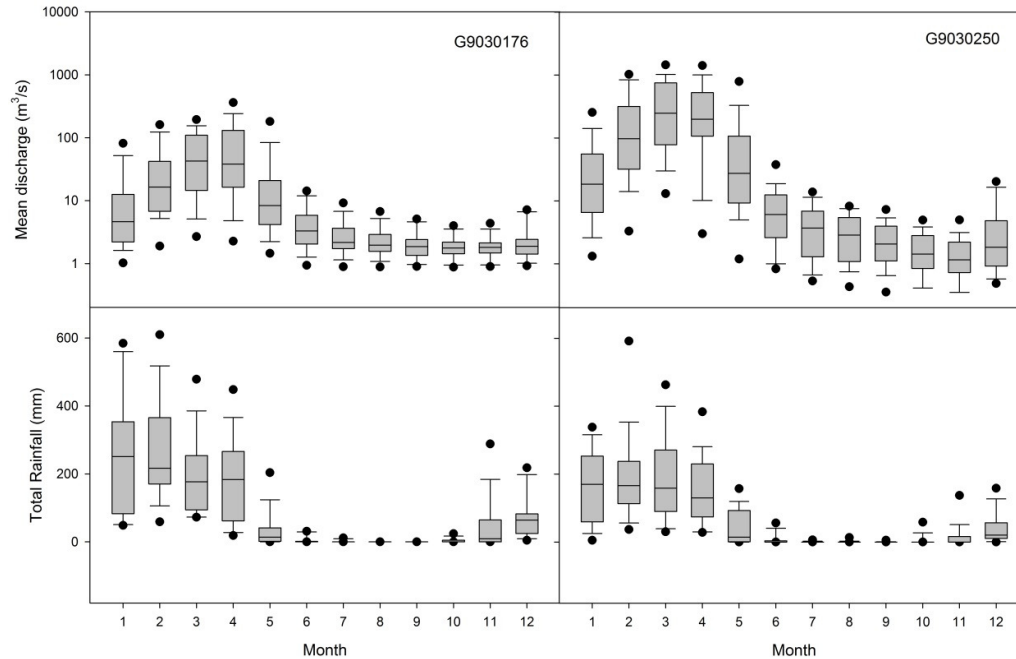


Figure 2. Monthly mean discharge and total rainfall in the upper (G9030176, Site 11) and middle reaches (G9030250, Site 22) of the Roper River for the period of record. The boxplots show the median and 25th to 75th percentile (grey boxes), 10th and 90th percentile (error bars), and maximum and minimum (dots). See Figure 3 for site locations.

The lower Waterhouse River, lower Little Roper River, lower Eley Creek and the Roper River are the only perennial streams in the catchment. During the dry season flow in these permanent streams is sustained by groundwater inflows from springs in the Mataranka region.

Mataranka lies on the boundary of the Daly and Georgina groundwater basins (Figure 1). Discharge from these basins enters the Roper River through springs in the upper reaches. Groundwater inflows end approximately 30 km downstream of Mataranka at Eley Station so that dry season flows in the Roper River are highest around Eley station and diminish gradually with increasing distance downstream due to water losses to the groundwater table and evapotranspiration (Kerle 2014, Kerle and Cruickshank 2014).

3 Data sources and sampling methods

3.1 Data Sources

Table 1 provides a summary of all sites, the years they were sampled and which section of the report the data were included in. A map of all site locations is given in Figure 3.

The water quality data used in this report was collected for a number of different projects in the Roper River catchment from 2012 to 2016. The following project datasets were included:

1. In September 2012 a longitudinal snapshot of water quality was taken along the non-tidal reaches of the Roper River. Eleven sites were sampled for field parameters, nutrients, major ions and chlorophyll.
2. In 2013, water quality data were collected from one location (Site 18, Judy Crossing) as part of a fish study at that site (Dostine 2014). Field parameters, nutrient samples and diurnal oxygen profiles were collected.
3. Over the 2013/14 hydrological year (September to August) a water quality sonde was deployed and continuous field data collected at Site 18 (Judy Crossing).
4. A biannual water quality monitoring program was commenced in 2013 to meet the requirements of the Mataranka Tindal Draft Water Allocation Plan (WRD 2011). Field parameters and nutrient data are collected in the early and late dry season from 12 sites in the upper and middle reaches of the Roper River. This monitoring program is ongoing. Data from 2013 to 2016 are included in this report. Individual sampling events have previously been reported in other technical reports (Kerle 2017a&b, Russ 2015, Schult 2014, Kerle 2014, Kerle and Cruickshank 2014, Waugh and Kerle 2014, Wagenaar 2013, Wagenaar and Tickell 2013).
5. Monthly water quality measurements of field parameters, nutrients and diurnal oxygen profiles were collected from three sites in the upper, middle and lower reaches of the Roper River in 2014 and 2015.

Historical data from 2008-2011 stored in the NTG water quality database were also used where appropriate to supplement the project data. With the exception of project 3, all water quality data was collected during the dry season only.

Water quality sampling extended downstream to Roper Bar crossing, which is the upper limit of tidal influence on the river approximately 110 km from its mouth.

Table 1. Site List. Shaded areas indicate which sites are included in each program and year.

Stream Name	Site #	Abbreviated Name	G code(NTG Hydstra database)	Site Description	Distance from WH/LR confluence	Longitudinal	Seasonal	Diurnal	Wet season	2012	2013	2014	2015	2016	Prior to 2012
Springs	3	BS	G9035212	Bitter Springs - Swimming Access	-8										
	6	RS	G9035092	Rainbow Springs (Mataranka Hot Springs)	-2										
	13	FTS	G9035157	Fig Tree Spring	8										
Little Roper	4		G9035085	Mataranka Homestead Crossing	-3.7										
	9		G9035406 G9030031	50 m upstream Waterhouse River confluence	-0.05										
Waterhouse River	1		G9030514	Downstream Diljin Hill	-90										
	2		G9030089	Central Arnhem Rd Bridge	-47.2										
	5	WR	G9035316	1.2 km u/s of Rainbow Springs	-3.1										
	7		G9035192	500m u/s Little Roper confluence	-0.5										
	8		G9030032 G9035407	100m u/s Little Roper confluence	-0.1 -0.1										
Roper River	10		G9035255	u/s 4 Mile boat Ramp	0.15										
	11		G9030176	Downstream Mataranka Homestead	6.6										
	12	ENP	G9030033	Elsley National Park-Mulurark area	7.1										
	14		G9030013	Near Elsley Station Homestead	22										
			G9035294		23										
	15		G9030022	Roper River 11 km D/S Elsley Homestead	33										
			G9030023												
	16		G9035398	Moroak Station Crossing	67.5										
			G9035408		67.6										
	17		G9035076	Roper River - Point Ao	72										
	18	FFS	G9035122	Flying Fox Station at Judy Crossing	118										
			G9030010		118.5										
	19		G9035068	Roper River - Point Ag	129.5										
	20		G9035409	Big River Station	155										
		G9035410	156												
21	MM	G9030028	Mt McMinn Station Main Channel	170											
22		G9030025	Red Rock Gauge station	189											
		G9030250		189											
23		G9035300	Roper Bar	200											
Elsley Ck	24	EC	G9035200	Elsley Creek d/s Roper Highway Crossing											

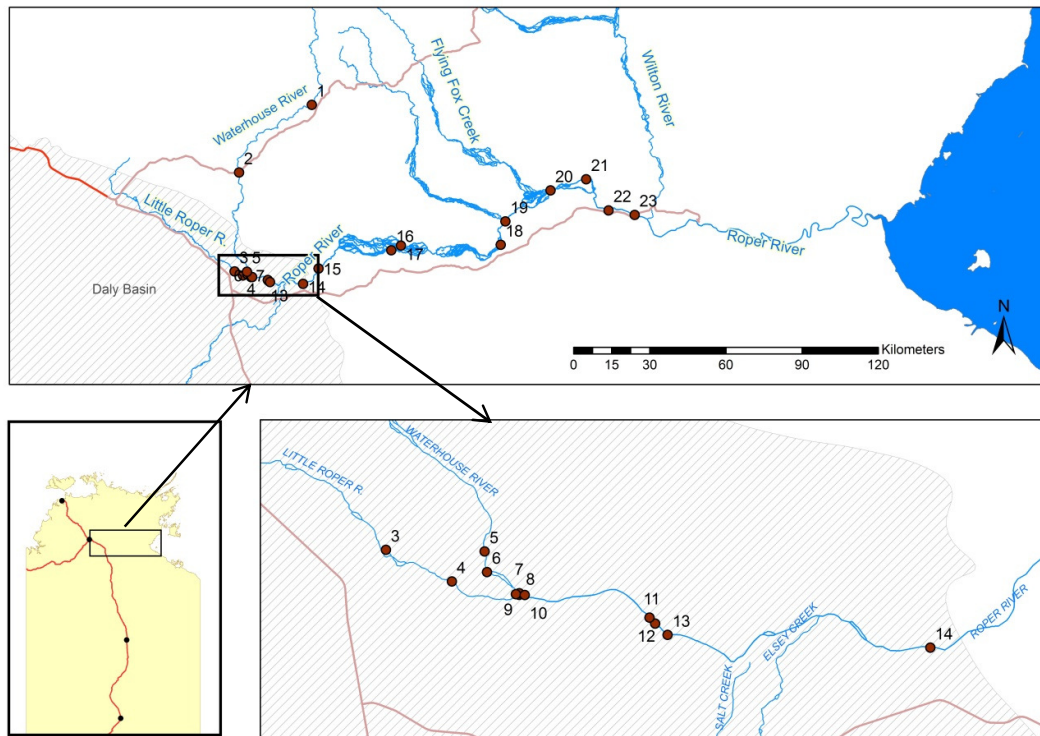


Figure 3. Map of the study area and site locations.

3.2 Sample collection and analysis methods

The data collection for all projects was carried out according to NT Government standard operating procedures for water quality data (Waugh 2016).

Field parameters were measured *in situ* using a Quanta multi-parameter probe (Hydrolab, USA). Measurements were made between 7am and 7pm with the majority of measurements collected between 10am and 5pm.

Nutrient, major ions and chlorophyll samples were collected in polypropylene bottles. Soluble nutrient samples were filtered in the field through a 0.45 µm Minisart PES syringe filter (Sartorius AG, Germany). All samples were stored on ice in the field and frozen or refrigerated upon return to the laboratory. Nutrient samples were analysed by the Northern Territory Environmental Laboratories (NTEL Intertek) according to APHA standard methods.

Chlorophyll samples were stored on ice, filtered through 0.7µm Whatman glass fibre filters upon return to the laboratory and filters and residue frozen until further analysis. Chlorophyll samples were analysed by fluorometry at Charles Darwin University using APHA standard methods.

Table 2 provides details of analysis and measurement methods for all water quality parameters.

Table 2. Measurement and analysis methods for water quality parameters

Sample Type	Parameter	Method	Laboratory
Field parameters	Temperature	In-situ, variable resistance thermistor	Field method
	pH	In situ, glass electrode	Field method
	Dissolved oxygen	In situ, Clark cell or Luminescent DO	Field method
	Electrical conductivity	In situ, graphite electrodes	Field method
	Turbidity	In-situ, 4-beam turbidity sensor	Field method
Nutrients	NO ₂	APHA 4500 NO ₂ I	NTEL
	NO ₃	APHA 4500 NO ₃ I	NTEL
	NH ₃	APHA 4500 NH ₃ H I	NTEL
	FRP	APHA 4500 P G	NTEL
	TN	APHA 4500 N C	NTEL
	TP	APHA 4500 P B3 G	NTEL
Major ions	Alkalinity	APHA 2320 B	NTEL
	Cations (Ca ⁺ , Mg ²⁺ , Na ⁺)	APHA 3120 B	NTEL
	Anions (Cl ⁻ , SO ₄ ²⁻ , F)	APHA 4500-Cl G/B; 3120 B, 4500-F C	NTEL
	pH	APHA 4500-H ⁺ B	NTEL
	EC	APHA 2510 B	NTEL
	TDS	APHA 2540 C	NTEL
	Hardness	APHA 2340 B	NTEL
Chlorophyll	Chlorophyll a	In-house fluorometry method based on APHA standard method	CDU

4 Water types

4.1 Introduction and Methods

The origin of natural waters is reflected in the ions that are dissolved in the water. For instance, as water passes through an aquifer some of the minerals contained in the rock are dissolved and carried to the surface with groundwater flows. Water from limestone aquifers is typically high in magnesium, calcium and bicarbonate ions, while rainwater contains very low amounts of all major ions. Other rock formations can contain higher proportions of sulphate (e.g. from gypsum deposits) or sodium chloride. Therefore different water types can be identified by comparing the ionic composition of waters.

Due to its groundwater origins, the dry season surface water quality of the rivers is strongly related to groundwater quality, which is typically divided into three groups in the region (Karp 2008):

- Groundwater typical of the Tindall limestone aquifer in the Daly Basin, with low total dissolved solids (TDS), low sodium, chloride and sulphate content.
- Groundwater with elevated TDS, sodium, chloride and sulphate dominated by Georgina Basin water
- Groundwater that shows mixing between the two groups.

Most of the groundwater in the Mataranka area is from the latter group.

To identify different water types, all available dry season major ions samples (n=39) were displayed in a Piper diagram. The Piper diagram plots water quality data according to the proportions of major ions found in each sample. Similar water types plot close together, while those that differ in their composition plot further away from each other.

4.2 Results and Discussion

The ionic composition of historical and current dry season samples reflects the different groundwater origins of the water. The Piper diagram is shown in Figure 4 with each symbol on the diagram representing one sample.

The waters of Rainbow Springs and the lower Waterhouse River are sourced from the Tindall aquifer in the Daly Basin and contain higher proportions of calcium and bicarbonate ions compared to samples from Fig Tree Springs, which is dominated by water from the Georgina Basin with a higher sodium, chloride and sulphate content (Figure 4). Samples from other sites on the Little Roper and Roper Rivers, Elsey Creek and the Waterhouse River plot in an almost straight line between these two extremes, indicating that they are a mix of the two water types. The full major ions results for samples used are given in Appendix 1.

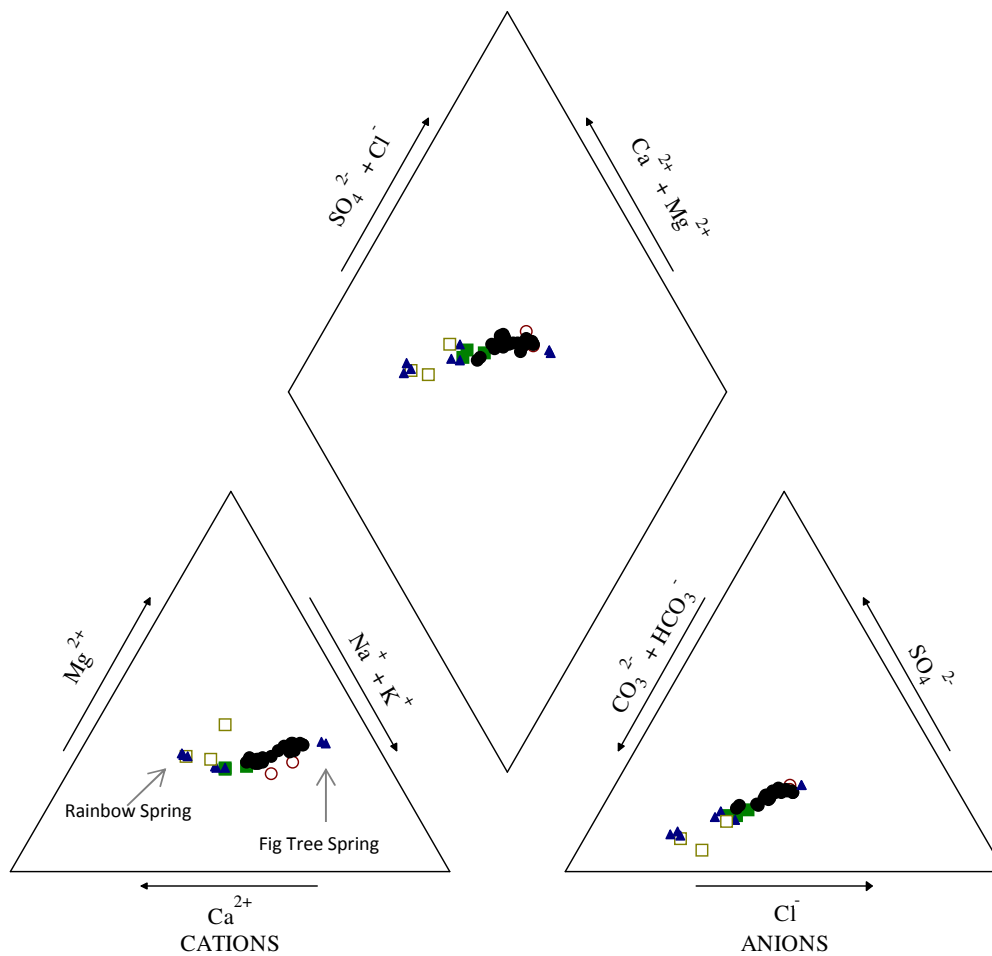


Figure 4. Piper diagram of ionic composition of Roper River catchment samples. Triangles: springs, open circles: Elsey Creek, closed circles: Roper River, open squares: Waterhouse River, green squares: Little Roper River.

5 Longitudinal variation in dry season water quality

5.1 Introduction and Methods

The Roper River has a total length of approximately 200 km from its origin at the confluence of the Waterhouse and Little Roper Rivers to Roper Bar Crossing, the upper limit of tidal influences on the river. In the dry season, when the river is groundwater-fed, its two main tributaries and the upper reaches receive water from the Tindall limestone aquifer. Groundwater inflows cease at Elsey Station (Site 11) and there are few surface water inputs from other surface water tributaries further downstream. Most of these tributaries cease to flow in the later part of the dry. The river's dry season water quality is therefore strongly influenced by its groundwater origins. Longitudinal differences in water quality were examined to determine how river processes influence water quality.

Data from all recent projects as well as relevant historical data from 2008 to 2011 was used to describe longitudinal changes in dry season water quality from the two headwater streams of the Roper River (Waterhouse River and Little Roper River) to Roper Bar Crossing in the lower reaches of river.

The number of samples collected at each site ranged from 1-23 with a median sample number of 9 for physico-chemical parameters and 5 for nutrients.

5.2 Results and Discussion

5.2.1 Physico-chemical parameters

Temperature

Mean dry season (May to November) water temperatures ranged from 21-33 °C with most sites recording temperatures between 23 and 30 °C (Figure 5a). The springs in the upper catchment, Bitter Springs (Site 3) and Rainbow Springs (Site 6), had a higher temperature than other sites in the catchment ranging from 32.4-33.3 throughout the dry season, while Fig Tree Springs (Site 14) was cooler than most other sites in the area with a mean temperature of 24.5 °C. River water temperature at stream sites is closely related to air temperature and therefore strongly dependent on the sample date, while the temperature of the three springs was consistent throughout the dry season. Historical time series data collected by WRD between 2008 and 2012 in Rainbow Springs shows an overall seasonal variation of only 0.5 °C (data from WRD Hydstra database).

Electrical conductivity

Electrical conductivity is low (< 50 µS/cm) in the upper Waterhouse River, and increased downstream with groundwater inflows from springs in the Mataranka region to 700 µS/cm near the confluence with the Little Roper River (Figure 5b). The Little Roper has a dry season conductivity of 1400 to 1500 µS/cm. Mean dry season conductivity on the Roper River ranged from 1130 to 1555 µS/cm. Fig Tree Springs has the highest conductivity of all sites with a mean of 2500 µS/cm. Mean

dry season EC increased with distance downstream in the upper section of the Roper River to a maximum of 1555 $\mu\text{S}/\text{cm}$ at Site 18 at the end of groundwater inflows. With further distance downstream EC decreased again slightly to approximately 1200 $\mu\text{S}/\text{cm}$ at the furthest downstream site (Site 37).

Table 3. Dry season sample numbers, n (2008-2016)

Site No.	River	#STATION	Location	n Phys-chem	n Nutrients
1	Waterhouse	G9030514	D/S Diljin Hill	5	0
2	Waterhouse	G9030089	Central Arnhem Rd bridge	4	0
3	Spring	G9035212	Bitter Springs Swimming Access	17	6
4	Little Roper	G9035085	Mataranka Homestead Crossing	16	6
5	Waterhouse	G9035316	12km U/S Rainbow Springs	9	5
6	Spring	G9035092	Rainbow Springs	18	6
7	Waterhouse	G9035192	500 m u/s Little Roper Confluence	5	0
8	Waterhouse	G9030032	100 m U/S Little Roper Confluence	3	2
		G9035407			
9	Little Roper	G9030031	U/S Waterhouse River Confluence	5	2
		G9035406			
10	Roper	G9035255	U/S 4 Mile Boat Ramp	3	0
11	Roper	G9030176	D/S Mataranka Homestead	10	6
12	Roper	G9030033	Eley National Park - Mulurark area	11	12
13	Spring	G9035157	Fig Tree Spring	11	6
14	Roper	G9030013	near Eley Homestead	17	14
		G9035294			
15	Roper	G9030022	10-12 Km D/S Eley Homestead Xng Site 17	11	11
		G9030023			
16	Roper	G9035398	Moroak Station Crossing	17	10
		G9035408			
17	Roper	G9035076	Roper River - Point Ao	4	1
18	Roper	G9030010	Flying Fox Station - Judy Xng	24	18
		G9035122			
19	Roper	G9035068	Roper River - Point Ag	4	2
		G9035409			
20	Roper	G9035410	Big River Station	6	0
		G9035410			
21	Roper	G9030028	MtMcMinn Station	17	16
22	Roper	G9030025	Red Rock gauge station	13	7
		G9030250			
23	Roper	G9035300	Roper Bar Crossing	5	3
Median sample n				10	6

Electrical conductivity can function as an indicator of groundwater source. Low conductivities in the upper Waterhouse River indicate sandstone aquifer origins while the higher conductivities of the springs around Mataranka are typical of the local limestone aquifers. Elevated conductivity in Fig Tree Springs is caused by the geology of the area. A build-up of salt occurs because groundwater

forms swamps where basalt with overlying limestone comes close to the surface. Over time, evapotranspiration concentrates the salts in the unsaturated zone and on the surface (Karp 2008).

There is a small gradual reduction in electrical conductivity between the limit of groundwater inflows at Elsey station (Site 14) to the lower reaches of the river. Several small intermittent streams enter the Roper River between Elsey Station and Roper Bar, with Flying Fox Creek and Jalboi Creek being the largest of those. During the early part of the dry season and during higher flow years, these creeks are still contributing to Roper River flows. While Jalboi Creek has ECs of 1200-1500 $\mu\text{S}/\text{cm}$, similar to the Roper River, historical data from Flying Fox Creek show ECs of 300-500 $\mu\text{S}/\text{cm}$ during the dry season during a high flow year. Inflows from Flying Fox Creek would consequently reduce EC in the Roper River.

Since the decline in EC appears to be gradual and also occurs in regions of no known tributary inflows, chemical or biological processes that lead to calcium and magnesium carbonate precipitation may also contribute by causing a reduction in dissolved ions in the water column. The formation of tufa in the Roper River and the presence of carbonate scale on rocks indicate that precipitation occurs quite extensively. Some common green algae form calcite encrustations on the outside of their filaments which may contribute to the reduction in EC from upstream to downstream.

pH

The median pH is slightly acidic (6.4-6.9) in the upper Waterhouse River and the two upper catchment springs, and alkaline at all other sites. The pH increases gradually with downstream distance in the Roper River (Figure 5c) to a median of 8.2 at Site 23.

pH is influenced by the buffering capacity of the water, the amount of carbon dioxide dissolved in the water, as well as photosynthesis and respiration. The sandstone waters of the upper Waterhouse River are poorly buffered, while limestone waters of the Daly and Georgina Basin contain dissolved calcium carbonate and are more alkaline.

Dissolved oxygen

With the exception of Rainbow and Bitter Springs, all sites were well oxygenated along the longitudinal gradient (Figure 5d). Dissolved oxygen saturation ranged from 50 to 80% in the upper catchment (Waterhouse and Little Roper Rivers) and from 75 to 105% in the Roper River proper.

Oxygen levels fluctuate over the course of a day and are influenced by photosynthesis and respiration. Diurnal patterns of dissolved oxygen at selected sites are discussed in more detail below. Bitter Springs and Rainbow Springs had low mean oxygen saturation (8-15%) due to their groundwater origins and lack of exposure to air at sampling sites near their source. Consistently higher oxygen saturation in Fig Tree Springs may be caused by it being sourced from shallower local swamps where some aeration may already occur prior to discharge at the surface (Karp 2008).

Turbidity

The upper Waterhouse River (sites 1 and 2) had the highest mean turbidities of 9 and 31 NTU respectively, while all other sites had mean turbidities of < 5 NTU throughout the dry season. The

springs had the lowest turbidity with < 1 NTU measured consistently at these sites (Figure 5e). There was no consistent longitudinal pattern in turbidity in the Roper River.

Dry season turbidity is typically low in Top End rivers, as surface runoff carrying sediment is replaced by groundwater dominated flow. The higher turbidity in the upper Waterhouse River may be due to local conditions and disturbances.

5.2.2 Nutrients

Soluble nutrients (NO₂, NO₃, NH₃, FRP)

Mean nitrite (NO₂) concentrations were close to the detection limit of 0.001 mg N/L at all sites with a maximum of 0.003 mg/L at Site 5 on the Waterhouse River (Figure 6a). An extreme outlier at Site 6 (Rainbow Springs) measured in May 2014 with an NO₂-N concentration of 1.34 mg/L was removed from the dataset. The cause of this high NO₂ concentration is unknown; however, it may have been due to sample contamination or a short term pollution event.

Nitrate (NO₃) concentrations are high (0.050 to 0.3 mg/L) in the upper catchment and decrease with distance downstream (Figure 6b). In the upper Waterhouse River, upstream of Tindall spring inflows, NO₃ is lower but concentrations increase downstream of Rainbow Springs. The highest NO₃ concentrations were measured in the three springs and the Little Roper River. The Roper River itself shows steadily decreasing NO₃ concentrations with increasing distance downstream up to Site 19 below which mean NO₃ concentrations rose again slightly.

There was no discernible pattern of ammonia (NH₃) concentrations with distance downstream (Figure 6c). Mean concentrations were variable throughout the catchment, ranging from 0.001 to 0.035 mg/L with the highest concentrations found in the Waterhouse River. The Little Roper and Roper Rivers had NH₃ concentrations of 0.001 to 0.014 mg/L while the three springs had some of the lowest ammonia concentrations of 0.001-0.004 mg/L.

Groundwater of the Tindall aquifer is known to contain relatively high levels of nitrate in many areas (Schult 2016). The source of the nitrate is not known but anthropogenic contamination, for instance from the application of fertilisers or leakage from septic systems, cannot be excluded as a potential source, nor can a change in land-use from woodland to agriculture that results in the loss of eucalypt trees. The groundwater inputs in the upper catchment are the major source of soluble nitrogen, in particular nitrate, to the river.

The Little Roper River contributes the majority of the soluble nitrogen to the system. Soluble nitrogen decreases quickly longitudinally as it is taken up by aquatic vegetation and algae and is at low levels in the middle and lower reaches of the Roper River.

Mean filterable reactive phosphorus was low in the Roper River tributaries of the upper catchment (<0.010 mg/L) while mean concentrations were higher and more variable in the Roper River with means of 0.050 mg/L found in the middle and lower study reaches (Figure 6d).

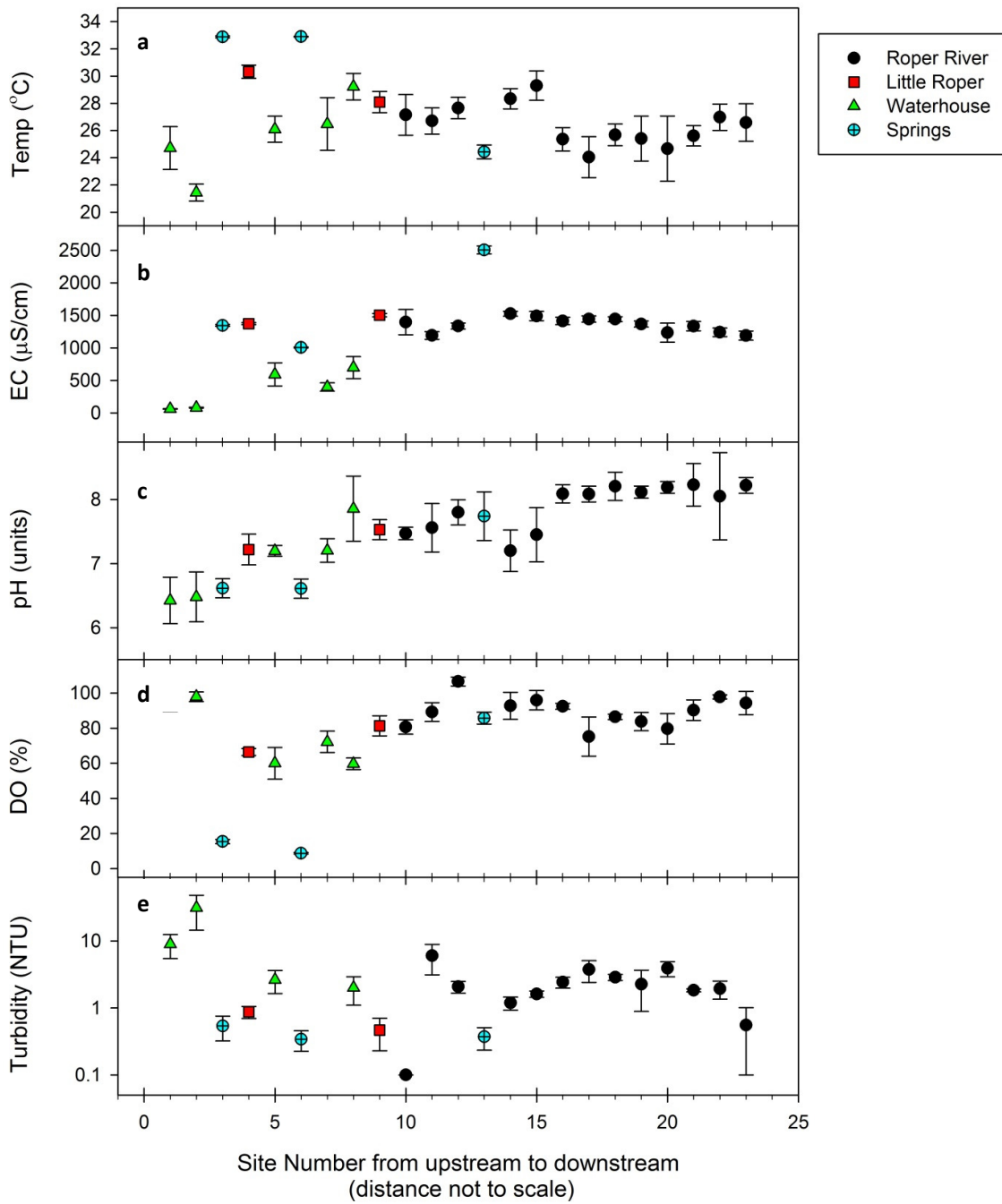


Figure 5. Longitudinal differences in dry season (May to November) water quality in the Roper River catchment, physico-chemical parameters (mean $\pm 1SE$, n=1-17). Data from 2008-2015. NOTE: distance downstream is not to scale!

The soluble N:P molar ratio decreases from the upper catchment to the lower reaches of the Roper River. The Redfield N:P ratio of 16:1 is often used to indicate likely N or P limitation of microscopic algae. While N:P ratios are above the Redfield ratio in the upper catchment, suggesting potential severe phosphorus limitation of primary producers, they are below 16:1 in most of the Roper River itself, indicating possible N limitation in the river (Figure 7). Soluble nutrient concentrations result from the flux of the nutrients, and any limitation inference needs to be tested experimentally.

Total nutrients

Dry season mean total nitrogen (TN) concentrations followed a similar pattern to NO_3 with high concentrations in the upper catchment and a gradual decrease in TN with increasing distance downstream (Figure 6e). Mean TN concentrations ranged from 0.110 to 0.320 mg/L in the upper catchment, decreasing to a minimum of 0.088 in the middle reaches.

Mean total phosphorus (TP) concentrations ranged from 0.009 to 0.049 mg/L. The lowest TP concentrations were found in the upper catchment and springs, with high TP in the lower reaches of the Roper River (Figure 7f).

Soluble N constitutes a relatively large proportion of TN in the upper catchment. At Rainbow Springs (Site 6) soluble N makes up more than 90% of total nitrogen but soluble N becomes negligible as a contributor to total N in the middle and lower reaches (Figure 8). FRP constituted a large proportion of TP concentrations throughout the catchment.

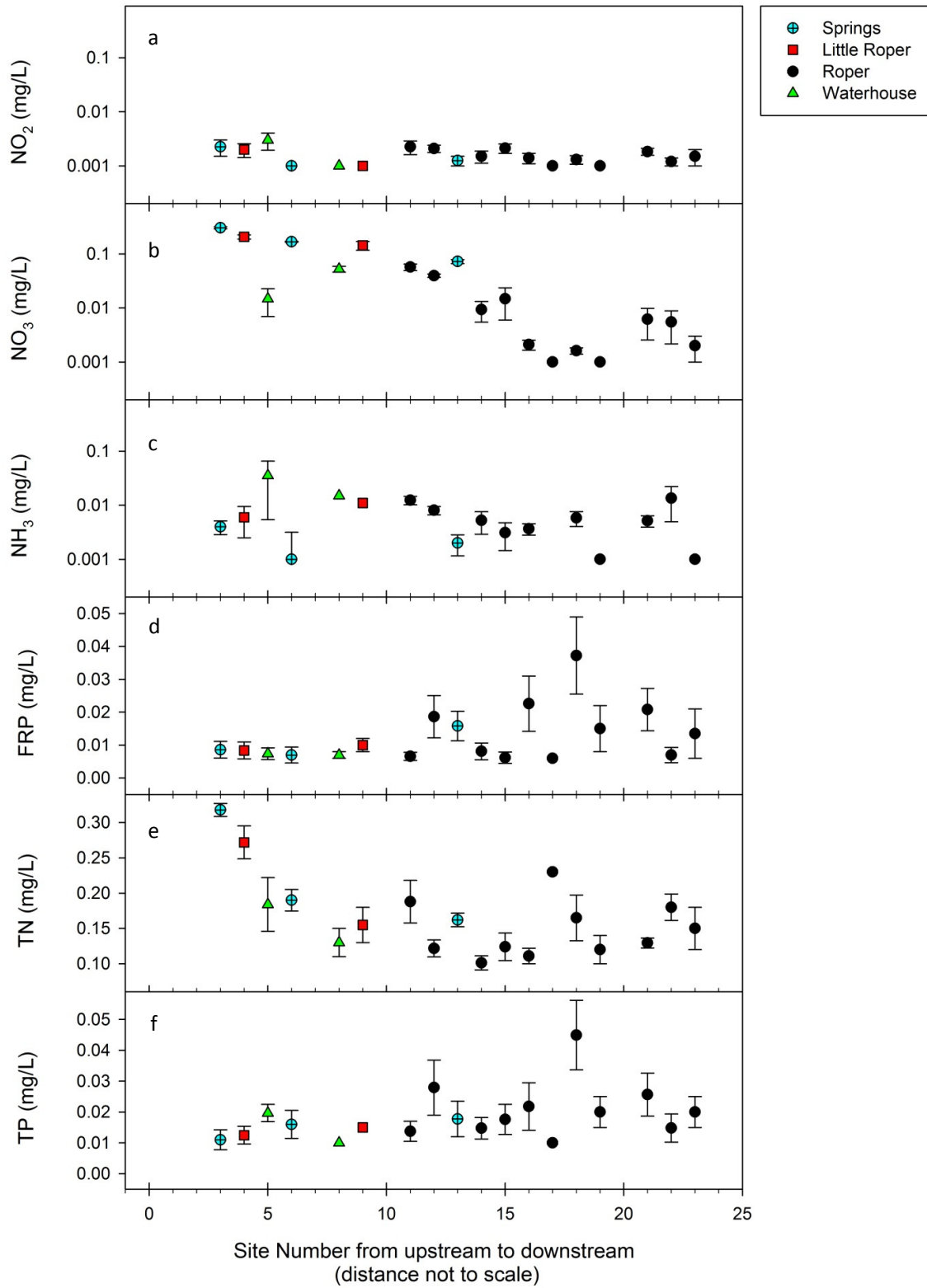


Figure 6. Longitudinal differences in dry season (May to November) water quality in the Roper River catchment, nutrients (mean $\pm 1SE$, n=1-16).

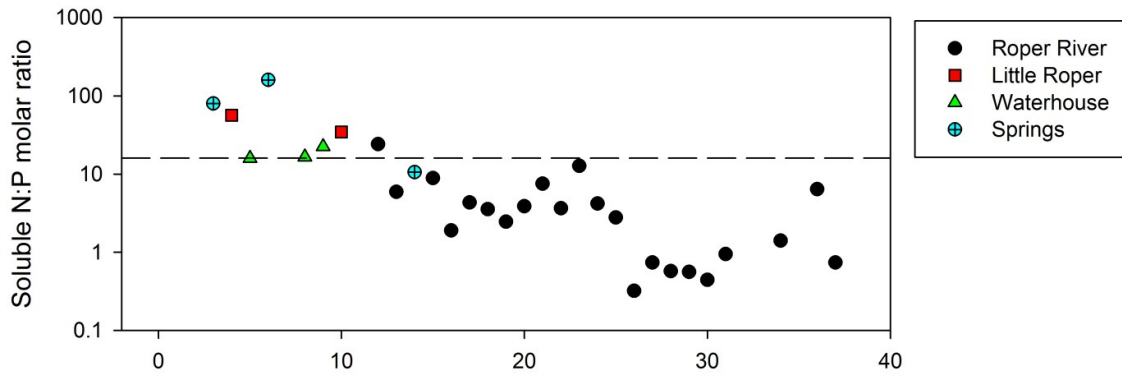


Figure 7. Longitudinal differences in dry season (May to November) soluble N:P molar ratio in the Roper River catchment. Dotted line indicates Redfield ratio of 16:1.

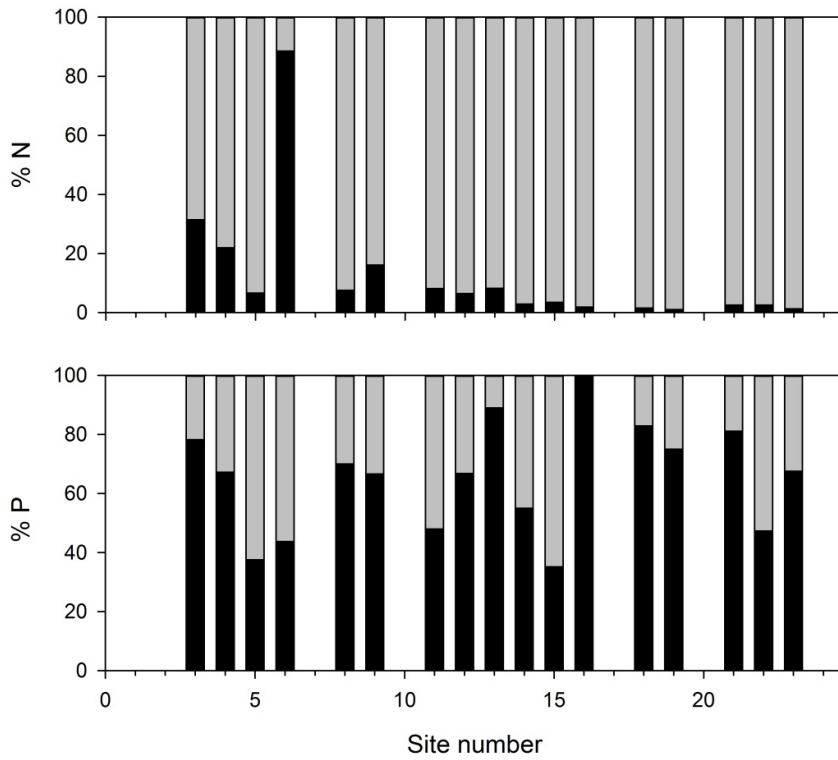


Figure 8. Longitudinal changes in mean dry season soluble and organic fractions of N and P. (soluble fractions shown in black).

6 Seasonal and interannual changes in water quality

6.1 Introduction and Methods

At the start of the dry season flow in the Roper River transitions from being predominantly provided by overland runoff to being almost solely groundwater-fed. At the beginning of the dry season groundwater levels and bank storage are usually high and smaller tributaries are still contributing to river flows. As the dry season progresses groundwater levels fall and the non-perennial tributaries gradually cease to flow. This section of the report examines the seasonal and interannual differences in water quality between the beginning and the end of the dry season.

Water Allocation Planning (WAP) sampling data (project 4) was used to examine differences in early and late dry season water quality. Early dry season samples are collected in May or early June each year, late dry season samples in October or November (Figure 9). Monthly monitoring data from project 5 supplements the WAP dataset adding additional sites to the analysis.

6.2 Results and Discussion

6.2.1 Physico-chemical parameters

With the exception of the springs, water temperature at all sites was generally lower in the early dry season than the late dry (Figure 10a, Figure 11a), in accordance with seasonal differences in air temperature, though in 2016 temperatures were almost the same. Spring water temperatures remained constant between seasons. Monthly measurements at Elsey National Park, Moroak Station and Mt McMinn Station (Sites 12, 16 and 21) show that the lowest temperatures occurred in July (Figure 12). The temperature range varied between years with larger seasonal temperature differences recorded in 2015.

In the Roper River tributaries electrical conductivity did not vary significantly between seasons and remained constant between years (Figure 10b). Only the Waterhouse River, which still receives low conductivity water from its upper reaches outside the Daly Basin at the start of the dry season, had a lower EC in the early dry season increasing towards the end of the dry (Figure 11b). In the Roper River, EC increases from the early to the late dry as groundwater becomes more dominant, and evapotranspiration causes a concentration of dissolved salts.

Early dry season EC varied between years while late dry season EC was similar in both years, reaching maxima of between 1400 and 1600 $\mu\text{S}/\text{cm}$. Differences in early dry season EC between years reflect the earlier onset of the low flow period in 2014, when the last major storm event occurred in March while in 2015, the last event was recorded in late April.

In 2014 pH was consistently lower in the early dry season and rose in the late dry at all sites in the upper catchment as well as the Roper River (Figure 10c, Figure 11c). This pattern was reversed in 2015 for most sites. It is unclear what may be the cause; however it may be due to poor instrument calibration in late 2015.

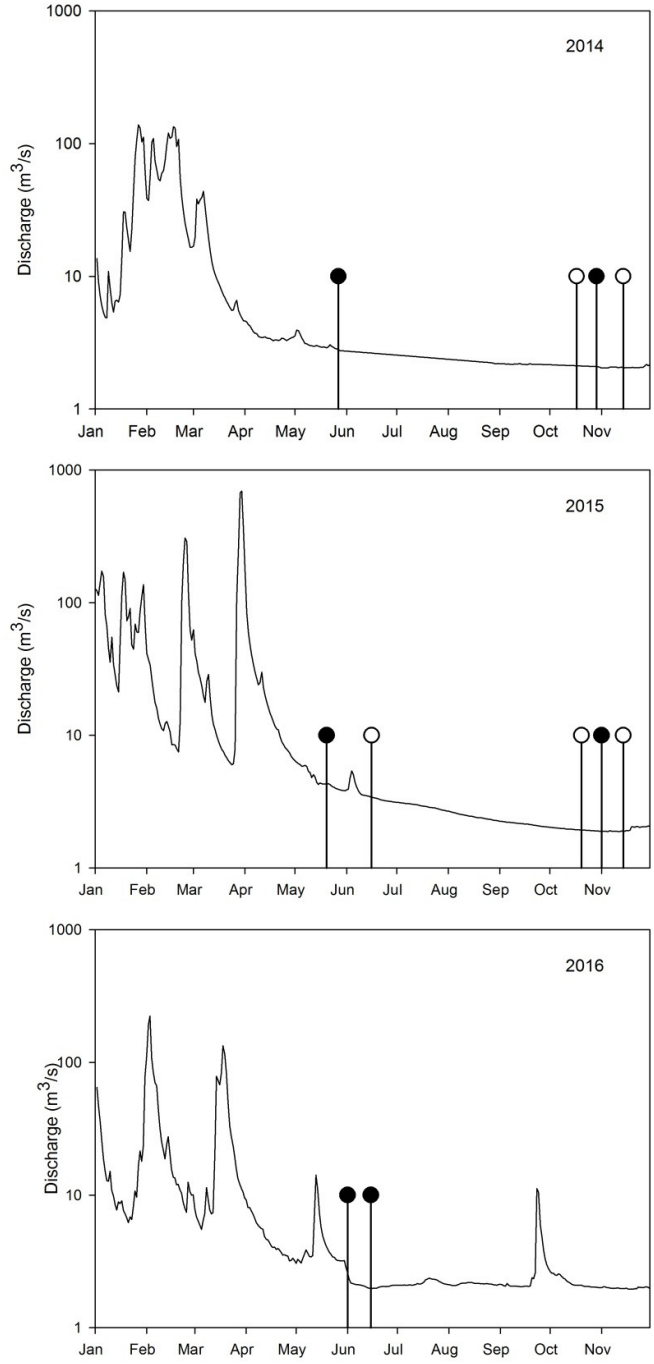


Figure 9. Hydrographs for station G9030176 (Mataranka) for 2014 to 2016. Dots and vertical lines indicate approximate time of sampling for seasonal water quality. Black dots: WAP sampling, white dots: supplementary data from Project 5.

At spring sites the dissolved oxygen saturation did not vary between seasons while in-stream sites in the upper catchment had higher DO earlier in the dry (Figure 10d). Stream sites on the Roper River had mostly higher DO saturation in the late dry compared to the early dry in 2014 and the reverse occurred in 2015, when DO saturation was mostly lower in the late dry season than the early dry. However, this interannual difference was not evident from the more detailed diurnal oxygen data collected at selected sites (see below, Section 8) and points to the caution that must be applied in using spot measurements taken at different times of the day to assess interannual and even seasonal changes in DO.

Turbidity was low (<5 NTU) throughout the dry season at all sites with springs being the clearest (Figure 10e). Due to the later onset of the low flow period in 2015 slightly higher turbidity was recorded in the early dry season of 2015 in the Roper River compared to 2014 and late 2015.

At Eley National Park (Site 12), Flying Fox Station (Site 16) and Mt McMinn Station (Site 21), monthly data were collected. This data confirms the trends observed in the separate early and late dry season samples (Figure 12). A drop in EC, pH and DO, and increase in turbidity at Mt McMinn Station in November 2014 was caused by an early wet season blackwater event that resulted in a fish kill at this site.

On 11 November 2014 a hypoxic blackwater event and fish kill was observed at Mt McMinn Station. Dissolved oxygen levels of less than 0.3 mg/L were measured and turbidity was >100 NTU. Large numbers of dead fish ranging in size from approximately 50 to 300 mm total length and a number of crustaceans (*Macrobrachium sp.*) were observed along the banks of the river (Schult, pers. obs.). Live fish were also seen on water surface “gasping” for air.

Similar fish kills are observed every year in the Top End and are considered to be natural events, though change in land-use could be a contributing factor. These events are known to occur when the first runoff events of the wet season carry large amounts of organic matter with high oxygen demand into the rivers (Townsend et al. 1992, Townsend 1994, Townsend and Edwards 2003, DoR 2016). The decomposition of the organic matter can deplete oxygen in the water and the hypoxic conditions lead to the death of aquatic organisms from asphyxiation. The event in 2014 is thought to have originated from the Flying Fox Creek area (Daniel Tapp, pers. comm. November 2014) and lasted for more than 5 days at Mt McMinn Station (Mark MtMcMinn station, pers. comm., November 2014). Black water was also reported from Ngukurr (DoR 2016), downstream of MtMcMinn station on 30 November 2014 and may have been related to the same event.

Anecdotal reports indicate that blackwater events are not common on the lower Roper River. The only other event known to a long term station owner in the region occurred 10 years prior (Daniel Tapp, pers. comm., November 2014). However, on 6 October 2016 a fish kill was reported from the Little Roper River in the upper catchment (Fish Kills and Disease Investigations Database, NT Dept. of Resources) with substantial rainfall recorded at Cave Creek Station near Mataranka on the days prior to the event (data from BoM 2016).

The occurrence of these hypoxic events highlights the vulnerability of river water quality to storm runoff from the catchment.

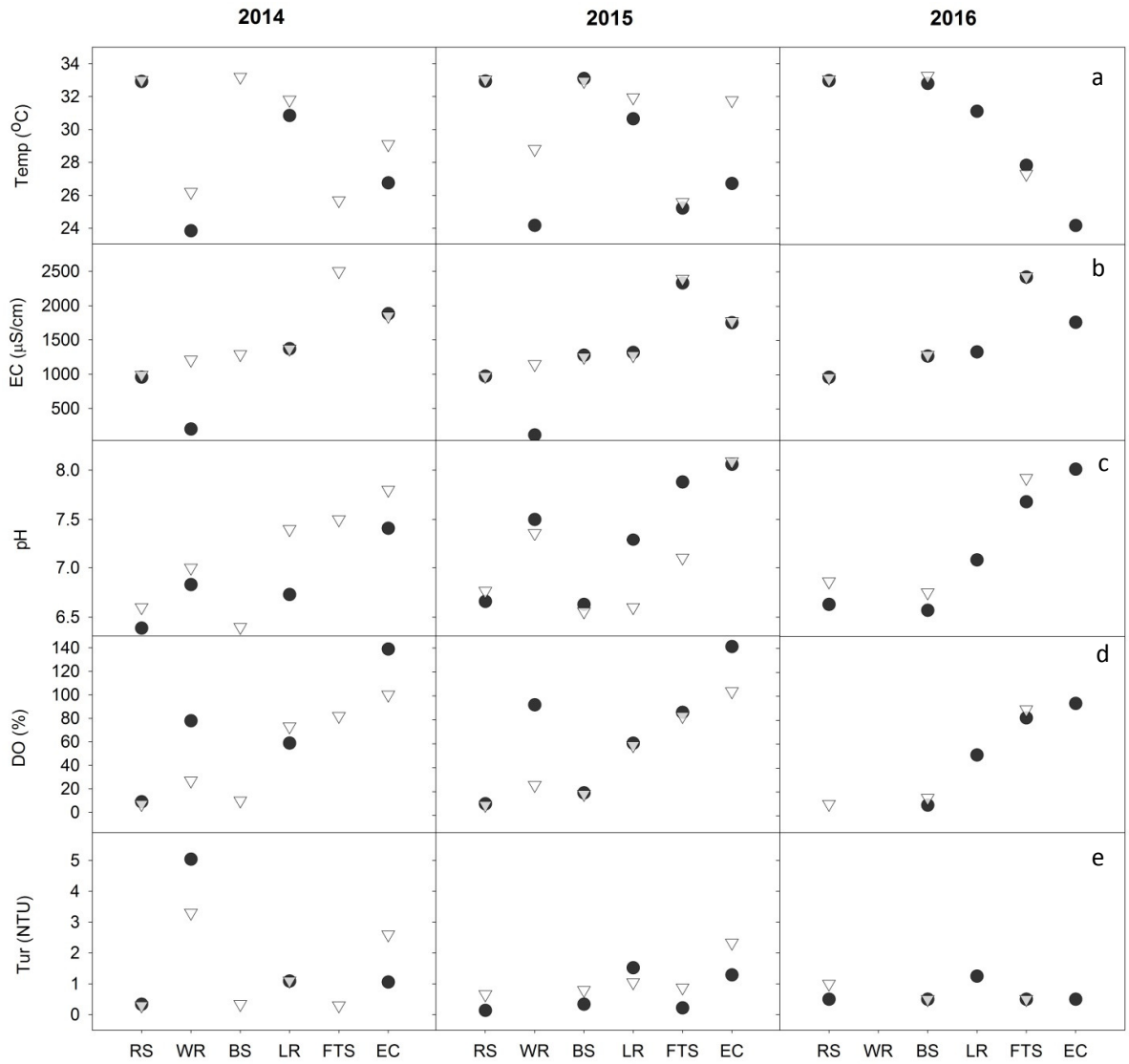


Figure 10. Early and late dry season physico-chemical water quality parameters between 2014 and 2016 for Roper River tributaries. Filled circles: early dry season, open triangles: late dry season. RS: Rainbow Springs, WR: Waterhouse River, BS: Bitter Springs, LR: Little Roper River, FTS: Fig Tree Springs, EC: Elsey Creek.

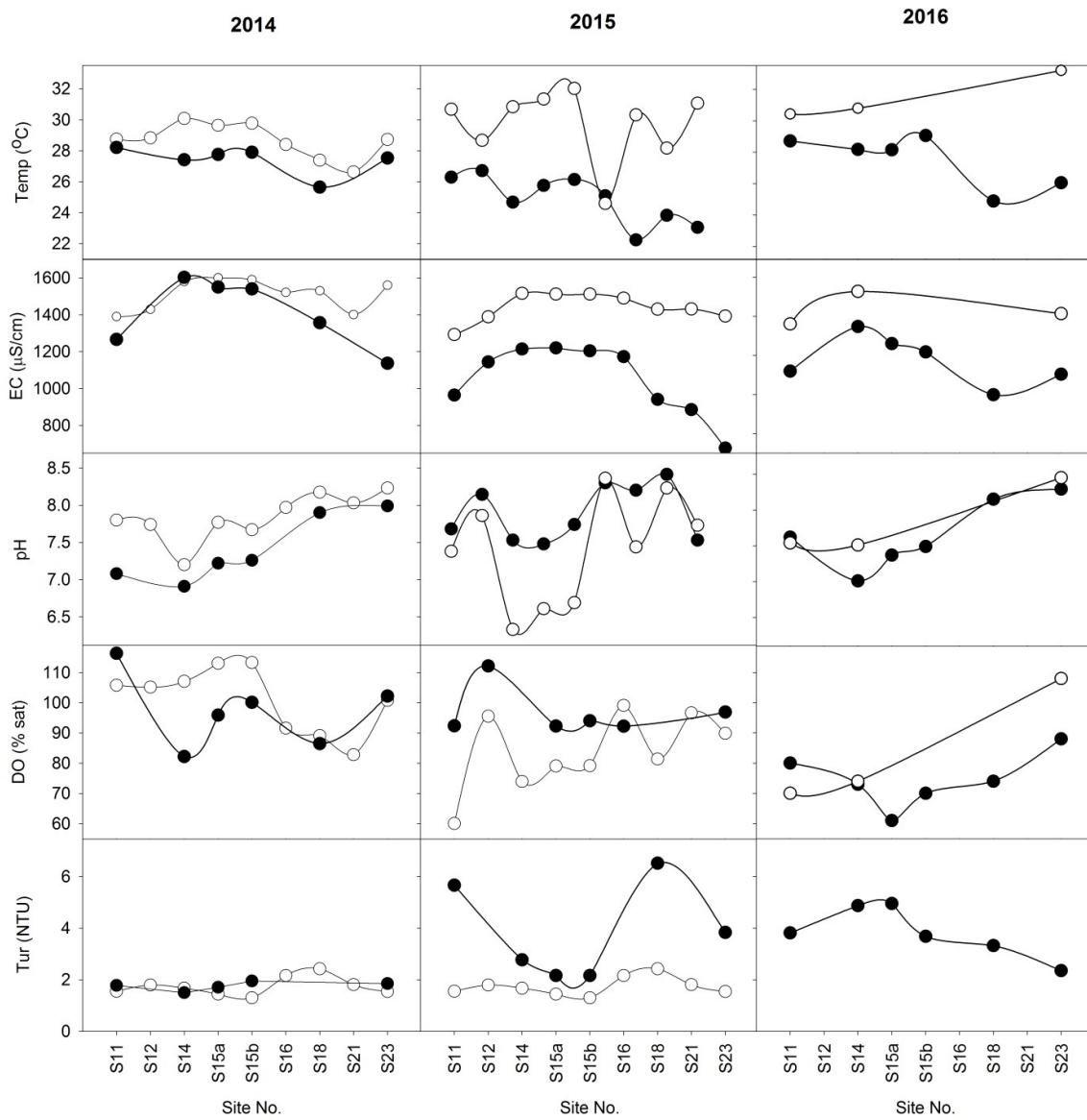


Figure 11. Early and late dry season physico-chemical water quality parameters between 2014 and 2016 for the Roper River. Closed circles: early dry season, open circles: late dry season.

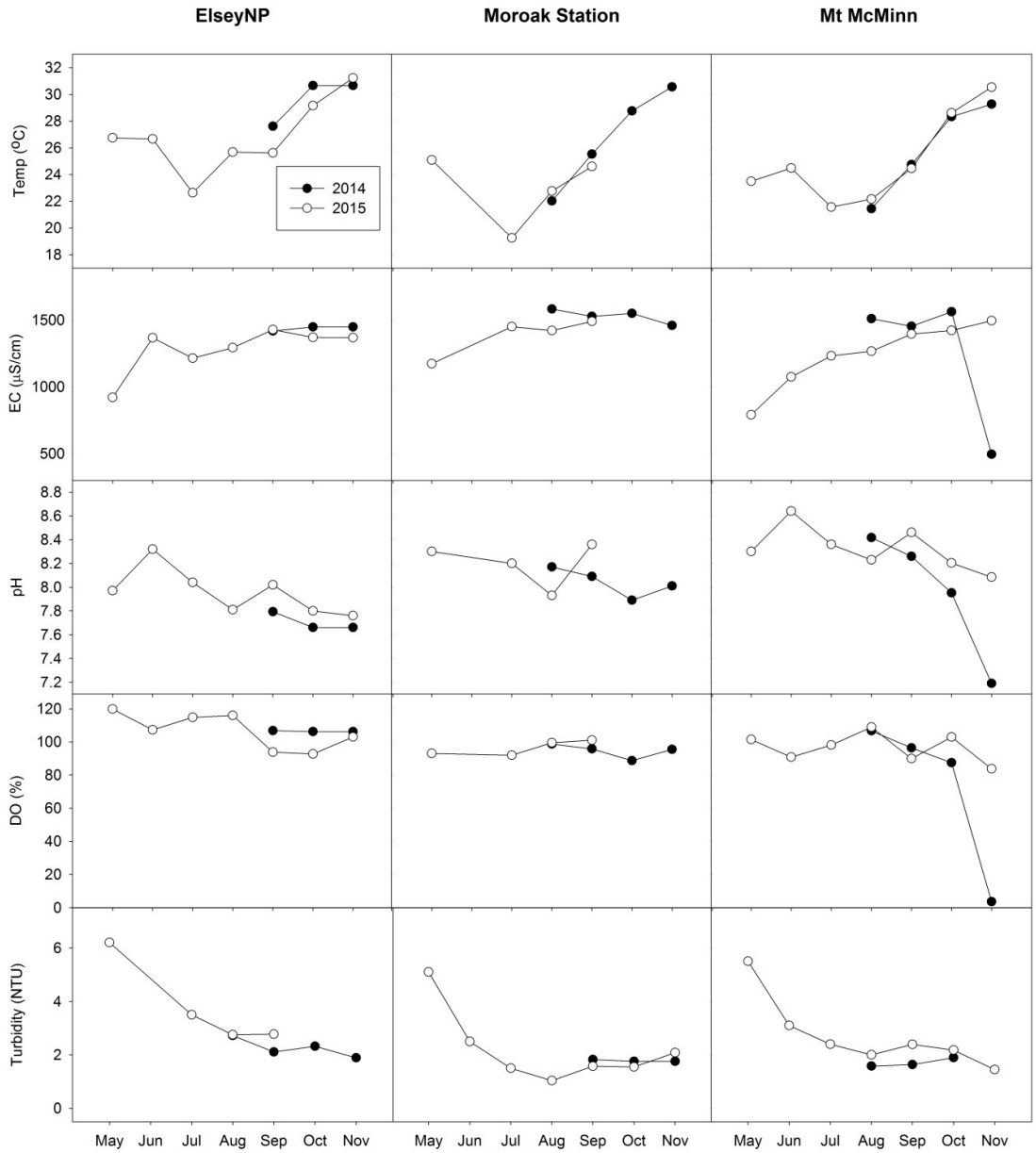


Figure 12. Monthly changes in physico-chemical parameters at three sites in the Roper River in 2014 and 2015. The November 2014 turbidity at McMinn's Station exceeded 100 NTU and is not shown.

6.2.2 Nutrients

Nitrite (NO_2) concentrations were very low (<0.007 mg/L) throughout the year at all sites. There was no clear seasonal pattern although early dry season NO_2 concentrations were slightly lower than late season concentrations in the middle reaches of the Roper River. However all the values were close to the limit of detection (Figure 13, Figure 14).

Nitrate (NO_3) concentrations ranged from <0.001 mg/L in the upper Waterhouse River to 0.800 mg/L in the Little Roper in early 2015. Spring sites had relatively constant NO_3 concentrations while NO_3 was higher in the early dry than the late dry season in stream sites both in the upper catchment and the lower and middle reaches of the Roper River. However, the most downstream sites showed an increase in NO_3 in the late dry in both years, most notably in 2014 (Figure 13, Figure 14).

Ammonia (NH_3) concentrations ranged from <0.001 mg/L to 0.155 mg/L and were variable across seasons, sites and years (Figure 13, Figure 14). There was no distinct seasonal pattern across all sites, however, monthly measurements from individual sites indicate that concentrations increase towards the end of the dry season (Figure 15).

Filterable reactive phosphorus was higher in the early dry than the late dry at all sites. FRP was markedly higher in 2015 than 2014, with concentrations ranging from 0.001-0.008 mg/L and 0.007-0.029 mg/L in 2014 and 2015 respectively in the tributary sites. The inter-annual difference was less pronounced but still noticeable in the Roper River where concentrations ranged from 0.001 to 0.008mg/L in 2014 compared to 0.004-0.012mg/L in 2015 (Figure 13, Figure 14).

Since FRP constituted a large proportion of total phosphorus, total P followed the same pattern observed for FRP. Total nitrogen was mostly higher in the early dry than the late dry in both years with the exception of the Waterhouse River and Sites 12 and 14 on the Roper River in 2015.

Overall, nutrient concentrations in the Roper River and its tributaries were higher in the early dry season than in the late dry season across both sampling years and most sites.

Nitrate concentrations in the springs are stable across the seasons, however, at stream sites, nitrate is lower in the late compared to the early dry season. Faster uptake of nutrients by established primary producers may be responsible for this change.

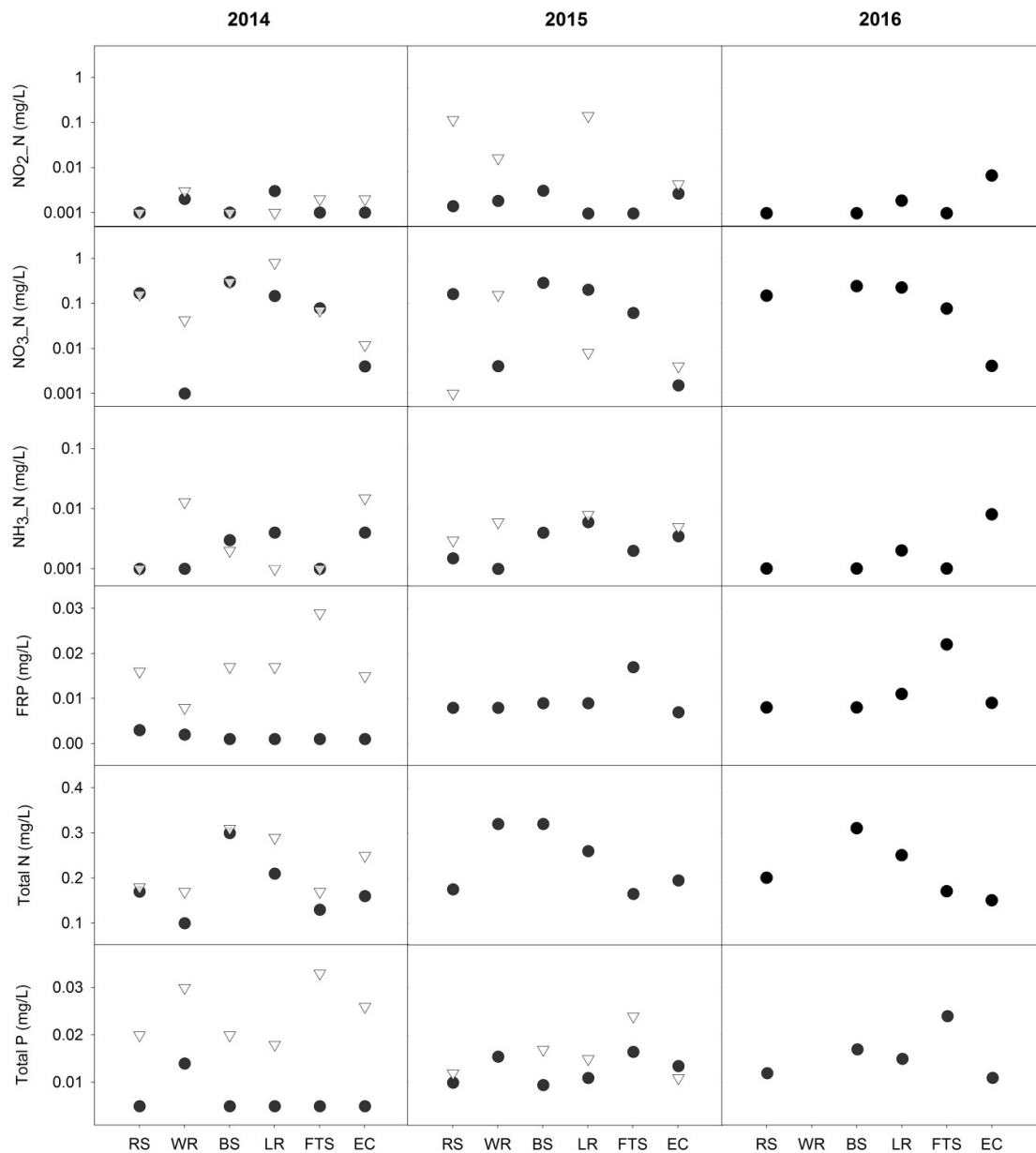


Figure 13. Early and late dry season nutrient concentrations between 2014 and 2016 for Roper River tributaries. Circles: early dry season, triangles: late dry season. RS: Rainbow Springs, WR: Waterhouse River, BS: Bitter Springs, LR: Little Roper River, FTS: Fig Tree Springs, EC: Elsey Creek.

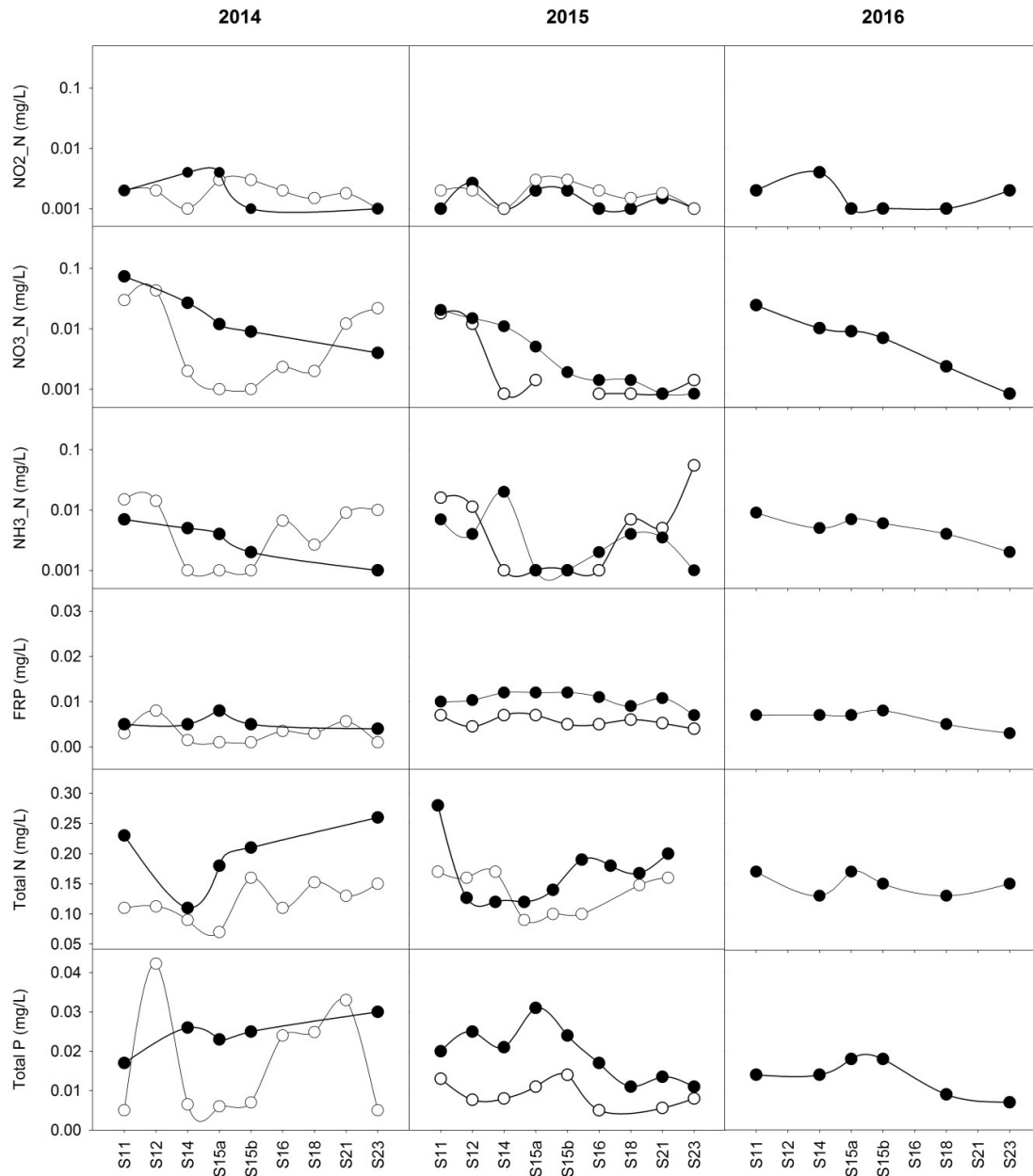


Figure 14. Early and late dry season nutrient concentrations between 2014 and 2016 for the Roper River. Closed circles: early dry season, open circles: late dry season.

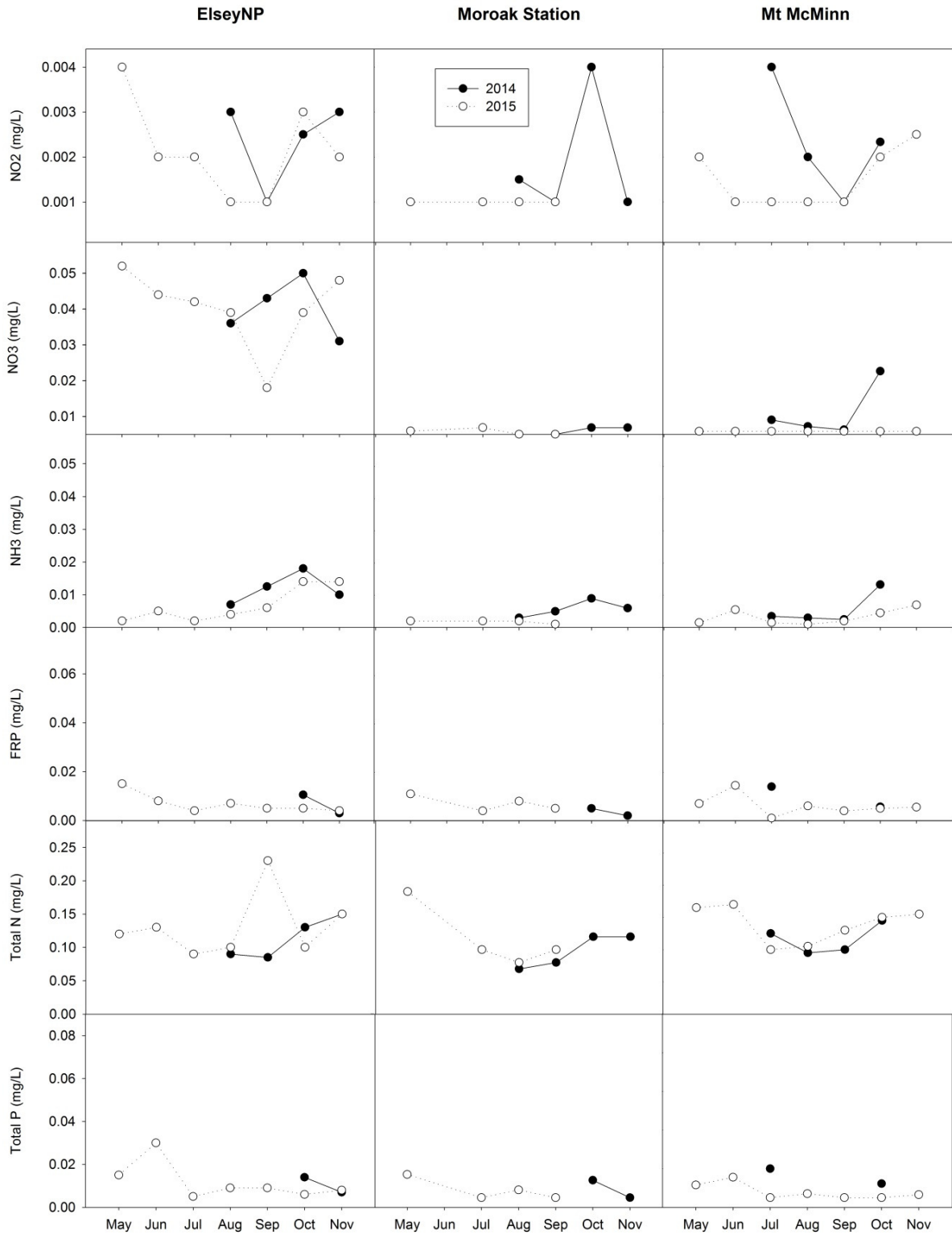


Figure 15. Monthly changes in nutrient concentrations for 3 sites in the Roper River, 2014 and 2015.
 Anomalously high FRP and TP values in August/September 2014 were considered to be an error and have been omitted from this graph.

7 Nutrient Loads

7.1 Introduction and Methods

The total amount of nutrients carried by the river is dependent not only on nutrient concentrations but also the total amount of flow in the river. Therefore, nutrient loads provide a better measure of the true quantity of nutrients that are transported by the river than concentrations alone.

Nutrient loads were calculated using flow measurements and nutrient concentrations from WAP monitoring in the early and late dry seasons 2014 and 2015. Flow gaugings were carried out by hydrographers of the Water Monitoring Group of the Department of Environment and Natural Resources using horizontal ADCPs (acoustic doppler current profiler) or handheld current meters for sites with low flows. Complete methods are described in departmental WAP monitoring reports (e.g. Kerle 2014). The load was calculated as the product of flow and concentration.

7.2 Results and Discussion

The vast majority of dry season discharge in the Roper River catchment is sourced from the limestone aquifer in the upper catchment. Of the limestone aquifer-fed tributaries in the upper catchment the Little Roper River contributes the majority of flow while Rainbow Springs and Eley Creek contribute smaller volumes (Figure 16a). The discharge at the Mataranka gauge station (Site 11) approximates the sum of the discharges from the Little Roper and Waterhouse Rivers. Dry season discharge in the Roper River proper approximately doubles between Mataranka (Site 11) and Eley Station (sites 15 a & b) where groundwater inflows cease.

Downstream of Eley Station (Sites 15a and b) the discharge decreases as the river loses water to evaporation and into the water table. This pattern of water loss in the lower catchment is more pronounced in the late dry season when surface water inflows from intermittent tributaries outside the Daly Basin are exhausted. Water losses of more than 50% occur in the reach from Eley Station to Red Rock (Site 22) in the late dry season.

Nutrient loads are the product of total discharge and the nutrient concentrations in the water column. The combination of higher discharge and higher nutrient concentrations in the early dry season (Section 0) led to higher nutrient loads in the early compared to the late dry.

The highest nitrate N load was carried by the Little Roper River in both years and during both seasons despite its relatively low discharge ($< 2 \text{ m}^3/\text{s}$). These high loads are a result of the very high nitrate concentrations in the upper catchment. The soluble nitrogen load in the Roper River decreased with distance downstream. In the early dry season of 2014 the Little Roper carried 34 kg/d of nitrate N, with the load decreasing to 21 kg/d at Mataranka and less than 2 kg/d at Red Rock. Loads in the late dry followed a similar pattern but were 40 to 60% lower with 20, 5.6 and 4 kg/d. An unusually high NO_3 concentration was measured at Red Rock (Site 22) in October 2014 leading to an increase in the calculated nitrate load.

Patterns were similar in 2015 with NO_3 loads decreasing from 36 kg/d in the Little Roper to 33 and 1 kg/d respectively in the early dry and 31, 11, 0.4 kg/d in the late dry season. The higher late dry

season load from the upper catchment in 2015 did not result in higher loads in the middle reaches of the Roper River, indicating that the available nitrogen is quickly taken up by primary producers.

Total nitrogen loads were more variable between the two years. In 2014 the TN load in the Roper River increased with increasing discharge between Mataranka and Eley Station in both the early and late dry seasons before a decrease further downstream. In early 2015 the pattern was reversed with the total nitrogen load being higher at the uppermost sites of the Roper then decreasing towards Eley station followed by an increase further downstream. High $\text{NO}_3\text{-N}$ loads at the upper Roper River sites in early 2015 contributed to this pattern.

The soluble phosphorus load was more closely related to discharge since FRP concentration did not vary widely along the longitudinal gradient. The FRP load rose between Mataranka and Eley station in both years and both seasons falling again in accordance with discharge in the lower Roper River.

FRP loads in the catchment ranged from 0.1 -4 kg/d in the early dry season of 2014 and reduced by 60 to 90% to 0.03 -0.57 kg/d in the late dry. In 2015 FRP loads were approximately double those of 2014 in both the early and late dry season. This occurred due to higher discharge in the early dry, and consistently higher FRP concentrations throughout 2015.

Since soluble P contributed a relatively large fraction of total P at most sites (Section 0) total phosphorus loads followed a similar general pattern as soluble P loads, with the exception of a higher load at Site 15a in early 2015 due to a high TP concentration at this site.

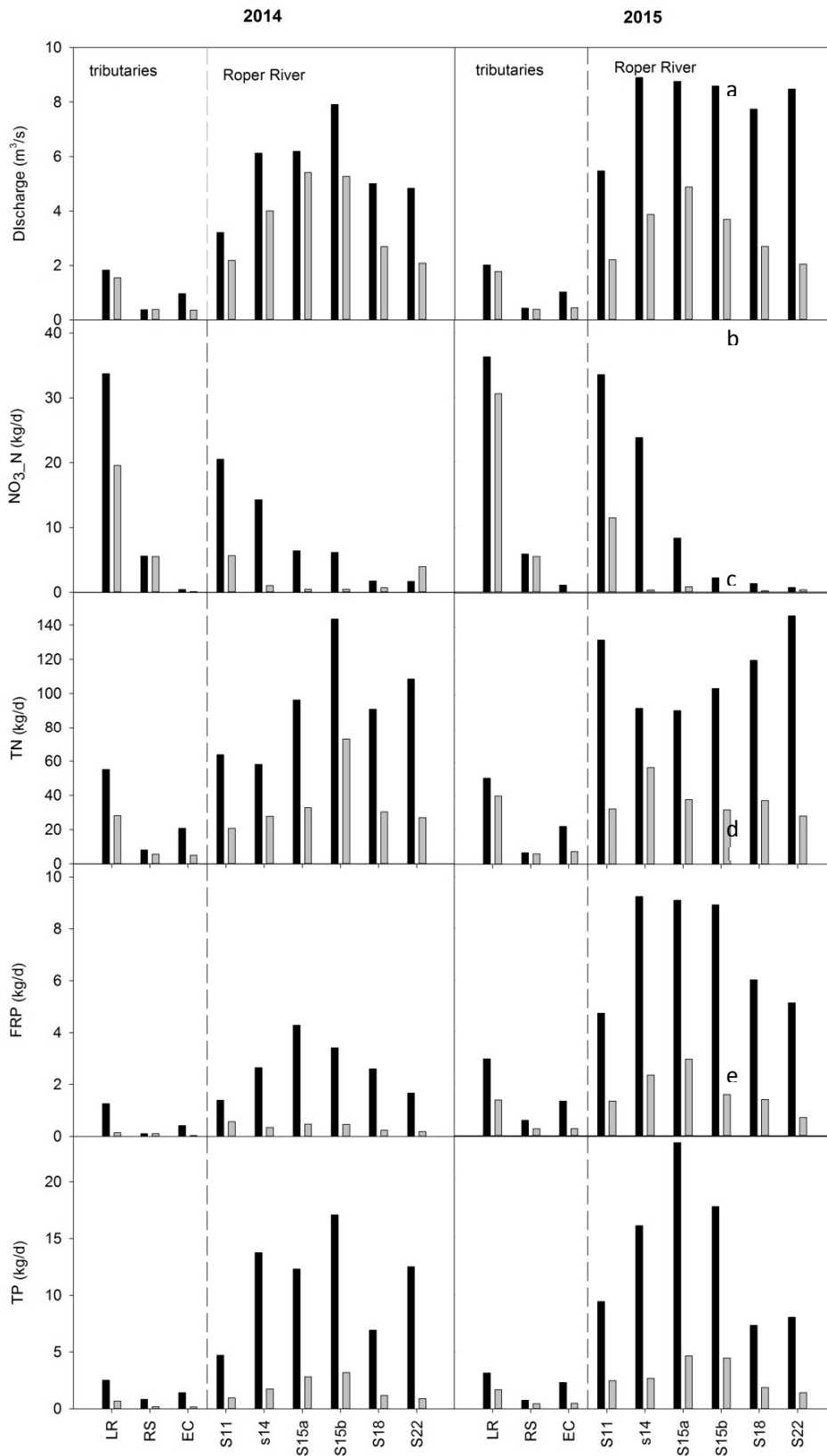


Figure 16. Discharge and nutrient loads in the early (black bars) and late (grey bars) dry seasons of 2014 and 2015.

8 Diurnal patterns of dissolved oxygen, pH and temperature

8.1 Introduction

Dissolved oxygen concentrations in natural waters are influenced by the rates of photosynthetic production of oxygen by algae and submerged aquatic plants, consumption of oxygen through plant and microbial respiration and the rate of oxygen exchange between air and water. Indirectly they are affected by light availability for photosynthesis, the amount of decomposing organic material, the turbulence of flow and subsequent re-aeration of the water, and the water temperature.

In a stream environment, dissolved oxygen concentrations measured at any one site provide an integrated measure of processes that occur upstream of the sampling site. Water that passes a measuring station at a particular time of day carries with it the history of the upstream conditions.

Oxygen concentrations fluctuate over the course of a 24-h period. Where the upstream distribution of primary producers is spatially equal and upstream hydraulic conditions (e.g. current speeds) are more or less uniform, diurnal oxygen concentrations typically follow a common pattern: oxygen concentrations rise rapidly between sunrise and solar noon as photosynthetic activity increases with increasing light availability. Maximum oxygen concentrations occur around or soon after solar noon, after which they decrease until they reach a minimum just before sunrise.

Different aspects of the shape of a diurnal curve are affected by primary production, respiration and the rate of gas exchange. The rate of photosynthetic activity, which (if photosaturation does not occur) is assumed to be highest at solar noon when light availability is highest, is the most important factor affecting DO maxima. Respiration is assumed to be constant over a 24h period, varying only with temperature. The respiration rate determines the extent of the DO minimum (Wilcock et al. 1998). The reaeration coefficient is responsible for the lag between solar noon and the time of the maximum oxygen concentration. The lower the reaeration coefficient, the later the maximum DO concentration occurs (Chapra and Di Toro 1991).

Temperature and pH are measures related to the oxygen concentration. The production of carbon dioxide by plant and microbial respiration reduces pH levels because the release of CO₂ into the water produces carbonic acid. As more CO₂ is produced and dissolved in the water, the aquatic environment becomes more acidic and the pH decreases. During photosynthesis, CO₂ is removed from the water and pH is raised. Both respiration and photosynthesis rates are dependent on the water temperature and increase with higher temperatures, while oxygen saturation concentrations decrease with increasing temperature because less oxygen can be dissolved in warmer water.

Temperature generally varies seasonally and diurnally due to changes in air temperature and incident light. Dissolved oxygen concentration, pH and temperature are positively correlated over a diurnal cycle.

8.2 Methods

Continuous diurnal measurements of dissolved oxygen, temperature and pH were collected for periods of 24-48 hours from 4 Roper River sites in 2014 and 2015 (project 4), and from 3 different habitats at one site in 2013.

In 2014, diurnal data were collected monthly between August and October from Elsey National Park (Site 13, ENP), Flying Fox Station (Site 29, FFS) and Mt McMinn Station (Site 34, MM), in the upper, middle and lower reaches of the Roper River. Additional data from Moroak Station (Site 16, MK) was collected in August 2014 only.

In 2015 data was collected monthly from May to November from only the two sites furthest upstream and downstream respectively (ENP and MM).

Sondes were positioned in areas with flowing water. Diurnal measurements were recorded at 6-minute intervals using an EXO 2 multi-parameter data sonde (YSI Inc., USA)

In 2013 diurnal water quality measurements were collected from three different habitats at Flying Fox station (Site 29, FFS):

1. the main channel, where flow was moderately fast,
2. a large pool upstream of Site FFS with slow flowing water, and
3. within a backwater pool with no visible flow.

Patterns of diurnal variation in oxygen concentration are compared between sites and monthly changes in the range of oxygen concentration are examined within sites over the dry season.

Single station diel oxygen curves can be used to estimate whole reach rates of photosynthesis (P), respiration (R) and re-aeration (K) (e.g. Odum 1956, Chapra and Di Toro 1991, Webster et al. 2005, Townsend et al. 2011) using a model fitting procedure to derive estimates of P, R and K. Such determinations rely on the assumption that the upstream environment is more or less homogenous in the distribution of primary producers and hydraulic conditions. However, model fitting and parameter estimation for P, R and K were beyond the scope of this report and were not attempted here. Furthermore, these model fitting techniques are only valid for sinusoidal curves with gas transfer velocities of $<0.5 \text{ m h}^{-1}$ (Demars et al. 2015) and cannot be applied to some of the sites monitored.

8.3 Results

Figure 17 shows typical examples of the diurnal curves of dissolved oxygen saturation, temperature and pH for each of the sites as measured in August 2014. The complete set of monthly figures for 2014 and 2015 is provided in Appendix 4.

The dissolved oxygen levels at Elsey National Park and Flying Fox Station followed a typical diurnal pattern with DO minima occurring in the early morning, rising DO during the day, maximum oxygen saturation at approximately 3pm and minimum before sunrise. At Mt McMinn station maximum DO

saturation occurred approximately 1.5 hours earlier and night time DO did not decline (Figure 17A,B).

Moroak Station showed a different diurnal oxygen pattern with a shift of maximum and minimum oxygen saturation periods by approximately 13 hours compared to the other sites (Figure 17C). The highest dissolved oxygen concentrations at this site were measured in the early hours of the morning and then dropped to a low in the late afternoon. A small secondary peak was evident close to midday.

In August 2014, oxygen saturation ranged from 85-112% at Elsey National Park. Supersaturation occurred during the day and the water remained well oxygenated throughout the night (Figure 17 A).

At Flying Fox Station the range of oxygen saturation values was much smaller with approximately 90-100 % saturation over the 48-hour period measured. Oxygen levels rose sharply during the morning and fell slowly during the afternoon and night (Figure 17 B).

Mt McMinn Station had an intermediate dissolved oxygen profile with saturation ranging from 95-110% over the diurnal period (Figure 17D).

Water temperatures follow a similar diurnal pattern to dissolved oxygen. In August 2014 water temperatures were highest at Elsey National Park ranging from 23.5-26°C (Figure 17A). At both Flying Fox Station and Mt McMinn temperatures were lower with a smaller range of 21-22°C, while Moroak Station had slightly higher temperatures ranging from 21.7-22.6 °C. The groundwater inflows in the upper catchment have a constant temperature of about 32°C, contributing to the higher river temperatures at Elsey NP. The diurnal fluctuations in pH were also closely correlated with the dissolved oxygen curves.

The general diurnal patterns of dissolved oxygen concentration, temperature and pH remained similar within each site throughout the year (see Appendix 4 for a complete set of figures). However, the diurnal ranges of oxygen concentrations varied markedly over the dry season (Figure 18). At Elsey National Park (Site 12) in the upper reaches of the Roper River, the diurnal range was large in the early dry and smaller in the later dry season months, with a maximum range of 3.7 mg/L (6.7 - 10.4) in June 2015 and a minimum range of 2.1 mg/L (7-9.1) in September.

In the lower reaches of the Roper River this pattern was reversed and overall the diurnal changes were much smaller. At Mt McMinn Station (Site 21) dissolved oxygen ranged from 7.6 to 7.9 mg/L in June and 6.6-8.5 mg/L in October. Minimum and maximum dissolved oxygen concentrations at all sites increased from May to July and then decreased from August to November.

Flying Fox station (FFS, Site 18) was only sampled in 2014 and with variations of less than 1mg/L over the sample period had the smallest DO ranges of the three sites during this time.

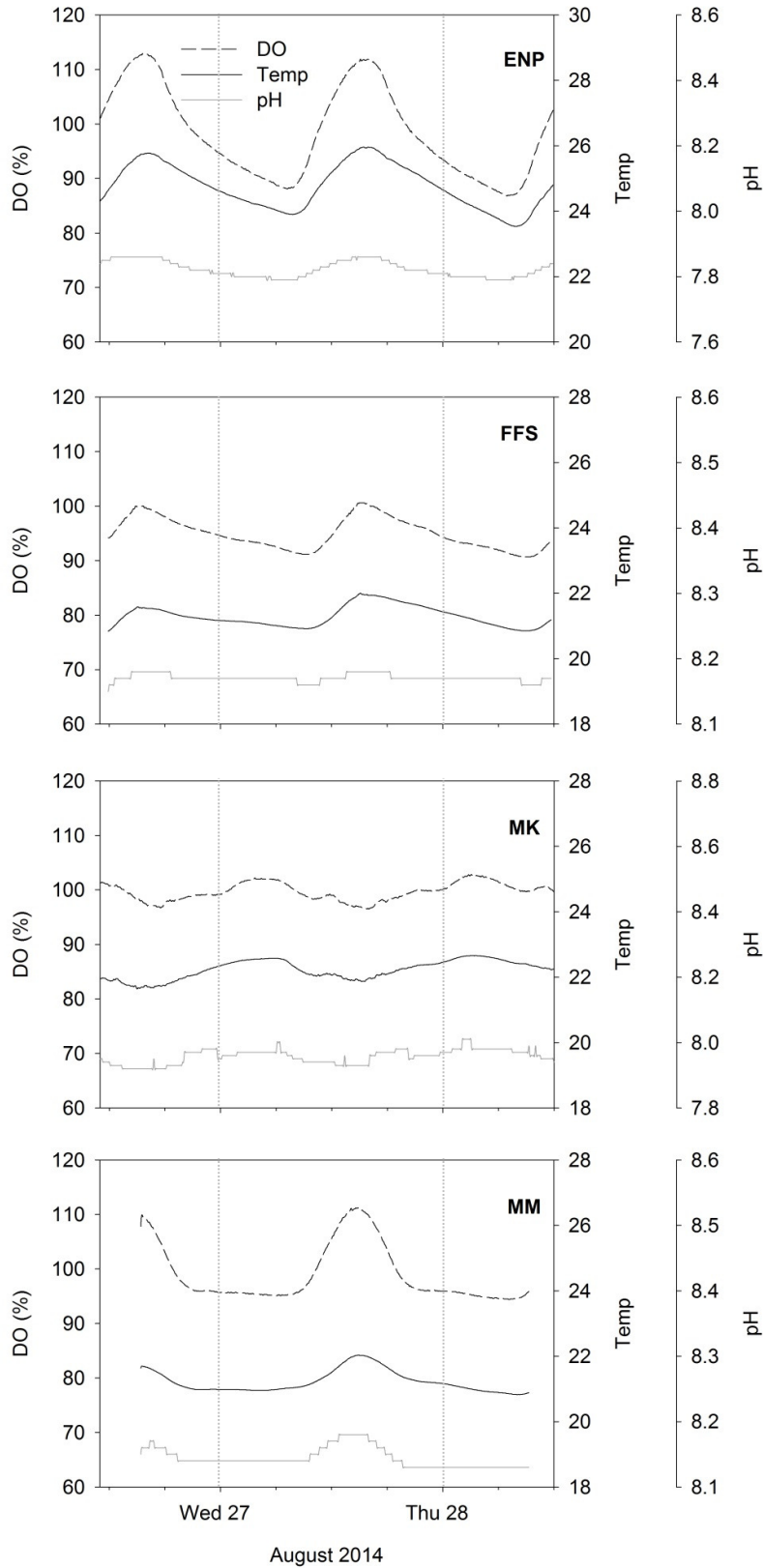


Figure 17. Typical diurnal curves of dissolved oxygen, temperature and pH at 4 sites on the Roper River as measured in August 2014. Vertical lines indicate midnight.

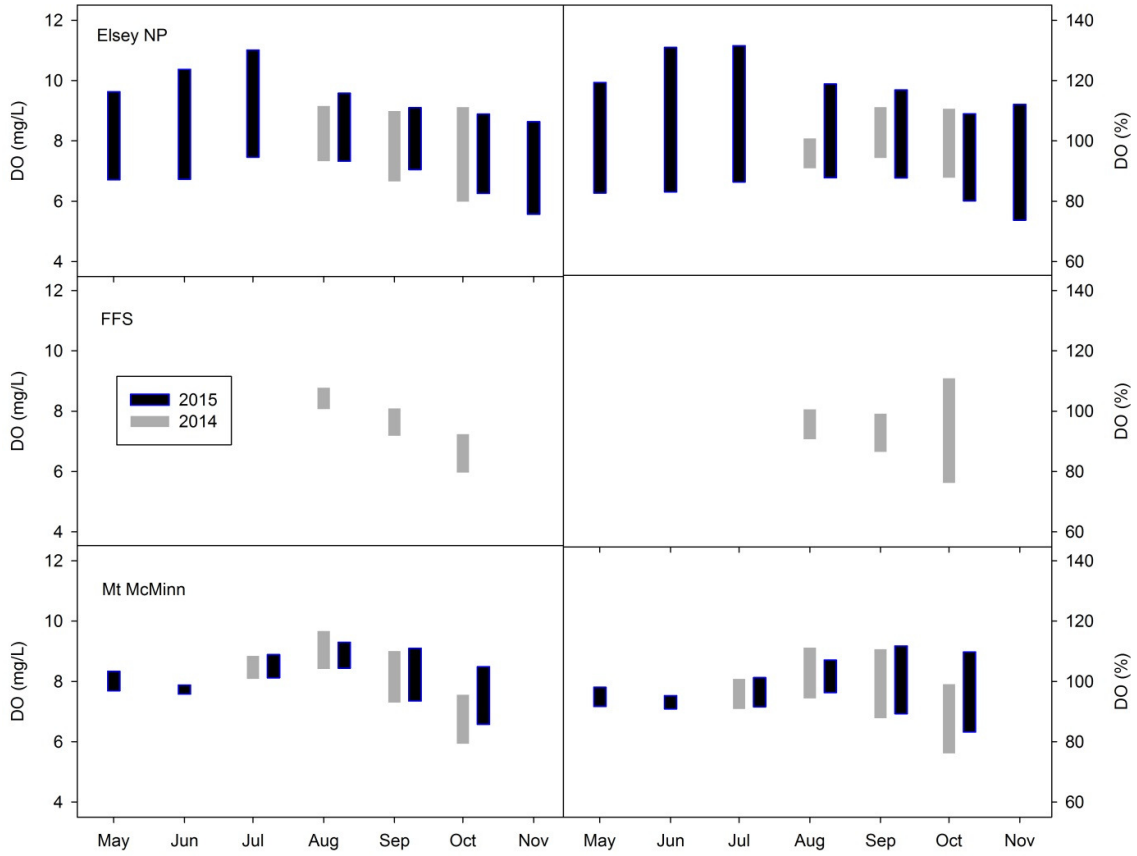


Figure 18. Range of diurnal variation in dissolved oxygen concentrations and % saturation measured monthly in the upper, middle and lower reaches of the Roper River in 2014 and 2015. (FFS: Flying Fox Station, G9030010).

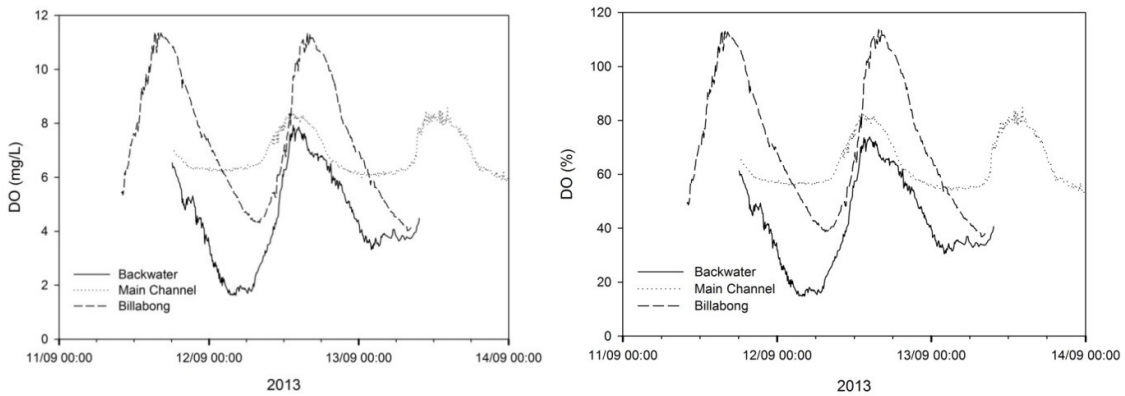


Figure 19. Diurnal dissolved oxygen patterns in three different in-stream habitat types in the Roper River at Flying Fox station, 11-13 September 2013.

Different habitats at Flying Fox station were measured in September 2013 and had markedly different diurnal oxygen patterns. While DO in the main channel fluctuated within a range of only 2.5 mg/L (6-8.5 mg/L) over a 24h period, the billabong and backwater habitats had diurnal ranges of 7.4 and 6.3 mg/L respectively. DO in the backwater habitat was much lower than in the billabong and main channel habitats with a maximum of 7.9 mg/L and a minimum of 1.6 mg/L during the night (Figure 19).

8.4 Discussion

The Roper River was well oxygenated throughout the dry season, with seasonal minima of oxygen saturation in the late dry season of around 75% at all sites. (An exception was the blackwater event and fish kill that occurred at Mt McMinn Station in November 2015 when oxygen levels close to zero were measured. See above for more detail on this event)

The variability in diurnal patterns of dissolved oxygen concentration between sites reflects differences in local hydraulic and ecological conditions. The high daytime oxygen concentrations above 100% saturation at Elsey National Park indicate high gross primary productivity that is likely fuelled by the high nutrient availability and higher water temperatures in this area. Large beds of filamentous algae were present at Site 12 at Elsey National Park early in the dry season 2015 (Schult pers. obs.). At this site the river is wide and open, with little shade to inhibit algal growth. The high levels of oxygen saturation and large diurnal fluctuations reflect this high productivity.

In the middle and lower reaches, where N availability is limited and temperatures are lower, primary production occurs on a more moderate scale. The lower maximum oxygen saturation and smaller range indicate lower rates of photosynthesis and respiration compared to Elsey National Park.

The dissolved oxygen pattern observed at Moroak Station differed markedly from the other sites. DO maxima occurred during the early hours of the morning with a small secondary peak at noon. The presence of a large pool with deep water and low current speeds upstream of the site results in low rates of gas exchange between air and water causing a large lag between solar noon and the maximum DO saturation and a delay in the arrival of the daytime oxygen peak from upstream. The smaller secondary daytime peak is likely to reflect localised oxygen production.

At Mt McMinn Station, the site furthest downstream, oxygen concentrations did not decline significantly over night. Such a pattern can result either if the reaeration coefficient is high, caused by shallow or turbulent water in the study reach that leads to equilibrium between respiration and reaeration during the night (e.g. Wilcocks et al. 2005, Uehlinger et al. 2000, Demars et al. 2015), or due to heterogeneity in channel morphology. A similar effect was observed in a study in the Daly River catchment (Townsend et al. 2011) at Hayes Creek. This study attributed the effect to channel heterogeneity, in particular the presence of a large pool upstream of the study site. The delayed arrival of the oxygen peak from this pool at the study site could have caused the observed stable night time oxygen concentration. In the absence of more detailed data on upstream channel morphology and gas exchange velocities at our Roper River study site, the reasons underlying the local diurnal dissolved oxygen pattern remain unknown.

The measurements from Flying Fox Station in 2013 demonstrate that diurnal oxygen patterns not only vary between sites but can differ widely between habitats within a single site. While waters in the pool (billabong) habitat were well oxygenated during the day and followed a typical pattern, the overnight oxygen concentration was much lower and DO in the backwater habitat declined over night to less than 20% saturation (<2 mg O₂/L).

Low dissolved oxygen levels can affect fish and invertebrates in streams. The tolerance of fish to low dissolved oxygen levels varies widely between species and life stages. Effects depend on the oxygen concentrations and the duration of exposure to low oxygen levels (Butler and Burrows 2007). Although fish can survive considerable periods at dissolved oxygen concentrations below their optimum, prolonged or frequent exposure to hypoxic conditions can lead to non-lethal effects such as reduced growth rates, loss of condition and reduced competitiveness.

Oxygen curves from the main channel showed a similar pattern to that observed at Mt McMinn Station with a relatively low diel variation in oxygen concentration and stable DO during the night. The interpretation of this pattern is confounded by the same factors mentioned above. It is worth noting that the oxygen curves measured in 2014 and 2015 at Flying Fox Station followed yet another pattern, probably due to the sonde being located in a different in-channel position.

The comparison of diurnal ranges of oxygen concentrations within each site over the course of the dry season shows contrasting patterns of seasonal variation at Sites 11 and 23.

At Eley National Park diel ranges increased in the early dry season and were highest in June and July after which they remained at a lower level for the rest of the year. High benthic algal biomass was observed at this site early in the season (Schult, pers. obs.) when both DO maxima and diurnal range were highest. Supersaturation in this period reached very high levels during the day. Later in the year sloughing of algae had already begun, presumably reducing productivity to a lower level and leading to a more moderate range of DO values. Similar patterns of benthic algal biomass accrual and loss over the dry season were reported by Townsend and Padovan (2005) in the Daly River where maximum biomass occurred in early August.

In contrast, benthic algal biomass at Mt McMinn station in 2015 was low early in the dry season and increased later in the year (DENR, unpublished data). The change in the diel oxygen range at the site reflects this pattern with an increase in DO range towards the late dry season.

The quantification of gross primary production, respiration and gas transfer velocities was beyond the scope of this report so that no assessment of whole reach metabolism or a determination of heterotrophy/autotrophy can be made. Furthermore, the common approaches to modelling of river metabolism are not valid for sites with high gas exchange velocities or heterogeneous channel morphology (Demars et al. 2015, Townsend et al. 2011) and should therefore not be applied to some of the Roper River sites described here.

However, the general diurnal oxygen patterns encountered suggest higher productivity in the upper reaches of the river compared to the lower parts and emphasise the importance of the physical environment upstream of the sample site for the interpretation of the diurnal oxygen curves.

If diurnal dissolved oxygen or whole river metabolism is included in a long-term monitoring program of river health, attention must be given to the placement of instruments and consistency of location to allow the meaningful comparison of data over time.

9 Wet season Water Quality

9.1.1 Introduction and Methods

The wet-dry monsoonal climate of the region determines the hydrology of Top End rivers and leads to distinct seasonal differences in water quality. While groundwater inputs overwhelmingly dominate dry season flows and water quality, with both flow and water quality being relatively stable during this time, wet season storm events and monsoonal periods bring large amounts of rainwater runoff to the rivers. Water quality during this time is much more variable.

During the 2013/14 hydrologic year a Hydrolab multi-parameter sonde was deployed at Flying Fox Station (Site 29) from October 2013 to August 2014. Temperature, pH, EC and depth were logged every 3 hours for the duration of the deployment. At the initial deployment and retrieval of the instrument calibration measurements for temperature, pH and EC were taken at the site using a calibrated Quanta probe. Temperature and EC were stable across the deployment period and no corrections were applied to the data. Calibration measurements indicated that there was drift in pH of 0.34 pH units over the long-term deployment. A linear correction was applied to all pH measurements to adjust for this drift. Turbidity measurements at the end of the deployment period also showed a discrepancy of 3.5 NTU. However, applying a linear correction factor to turbidity rendered unsatisfactory results. The raw data were still considered informative and are included without correction.

The hydrograph was divided into individual storm events defined by the start of a rise in water level. Return to baseflow after early wet season storms and the beginning and end of the wet to dry season transition period was defined visually by a change in the slope of the hydrograph. The inflection point of the falling limb of the final event of the 2013/14 hydrological year was taken to be the start of the wet to dry transition period (Figure 20). There were six distinct storm events during the 2013 wet season. The largest event (event #5) was treated as one event with a double peak.

More sophisticated methods of hydrograph separation are available, however, this quick visual method was considered sufficient for the purposes of this report.

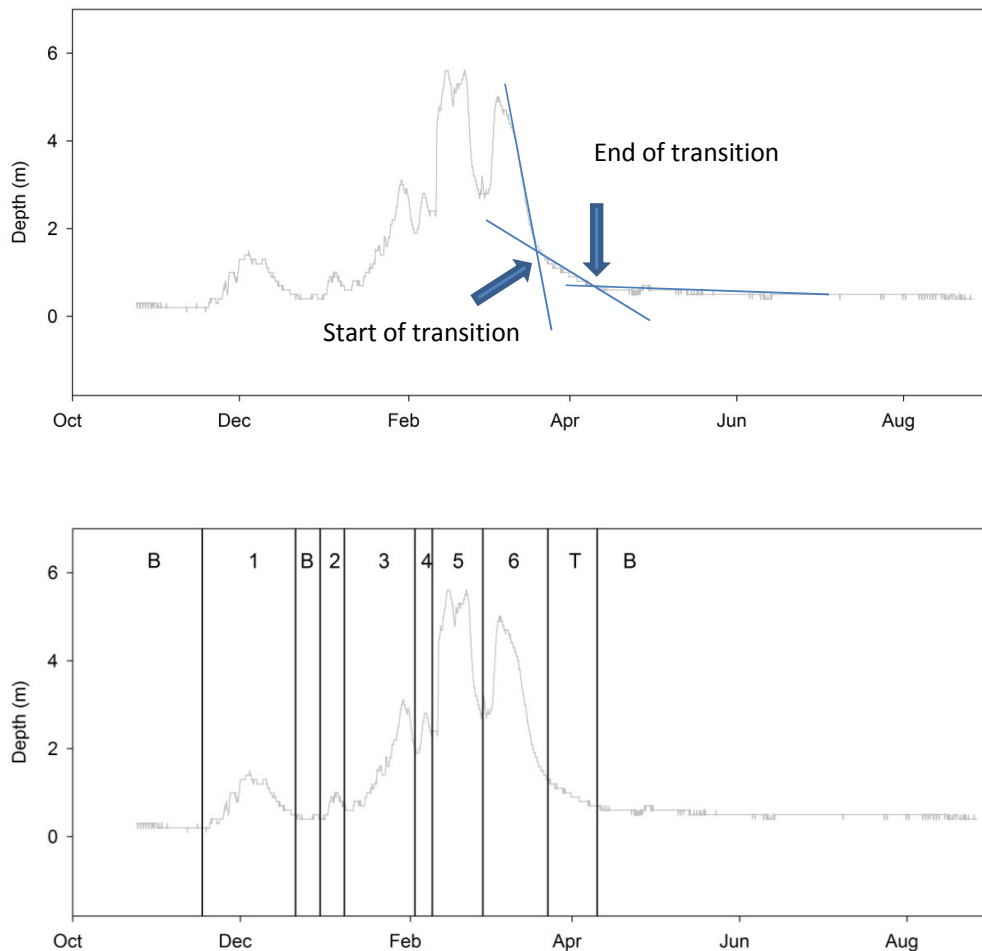


Figure 20. Visual determination of Storm events and the start and end of the wet/dry transition period. Numbers indicate individual storm events, B=baseflow, T=transition period.

9.1.2 Results and Discussion

Patterns of wet season water quality are closely related to flow and climatic conditions. Water temperature rose from October to January 2013 but dropped periodically during the early stages of major flood events. During recessional and base flows from late March to July 2014 the average temperature fell gradually and started to rise again from August to September (Figure 21a) and patterns closely followed air temperature (linear regression, $R^2=0.84$, Figure 22)

Electrical conductivity and pH were inversely related to depth (Figure 23). Due to a faulty setting on the instrument, EC was recorded in 100 $\mu\text{S}/\text{cm}$ increments, leading to a lack of detail in the dataset. Nevertheless, EC ranged from approximately 200 $\mu\text{S}/\text{cm}$ during the peak of a flood event to 1500 $\mu\text{S}/\text{cm}$ during the dry (Figure 21c).

During the peak flood pH fell to 7.0 but was otherwise slightly alkaline with a maximum of 8.3 during the late dry season (Figure 21b).

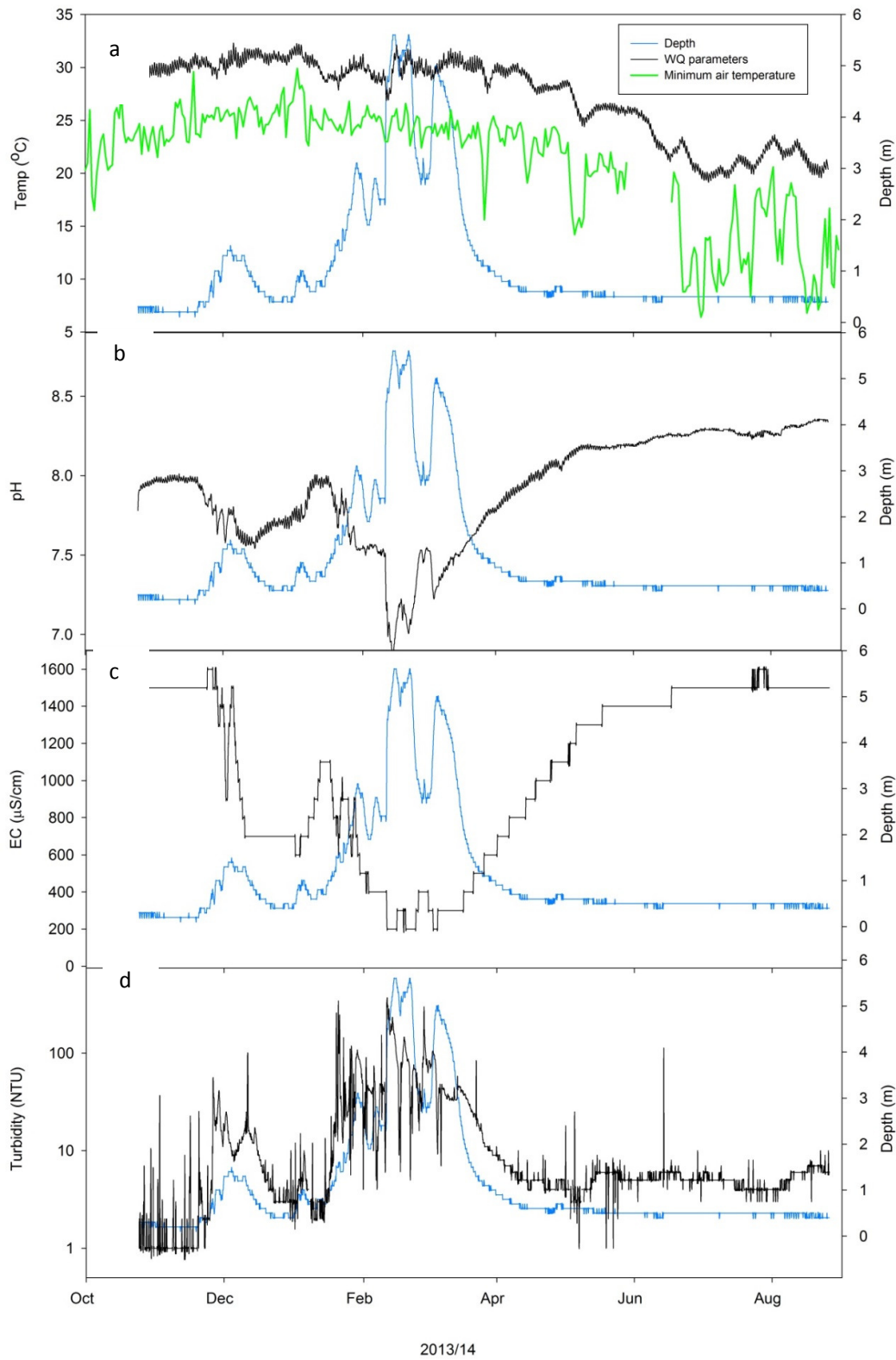


Figure 21. Continuous measurements of water quality at Flying Fox Station in 2013. Minimum air temperature at Ngukurr is shown in light grey in part (a).

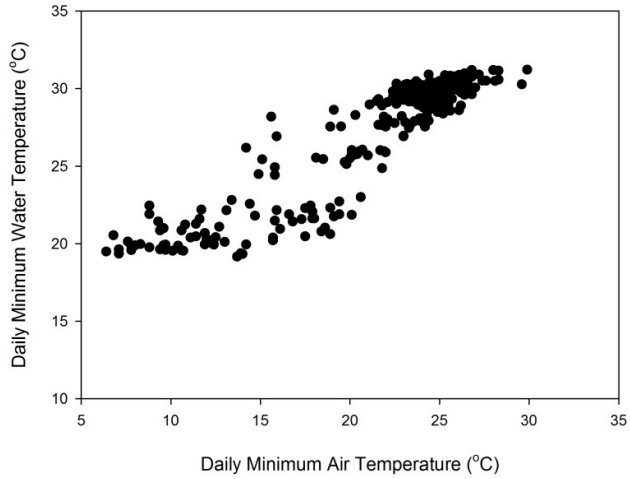


Figure 22. Air temperature vs. water temperature in the middle reaches of the Roper River in 2013/14

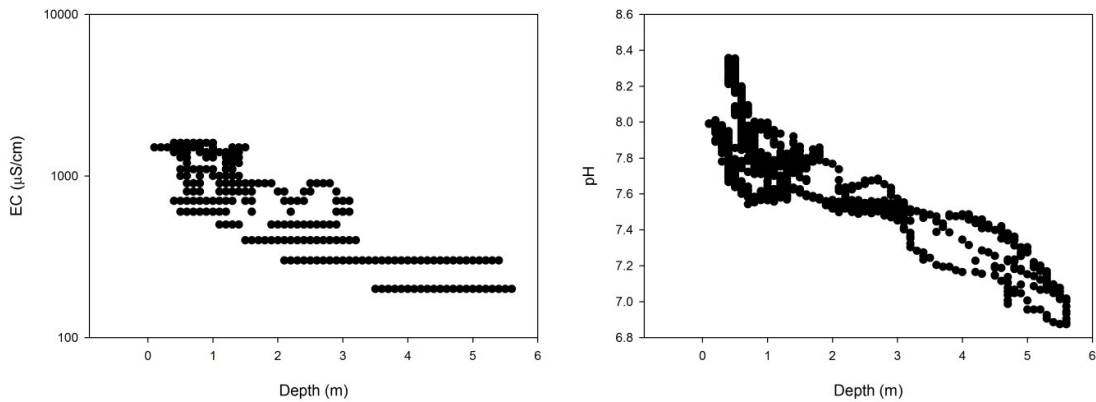


Figure 23. Electrical conductivity and pH relationship with depth.

Overall, turbidity ranged from <1 NTU during late dry season base flow conditions to a maximum of 356 NTU during the biggest flow event of the season.

Turbidity was lowest during baseflow conditions (1-10 NTU) with occasional peaks during the dry season likely to be caused by localised disturbances or instrument fouling (Figure 21d)

The first major storm event of the wet season (Event 3) was associated with high turbidities. Later storm events (e.g. events 5, 6), although much bigger in size, had similar or lower maximum turbidities. Turbidity was highest during the rising limbs of storm events and showed an exhaustion effect with continuing high flows (Figure 24). There was a distinct drop in turbidity during the peak flows of the two largest storm events (Figure 21, Figure 24).

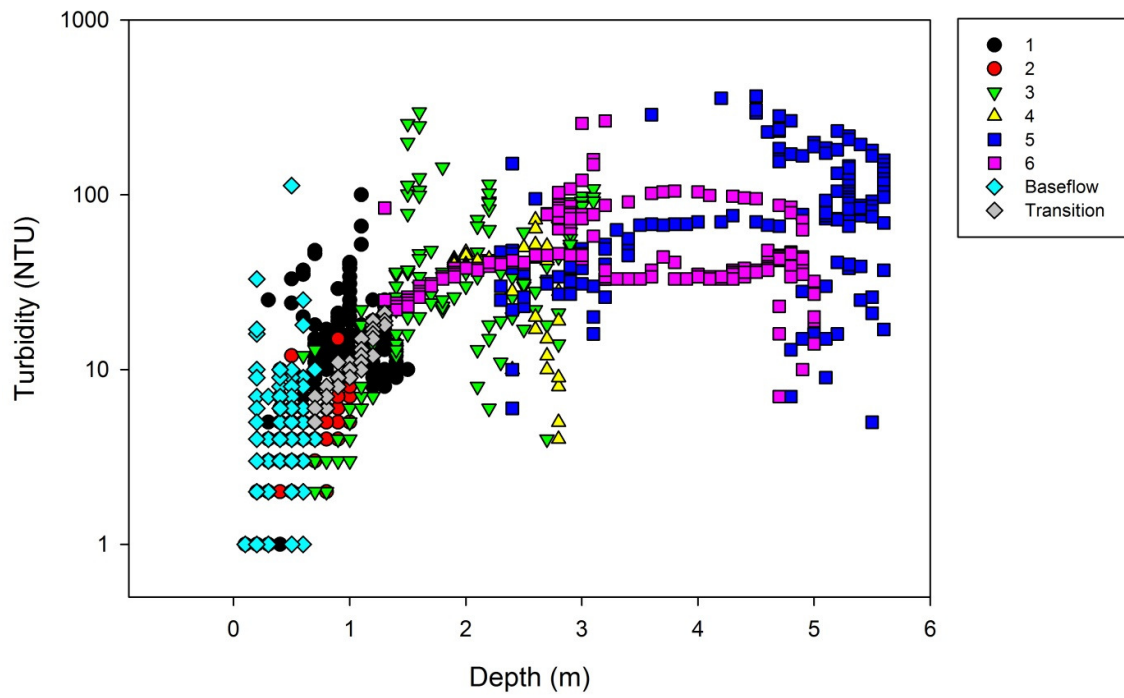


Figure 24. Turbidity of individual storm events, transition and baseflow periods.

10 Conclusion

Longitudinal variability in the dry season water quality of the Roper River and its tributaries is determined by the groundwater origins of the waters and by biological and chemical processes in the river. Because of their different groundwater sources, the headwater streams of the Roper River have more variable water quality than the Roper River itself, which is a mix of water types and therefore more uniform downstream of the groundwater inflows.

High conductivity and alkaline pH are typical of the limestone dominated waters of the Daly and Georgina geological formations that are high in calcium, magnesium and bicarbonate.

Soluble nutrient inputs, in particular nitrate, are sourced from groundwater in the headwaters of the Roper River in the Mataranka area and are not replenished downstream of the groundwater inputs, presumably leading to a change from phosphorus-limitation of algal growth in the headwaters to nitrogen limitation in the Roper River downstream.

The changes in water quality over the dry season are mainly driven by a reduction in flow, increased groundwater dominance, and biological processes. Increased groundwater dominance due to a gradual reduction in residual bank storage from the wet season, and evapotranspiration leads to an increase in conductivity and pH towards the end of the dry. The reduction in flow from the nutrient-rich springs contributes to a large reduction in nutrient load over the dry season.

Groundwater nitrogen may support significant plant biomass in the Roper River system. Seasonal changes in productivity inferred from the diel range of dissolved oxygen differed between the upstream and downstream sites. Productivity is affected by a range of factors including flow, light and nutrient availability. Aquatic vegetation, in particular filamentous green algae, has been observed to grow in extensive carpets in the upper reaches of the river, in particular at Site 11 at Eley National Park, in the early dry season, while in the lower reaches (e.g. MM site) aquatic vegetation, notably macroalgae, established later (Schult pers obs.; AHU unpublished data). The high nutrient availability in the upper reaches may mean that algae are able to establish quickly as soon as flow and light conditions become favourable after the wet. In the lower reaches, the reduced nutrient and light availability could be delaying the growth of aquatic vegetation.

The seasonal patterns in water quality were similar in the two years for most parameters. Interannual variation could not be assessed in detail, because more long-term monitoring data is required for this type of assessment. Many parameters are sensitive to the time of day of sampling, and with only 2 sampling occasions per year the data are insufficient to draw firm conclusions.

Wet season water quality is predominantly dependent on flow. While baseflow water quality is determined by the groundwater inputs, storm flows are characterised by the dominance of low conductivity rain water and higher turbidity due to overland runoff with high sediment loads. However, groundwater influence on water quality can be observed throughout the wet season.

The occurrence of hypoxic blackwater events in the catchment highlights the vulnerability of river water quality to storm runoff from the catchment.

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12 Appendices

12.1 Appendix 1: GP samples

Site	Station	Date	Ec	pH	Alk	Hard- ness	Ca	Mg	Na	K	Cl	SO4	Hco3	Co3	OH	tds
Elsey Ck	G9035200	29/10/2014	1730	8.6	383	582	121	67.9	219	22.3	249	192	361	21	1	1080
Elsey Ck	G9035200	21/05/2015	1650	8.6	363	439	74.5	61.4	186	26.7	237	172	344	20	1	980
LR u/s WH	G9030031	20/09/2012	1430	8.2	438	451	97.4	50.5	128	16.8	171	112	438	1	1	820
WH u/s LR Mataranka	G9030032	20/09/2012	708	7.9	279	277	66.3	27.1	38.6	6.4	51	28.2	279	1	1	390
h/stead Mataranka	G9035085	30/10/2014	1250	8.4	411	472	110	47.8	109	16.1	142	90.8	406	5	1	800
h/stead Judy	G9035085	20/05/2015	1270	8.1	412	448	104	45.8	103	15.2	127	87.5	412	1	1	740
Crossing Judy	G9030010	28/08/2014	1420	8.7	325	396	57.6	61.3	151	19.2	189	150	302	23	1	900
Crossing Judy	G9030010	16/10/2014	1530	8.7	324	397	54.2	63.6	163	20.8	217	152	300	23	1	880
Crossing Elsey	G9030010	19/05/2015	921	8.4	231	280	56.4	33.8	86.2	10.6	114	83.6	226	4	1	550
h/stead	G9030013	19/05/2015	1180	8	302	362	73.3	43.5	113	14.7	147	111	302	1	1	710
WAP 17	G9030022	29/10/2014	1480	8.4	390	490	97.3	60.1	149	20	198	143	380	10	1	910
WAP 17	G9030022	20/05/2015	1180	8.1	305	363	74.7	42.8	108	13.8	144	109	305	1	1	670
WAP 18	G9030023	29/10/2014	1440	8.5	388	473	90.8	59.8	149	20.1	197	144	376	12	1	890
WAP 18	G9030023	20/05/2015	1160	8.2	299	360	73.9	42.5	108	13.8	141	108	299	1	1	690
MtMCMinn	G9030028	16/07/2014	1310	8.5	327	373	59.2	54.7	146	16.8	179	134	313	14	1	810
MtMCMinn	G9030028	28/08/2014	1400	8.7	316	386	55.4	60.2	148	18.2	205	146	292	24	1	830
MtMCMinn	G9030028	16/10/2014	1580	8.8	318	393	52.5	63.7	167	20.8	223	154	284	35	1	870
MtMCMinn	G9030028	14/07/2015	1120	8.5	284	328	59.8	43.4	111	13.1	145	103	273	11	1	690
MtMCMinn	G9030028	12/08/2015	1150	8.4	288	346	58.6	48.4	121	14.9	148	116	282	6	1	710
ENP Mataranka	G9030033	28/08/2014	1330	8.4	408	451	91.1	54.3	124	17	146	111	397	10	1	810
GS Mataranka	G9030176	30/10/2014	1320	8.4	410	443	93.3	50.9	121	16.8	142	103	406	5	1	790
GS	G9030176	21/05/2015	950	8.3	260	291	57.7	35.6	87.6	12.1	113	76.7	260	1	1	580
Red Rock	G9030250	18/09/2012	1330	8.4	321	355	53.4	53.9	139	17	184	133	316	5	1	760
Red Rock Judy	G9030250	18/05/2015	685	8.4	177	205	41.9	24.5	59	7.2	77.4	53.2	174	3	1	390
Crossing Judy	G9035122	19/09/2012	1420	8.3	328	376	57.1	56.6	151	18.7	196	145	326	2	1	800
Crossing d/s Elsey	G9035122	28/10/2014	1450	8.8	324	395	53.5	63.6	167	21.6	224	154	291	32	1	890
h/stead d/s Elsey	G9035294	20/09/2012	1560	8	425	464	92.4	56.7	150	19.6	194	144	425	1	1	890
h/stead	G9035294	29/10/2014	1500	8.5	410	478	94.5	58.7	149	20.1	204	142	399	11	1	910
Moroak	G9035408	28/08/2014	1440	8.6	350	417	65.8	61.4	151	19.5	196	150	328	21	1	890
Rainbow	G9035092	23/04/2008	991	7.5	436	437	105	42.7	62.9	9.9	76.1	51.3	436	1	1	610
Rainbow	G9035092	30/10/2014	922	7.8	383	391	93.6	38.1	49.4	9.2	69.9	39.7	383	1	1	540
Rainbow	G9035092	20/05/2015	931	7.9	372	386	92.5	37.6	51.3	9.1	59	39.2	372	1	1	550
Fig Tree	G9035157	31/10/2014	2380	8.5	524	610	63.3	110	320	41	378	268	507	17	1	1490
Fig Tree	G9035157	19/05/2015	2230	8.5	470	542	58.2	96.4	271	37.2	338	241	456	14	1	1370
Bitter	G9035212	23/04/2008	1340	7.5	499	507	118	51.3	117	16.3	143	108	499	1	1	850
Bitter	G9035212	28/10/2014	1230	8.1	425	459	109	45.3	96.9	15.1	147	81.7	425	1	1	730
Bitter u/s	G9035212	20/05/2015	1240	8.1	414	445	106	44	92.5	14.6	112	78.9	414	1	1	740
Rainbow u/s	G9035316	30/10/2014	1070	8.3	414	442	102	45.8	83.5	10.2	127	76	414	1	1	670
Rainbow	G9035316	20/05/2015	120	7.7	38	37.3	6.7	5	6.5	1.3	10	2.8	38	1	1	90

12.2 Appendix 2: raw water quality data (longitudinal and seasonal)

#STATION	Site No	River	Name	Date	Distance from confl	Conductivity field	Dissolved oxygen %	Dissolved oxygen membrane electrode	pH field measure	Temperature	Turbidity field	Ammonia as Nitrogen (Lower DL)	Nitrate as N (Low DL)	Nitrite as N(Lower DL)	Phosphorous reactive (P)	Nitrogen - Total	Phosphorus - Total	Chlorophyll a
G9030514	1	Waterhouse	D/S Diljin Hill	28/05/2010	-90	63	93	7.0	7.2	29.7	7.0							
G9030514	1	Waterhouse	D/S Diljin Hill	22/06/2010	-90	56	83	7.1	6.9	23.4	6.0							
G9030514	1	Waterhouse	D/S Diljin Hill	4/08/2010	-90	55	101	8.0	6.9	26.9	4.0							
G9030514	1	Waterhouse	D/S Diljin Hill	31/05/2011	-90	76	105	9.3	5.9	21.0	23.0							
G9030514	1	Waterhouse	D/S Diljin Hill	29/08/2011	-90	60	87	7.5	5.3	22.6	5.0							
G9030089	2	Waterhouse	D/S Diljin Hill	22/06/2010	-47	65	90	7.8	7.3	22.4	10.0							
G9030089	2	Waterhouse	D/S Diljin Hill	4/08/2010	-47	77	98	8.9	7.0	20.1	39.0							
G9030089	2	Waterhouse	D/S Diljin Hill	31/05/2011	-47	95	101	9.0	5.9	20.7	76.0							
G9030089	2	Waterhouse	D/S Diljin Hill	30/08/2011	-47	88	102	8.9	5.8	22.6	1.0							
G9035212	3	Spring	Bitter Springs	3/07/2008	-8	1421	15	1.1	6.4	32.5	0.1							
G9035212	3	Spring	Bitter Springs	9/09/2008	-8	1403	14	1.0	6.5	32.8	0.1							
G9035212	3	Spring	Bitter Springs	25/10/2008	-8	1422	13	0.9	6.7	32.8	0.1							
G9035212	3	Spring	Bitter Springs	9/09/2009	-8	1380	13	0.9	6.4	33.0								
G9035212	3	Spring	Bitter Springs	24/11/2009	-8	1415	19	1.4	6.7	33.1								
G9035212	3	Spring	Bitter Springs	18/08/2010	-8	1349	10	0.7	6.5	32.6								
G9035212	3	Spring	Bitter Springs	25/11/2010	-8	1337	12	0.9	6.8	33.3								
G9035212	3	Spring	Bitter Springs	23/06/2011	-8	1331	17	1.2	6.8	32.5								
G9035212	3	Spring	Bitter Springs	21/09/2011	-8	1360	13	0.9	6.7	32.8								
G9035212	3	Spring	Bitter Springs	23/08/2012	-8	1344	17	1.2	6.6	32.6								
G9035212	3	Spring	Bitter Springs	7/11/2012	-8	1350	11	0.8	6.4	32.9								
G9035212	3	Spring	Bitter Springs	22/10/2013	-8	1295	22	1.6	6.8	33.3	0.2	0.005	0.353		0.008	0.34		
G9035212	3	Spring	Bitter Springs	28/10/2014	-8	1290	10	0.7	6.4	33.2	0.3	0.003	0.301	0.001	0.001	0.3	0.005	
G9035212	3	Spring	Bitter Springs	20/05/2015	-8	1278	19	1.4	6.6	33.1	0.3	0.002	0.299	0.001	0.017	0.31	0.020	
G9035212	3	Spring	Bitter Springs	24/09/2015	-8	1282	28	2.1	6.7	32.7	0.6	0.004	0.272	0.004	0.008	0.3	0.008	0.53
G9035212	3	Spring	Bitter Springs	5/11/2015	-8	1235	13	0.9	6.5	33.1	1.0	0.004	0.291	0.003	0.009	0.34	0.011	
G9035085	4	Little Roper	Mataranka Homestead Xng	2/07/2008	-3.7	1387	78	6.1	7.2	28.2	0.1							
G9035085	4	Little Roper	Mataranka Homestead Xng	8/09/2008	-3.7	1431	64	4.8	7.2	30.6	1.1							
G9035085	4	Little Roper	Mataranka Homestead Xng	25/10/2008	-3.7	1480	78	5.8	7.3	30.3	0.1							
G9035085	4	Little Roper	Mataranka Homestead Xng	26/11/2009	-3.7	1480	76	5.6	7.3	31.7								
G9035085	4	Little Roper	Mataranka Homestead Xng	18/08/2010	-3.7	1383	62	4.7	7.0	29.7								
G9035085	4	Little Roper	Mataranka Homestead Xng	25/11/2010	-3.7	1394	54	3.9	7.3	31.9								
G9035085	4	Little Roper	Mataranka Homestead Xng	22/06/2011	-3.7	1275	72	5.9	7.5	24.8								

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G9035085	4	Little Roper	Mataranka Homestead Xng	20/09/2011	-3.7	1338	67	5.0	7.2	30.0								
G9035085	4	Little Roper	Mataranka Homestead Xng	22/08/2012	-3.7	1334	72	5.5	7.1	29.2								
G9035085	4	Little Roper	Mataranka Homestead Xng	7/11/2012	-3.7	1400	61	4.5	7.1	31.3								
G9035085	4	Little Roper	Mataranka Homestead Xng	22/10/2013	-3.7	1353	59	4.4	7.3	31.8	1.0	0.010	0.265		0.007	0.25		
G9035085	4	Little Roper	Mataranka Homestead Xng	28/05/2014	-3.7	1373	59	4.4	6.7	30.9	1.1	0.008	0.214	0.003	0.008	0.35	0.016	
G9035085	4	Little Roper	Mataranka Homestead Xng	30/10/2014	-3.7	1370	73	5.3	7.4	31.8	1.1	0.004	0.146	0.003	0.001	0.21	0.005	
G9035085	4	Little Roper	Mataranka Homestead Xng	20/05/2015	-3.7	1318	62	4.5	7.3	30.7	1.5	0.001	0.208	0.001	0.017	0.29	0.018	
G9035085	4	Little Roper	Mataranka Homestead Xng	5/11/2015	-3.7	1275	59	4.3	6.6	32.0	1.0	0.006	0.199	0.001	0.009	0.26	0.011	
G9035316	5	Waterhouse	1.2km U/S Rainbow Springs	30/06/2008	-3.1	107	94	8.4	7.1	20.6	0.9							
G9035316	5	Waterhouse	1.2km U/S Rainbow Springs	6/09/2008	-3.1	114	80	6.6	7.0	25.5	0.1	0.007	0.005	0.001	0.013	0.13	0.020	
G9035316	5	Waterhouse	1.2km U/S Rainbow Springs	24/10/2008	-3.1	209	47	3.7	7.4	28.3	0.7							
G9035316	5	Waterhouse	1.2km U/S Rainbow Springs	6/11/2012	-3.1	1050	57	4.4	7.1	29.2								
G9035316	5	Waterhouse	1.2km U/S Rainbow Springs	22/10/2013	-3.1	1171	38	3.0	7.6	28.2	5.8							
G9035316	5	Waterhouse	1.2km U/S Rainbow Springs	28/05/2014	-3.1	200	78	6.6	6.8	23.9	5.0	0.155	0.021	0.007	0.006	0.2	0.019	
G9035316	5	Waterhouse	1.2km U/S Rainbow Springs	30/10/2014	-3.1	1210	27	2.2	7.0	26.2	3.3	0.001	0.001	0.002	0.002	0.1	0.014	
G9035316	5	Waterhouse	1.2km U/S Rainbow Springs	20/05/2015	-3.1	114	93	7.8	7.5	24.2		0.013	0.043	0.003	0.008	0.17	0.030	
G9035316	5	Waterhouse	1.2km U/S Rainbow Springs	4/11/2015	-3.1	1145	26	2.0	7.4	28.8		0.001	0.004	0.002	0.008	0.32	0.016	
G9035092	6	Spring	Rainbow Springs	22/05/2008	-2	1047	9	0.6	6.9	32.9								
G9035092	6	Spring	Rainbow Springs	1/07/2008	-2	1045	9	0.6	6.5	32.8	0.1							
G9035092	6	Spring	Rainbow Springs	9/09/2008	-2	1028	9	0.6	6.6	33.0	0.1							
G9035092	6	Spring	Rainbow Springs	1/10/2008	-2	1037	8	0.6	6.5	33.0	0.1							
G9035092	6	Spring	Rainbow Springs	8/09/2009	-2	1015	9	0.6	6.4	33.0								
G9035092	6	Spring	Rainbow Springs	24/11/2009	-2	1034	10	0.7	6.7	32.9								
G9035092	6	Spring	Rainbow Springs	17/08/2010	-2	1002	8	0.6	6.5	32.8								
G9035092	6	Spring	Rainbow Springs	24/11/2010	-2	1000	7	0.5	6.7	32.9								
G9035092	6	Spring	Rainbow Springs	22/06/2011	-2	1015	7	0.5	6.8	32.7								
G9035092	6	Spring	Rainbow Springs	20/09/2011	-2	1015	14	1.0	6.7	32.6								
G9035092	6	Spring	Rainbow Springs	21/08/2012	-2	992	8	0.6	6.5	32.8								
G9035092	6	Spring	Rainbow Springs	6/11/2012	-2	989	11	0.8	6.4	32.9								
G9035092	6	Spring	Rainbow Springs	21/10/2013	-2	986	8	0.6	6.9	33.0	0.7	0.006	0.177		0.005	0.17		
G9035092	6	Spring	Rainbow Springs	28/05/2014	-2	957	9	0.6	6.4	32.9	0.3	0.001	0.173	1.340	0.003	0.25	0.026	
G9035092	6	Spring	Rainbow Springs	30/10/2014	-2	990	7	0.5	6.6	33.0	0.3	0.001	0.168	0.001	0.003	0.17	0.005	
G9035092	6	Spring	Rainbow Springs	20/05/2015	-2	971	10	0.7	6.7	32.9	0.1	0.001	0.158	0.001	0.016	0.18	0.020	
G9035092	6	Spring	Rainbow Springs	2/11/2015	-2	967	6	0.4	6.8	33.1	1.0	0.002	0.163	0.001	0.008	0.18	0.013	

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G9035192	7	Waterhouse	500 m U/S Little Roper Confl.	10/09/2009	-0.5	515	66	5.0	7.2	29.2								
G9035192	7	Waterhouse	500 m U/S Little Roper Confl.	17/08/2010	-0.5	293	63	4.9	6.8	28.9								
G9035192	7	Waterhouse	500 m U/S Little Roper Confl.	23/06/2011	-0.5	213	94	8.7	7.9	19.1								
G9035192	7	Waterhouse	500 m U/S Little Roper Confl.	21/09/2011	-0.5	418	77	5.9	7.3	29.1								
G9035192	7	Waterhouse	500 m U/S Little Roper Confl.	21/08/2012	-0.5	551	61	5.0	6.9	26.3								
G9030032	8	Waterhouse	100 m U/S Little Roper Confl.	20/09/2012	-0.1	706	66	5.1	7.1	28.9	2.9		0.059	0.001	0.008	0.15	0.010	1
G9035407	8	Waterhouse	100 m U/S Little Roper Confl.	23/10/2013	-0.1	985	58	4.3	7.6	31.0	1.1	0.015	0.046		0.006	0.11		
G9035406	9	Little Roper	U/S Waterhouse R Confluence	2/07/2008	-0.1	1540	71	5.9	7.4	25.0	0.1							
G9035406	9	Little Roper	U/S Waterhouse R Confluence	8/09/2008	-0.1	1530	97	7.5	7.5	28.5	0.1							
G9035406	9	Little Roper	U/S Waterhouse R Confluence	25/10/2008	-0.1	1560	84	6.5	7.5	28.6	0.1							
G9030031	9	Little Roper	U/S Waterhouse R Confluence	20/09/2012	-0.1	1451	89	6.7	7.5	28.9	1.3		0.117	0.001	0.012	0.18	0.015	1.0
G9035406	9	Little Roper	U/S Waterhouse R Confluence	23/10/2013	-0.1	1427	66	5.0	7.8	29.4	0.8	0.011	0.170		0.008	0.13		
G9035255	10	Roper	U/S 4 Mile Boat Ramp	2/07/2008	0.2	1007	73	6.1	7.3	24.2	0.1							
G9035255	10	Roper	U/S 4 Mile Boat Ramp	8/09/2008	0.2	1590	87	6.8	7.5	28.2	0.1							
G9035255	10	Roper	U/S 4 Mile Boat Ramp	25/10/2008	0.2	1590	82	6.3	7.5	29.1	0.1							
G9030176	11	Roper	D/S Mataranka Homestead	23/06/2010	6.6	1029	86	7.2	7.8	23.8	10.0							
G9030176	11	Roper	D/S Mataranka Homestead	5/08/2010	6.6	1238	87	7.2	7.9	25.3	3.0							
G9030176	11	Roper	D/S Mataranka Homestead	1/06/2011	6.6	936	96	8.3	6.7	22.5	28.0							
G9030176	11	Roper	D/S Mataranka Homestead	31/08/2011	6.6	1179	86	7.1	7.5	24.7	1.0							
G9030176	11	Roper	D/S Mataranka Homestead	22/10/2013	6.6	1420	81	6.1	7.6	30.1	1.4	0.017	0.050		0.008	0.15		
G9030176	11	Roper	D/S Mataranka Homestead	26/05/2014	6.6	1266	117	9.1	7.1	28.2	1.8	0.007	0.074	0.002	0.005	0.23	0.017	
G9030176	11	Roper	D/S Mataranka Homestead	30/10/2014	6.6	1390	106	8.2	7.8	28.8	1.6	0.015	0.030	0.002	0.003	0.11	0.005	
G9030176	11	Roper	D/S Mataranka Homestead	21/05/2015	6.6	964	84	7.4	7.7	26.3	5.7	0.007	0.071	0.001	0.01	0.28	0.020	
G9030176	11	Roper	D/S Mataranka Homestead	3/11/2015	6.6	1293	60	4.5	7.4	30.7	2.0	0.016	0.060	0.004	0.007	0.17	0.013	
G9030033	12	Roper	Eley National Park - Mulurark	28/08/2014	7.1							0.007	0.036	0.003	0.056	0.09	0.084	0.42
G9030033	12	Roper	Eley National Park - Mulurark	16/09/2014	7.1	1420	108	8.36	7.795	27.7	2.1	0.012	0.040	0.001	0.053	0.08	0.064	
G9030033	12	Roper	Eley National Park - Mulurark	18/09/2014	7.1	1413	104	8.125	7.79	27.4	1.6	0.013	0.046	0.001	0.045	0.09	0.084	0.65
G9030033	12	Roper	Eley National Park - Mulurark	14/10/2014	7.1	1448	106	7.83	7.66	30.7	1.8					0.13	0.014	
G9030033	12	Roper	Eley National Park - Mulurark	17/10/2014	7.1													1.17
G9030033	12	Roper	Eley National Park - Mulurark	14/11/2014	7.1	1448	106	7.83	7.66	30.7	1.8	0.01	0.031	0.003	0.003	0.15	0.007	
G9030033	12	Roper	Eley National Park - Mulurark	19/05/2015	7.1							0.002	0.052	0.004	0.015	0.12	0.015	
G9030033	12	Roper	Eley National Park - Mulurark	22/05/2015	7.1	921	120	9.48	7.97	26.8	5.3							
G9030033	12	Roper	Eley National Park - Mulurark	17/06/2015	7.1	1367	107	8.46	8.32	26.7		0.005	0.044	0.002	0.008	0.13	0.030	0.93
G9030033	12	Roper	Eley National Park - Mulurark	15/07/2015	7.1	1215	115	9.78	8.04	22.6		0.002	0.042	0.002	0.004	0.09	0.005	0.47

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G9030033	12	Roper	Eley National Park - Mulurark	13/08/2015	7.1	1293	116	9.34	7.81	25.7	1.0	0.004	0.039	0.001	0.007	0.1	0.009	0.59
G9030033	12	Roper	Eley National Park - Mulurark	24/09/2015	7.1	1428	94	7.57	8.02	25.6	1.6	0.006	0.018	0.001	0.005	0.23	0.009	0.48
G9030033	12	Roper	Eley National Park - Mulurark	15/10/2015	7.1	1370	93	7.05	7.8	29.2	1.6	0.014	0.039	0.003	0.005	0.1	0.006	0.67
G9030033	12	Roper	Eley National Park - Mulurark	12/11/2015	7.1	1368	103	7.51	7.76	31.2	2.1	0.014	0.048	0.002	0.004	0.15	0.008	2.78
G9035157	13	Spring	Fig Tree Spring	1/07/2008	8	2870	90	7.54	7.6	23.7	0.1							
G9035157	13	Spring	Fig Tree Spring	10/09/2008	8	2840	89	7.37	7.7	24.6	0.1							
G9035157	13	Spring	Fig Tree Spring	23/06/2011	8	2330	97	8.59	8.02	21.0								
G9035157	13	Spring	Fig Tree Spring	21/09/2011	8	2480	93	7.81	7.86	23.6								
G9035157	13	Spring	Fig Tree Spring	8/11/2012	8	2440	87	7.33	7.49	23.6								
G9035157	13	Spring	Fig Tree Spring	23/10/2013	8	2470	59	4.73	7.78	26.4	0.1	0.003	0.093		0.018	0.18		
G9035157	13	Spring	Fig Tree Spring	13/10/2014	8	2500	82	6.5	7.5	25.7	0.3	0.001	0.078	0.001	0.001	0.13	0.005	
G9035157	13	Spring	Fig Tree Spring	19/05/2015	8	2330	88	7.08	7.88	25.2	0.2	0.001	0.070	0.002	0.029	0.17	0.033	
G9035157	13	Spring	Fig Tree Spring	24/09/2015	8	2430	92	7.55	7.93	24.4	0.8	0.002	0.058	0.001	0.014	0.15	0.016	0.1
G9035157	13	Spring	Fig Tree Spring	5/11/2015	8	2372	80	6.4	6.69	26.2	1.0	0.002	0.063	0.001	0.017	0.18	0.017	
G9030013	14	Roper	Eley Homestead	30/06/2008	22	1371	89	7.49	7.19	23.9	0.1							
G9030013	14	Roper	Eley Homestead	6/09/2008	22	1500	79	6.13	7.3	27.9	0.1	0.004	0.012	0.001	0.025	0.08	0.030	
G9030013	14	Roper	Eley Homestead	24/10/2008	22	1630	75	5.65	7.45	30.1	0.1							
G9030013	14	Roper	Eley Homestead	20/09/2012	22	1580	87	6.87	7.36	26.8	1.5		0.001	0.002	0.008	0.08	0.015	2
G9030013	14	Roper	Eley Homestead	23/10/2013	22	1592	89	6.57	7.24	30.9	1.5	0.009	0.005		0.012	0.09		
G9030013	14	Roper	Eley Homestead	27/05/2014	22						1.5	0.005	0.027	0.004	0.005	0.11	0.026	
G9030013	14	Roper	Eley Homestead	27/10/2014	22	1610	138	10.59	7.2	29.0	1.0	0.001	0.003	0.001	0.001	0.08	0.005	
G9030013	14	Roper	Eley Homestead	14/11/2014	22	1550	76	5.58	7.2	31.2	2.3	0.001	0.001	0.001	0.002	0.1	0.008	
G9030013	14	Roper	Eley Homestead	19/05/2015	22	1214			7.53	24.7	2.8	0.020	0.031	0.001	0.012	0.12	0.021	
G9030013	14	Roper	Eley Homestead	2/11/2015	22	1516	74	5.51	6.33	30.8	1.2	0.001	0.001	0.001	0.007	0.17	0.008	
G9035294	14	Roper	Eley Homestead	30/06/2008	23	1371	89	7.49	7.19	23.9	0.1							
G9035294	14	Roper	Eley Homestead	6/09/2008	23	1500	79	6.13	7.3	27.9	0.1	0.004	0.012	0.001	0.025	0.08	0.030	
G9035294	14	Roper	Eley Homestead	24/10/2008	23	1630	75	5.65	7.45	30.1	0.1							
G9035294	14	Roper	Eley Homestead	20/09/2012	23	1580	87.1	6.87	7.36	26.8	1.5		0.001	0.002	0.008	0.08	0.015	2
G9035294	14	Roper	Eley Homestead	23/10/2013	23	1592	89	6.57	7.24	30.9	1.5	0.009	0.005		0.012	0.09		
G9035294	14	Roper	Eley Homestead	27/10/2013	23	1610	138	10.59	7.2	29.0	1.0							
G9035294	14	Roper	Eley Homestead	27/05/2014	23	1603	82	6.49	6.91	27.4	1.5	0.005	0.027	0.004	0.005	0.11	0.026	
G9035294	14	Roper	Eley Homestead	29/10/2014	23							0.001	0.003	0.001	0.001	0.08	0.005	
G9030022	15	Roper	10.5Km D/S Eley Homestead	24/10/2013	32	1582	94	6.93	7.36	30.9	1.0	0.010	0.007		0.01	0.09		
G9030022	15	Roper	10.5Km D/S Eley Homestead	27/05/2014	32	1550	96	7.54	7.22	27.8	1.7	0.004	0.012	0.004	0.008	0.18	0.023	

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G9030022	15	Roper	10.5Km D/S Elsey Homestead	29/10/2014	32	1600	114	8.6	7.77	29.6	1.4	0.001	0.001	0.003	0.001	0.07	0.006	
G9030022	15	Roper	10.5Km D/S Elsey Homestead	20/05/2015	32	1220	92.7	7.52	7.48	25.8	2.2	0.001	0.011	0.002	0.012	0.12	0.031	
G9030022	15	Roper	10.5Km D/S Elsey Homestead	3/11/2015	32	1512	79	5.84	6.61	31.3	1.2	0.001	0.002	0.001	0.007	0.09	0.011	
G9030023	15	Roper	10.5Km D/S Elsey Homestead	24/10/2013	34	1582	95	6.96	7.54	31.8	2.2	0.009	0.005		0.001	0.08		
G9030023	15	Roper	10.5Km D/S Elsey Homestead	27/05/2014	34	1540	101	7.85	7.26	27.9	2.0	0.002	0.009	0.001	0.005	0.21	0.025	
G9030023	15	Roper	10.5Km D/S Elsey Homestead	29/10/2014	34	1590	114	8.6	7.67	29.8	1.3	0.001	0.001	0.003	0.001	0.16	0.007	
G9030023	15	Roper	10.5Km D/S Elsey Homestead	20/05/2015	34	1204	93.4	7.61	7.74	26.1	2.2	0.001	0.003	0.002	0.012	0.14	0.024	
G9030023	15	Roper	10.5Km D/S Elsey Homestead	3/11/2015	34	1512	80	5.78	6.69	32.0	1.2	0.001	0.097	0.001	0.005	0.1	0.014	
G9035398	16	Roper	Moroak Station Crossing	28/06/2008	68	1280	97	8.43	7.97	21.9	0.1							
G9035398	16	Roper	Moroak Station Crossing	5/09/2008	68	1386	90	7.23	8.05	26.4	0.1							
G9035398	16	Roper	Moroak Station Crossing	24/10/2008	68	1475	89	6.81	8.13	28.9	0.1							
G9035398	16	Roper	Moroak Station Crossing	16/10/2014	68	1550	84.1	6.6	7.89	28.1	2.8	0.009	0.003	0.004	0.005	0.12	0.014	0.69
G9035398	16	Roper	Moroak Station Crossing	14/11/2014	68	1460	95.5	7.05	8.01	30.6	1.9	0.006	0.003	0.001	0.002	0.12	0.005	
G9035398	16	Roper	Moroak Station Crossing	21/05/2015	68	1173	93	7.61	8.3	25.1	6.2	0.002	0.002	0.001	0.011	0.19	0.017	
G9035398	16	Roper	Moroak Station Crossing	15/07/2015	68	1450	91.9	8.57	8.2	19.3	3.5	0.002	0.003	0.001	0.004	0.1	0.005	0.33
G9035398	16	Roper	Moroak Station Crossing	13/08/2015	68	726.5	99.5	8.48	7.93	22.8	2.8	0.002	0.001	0.001	0.008	0.08	0.009	0.34
G9035398	16	Roper	Moroak Station Crossing	23/09/2015	68	1490	101	8.25	8.36	24.6	2.8	0.001	0.001	0.001	0.005	0.1	0.005	0.42
G9035408	16	Roper	Moroak Station Crossing	28/06/2008	68	1277	93	8.11	7.98	21.9	0.7							
G9035408	16	Roper	Moroak Station Crossing	5/09/2008	68	1386	90	7.23	8.05	26.4	0.1							
G9035408	16	Roper	Moroak Station Crossing	23/10/2008	68	1480	76	5.81	8.11	28.9	1.1							
G9035408	16	Roper	Moroak Station Crossing	20/09/2012	68	1480	86.4	7.06	7.96	24.8	5.5		0.005	0.001	0.008	0.13	0.015	1
G9035408	16	Roper	Moroak Station Crossing	26/08/2014	68	1580	99.1	8.56	8.19	22.0	2.5	0.004	0.001	0.001	0.061	0.07	0.071	
G9035408	16	Roper	Moroak Station Crossing	28/08/2014	68	1590	97.3	8.57	8.11	22.2	3.0	0.002	0.001	0.002	0.065			0.15
G9035408	16	Roper	Moroak Station Crossing	18/09/2014	68	1527.4	95.8	7.81	8.09	25.5	2.1	0.005	0.001	0.001	0.057	0.08	0.063	0.37
G9035408	16	Roper	Moroak Station Crossing	14/10/2014	68	1550	93.2	7.02	7.89	29.4	1.8					0.12	0.014	
G9035076	17	Roper	5 km d/s Moroak Crossing	28/06/2008	72	1338	83	7.4	8	20.6	6.5							
G9035076	17	Roper	6 km d/s Moroak Crossing	5/09/2008	72	1425	80	6.57	8.17	25.5	5.6							
G9035076	17	Roper	7 km d/s Moroak Crossing	24/10/2008	72	1570	43	3.42	7.95	27.4	1.8							
G9035076	17	Roper	8 km d/s Moroak Crossing	20/09/2012	72	1435	94.7	8.05	8.2	22.7	1.1		0.001	0.001	0.006	0.23	0.010	
G9035122	18	Roper	Flying Fox Station -Judy Xng	28/06/2008	118	1258	88	7.86	8	20.6	3.6							
G9035122	18	Roper	Flying Fox Station -Judy Xng	4/09/2008	118	1370	85	6.86	8.25	26.1	1.7							
G9035122	18	Roper	Flying Fox Station -Judy Xng	5/09/2008	118							0.001	0.003	0.001	0.027	0.1	0.025	
G9035122	18	Roper	Flying Fox Station -Judy Xng	23/10/2008	118	1439	73	5.55	8.22	29.3	1.8							
G9035122	18	Roper	Flying Fox Station -Judy Xng	19/09/2012	118	1443	91.2	7.46	8.18	25.0	3.2		0.002	0.001	0.007	0.13	0.015	1

#STATION	Site No	River	Name	Date	Distance from confi	Conductivity field	Dissolved oxygen %	Dissolved oxygen membrane electrode	pH field measure	Temperature	Turbidity field	Ammonia as Nitrogen (Lower DL)	Nitrate as N (Low DL)	Nitrite as N(Lower DL)	Phosphorous reactive (P)	Nitrogen - Total	Phosphorus - Total	Chlorophyll a
G9035122	18	Roper	Flying Fox Station -Judy Xng	28/08/2013	118	1454	90	7.53	8.24	23.6	4.6	0.008	0.001	0.001	0.116	0.12	0.120	
G9035122	18	Roper	Flying Fox Station -Judy Xng	29/08/2013	118							0.022	0.001	0.002	0.005	0.55	0.010	
G9035122	18	Roper	Flying Fox Station -Judy Xng	12/09/2013	118	1491	77	6.29	8.37	25.2	2.9	0.011	0.001	0.001	0.113	0.12	0.120	
G9035122	18	Roper	Flying Fox Station -Judy Xng	28/05/2014	118	1357	87	7.06	7.9	25.7								
G9035122	18	Roper	Flying Fox Station -Judy Xng	28/10/2014	118	1540	89	6.92	8.27	27.9	2.3	0.001	0.003	0.001	0.001	0.13	0.005	
G9030010	18	Roper	Flying Fox Station -Judy Xng	28/06/2008	119	1258	88	7.86	8	20.6	3.6							
G9030010	18	Roper	Flying Fox Station -Judy Xng	4/09/2008	119	1370	85	6.86	8.25	26.1	1.7							
G9030010	18	Roper	Flying Fox Station -Judy Xng	5/09/2008	119							0.001	0.003	0.001	0.027	0.1	0.025	
G9030010	18	Roper	Flying Fox Station -Judy Xng	23/10/2008	119	1439	73	5.55	8.22	29.3	1.8							
G9030010	18	Roper	Flying Fox Station -Judy Xng	19/09/2012	119	1443	91	7.46	8.18	25.0	3.2		0.002	0.001	0.007	0.13	0.015	1
G9030010	18	Roper	Flying Fox Station -Judy Xng	28/05/2014	119	1357	87	7.06	7.9	25.7								
G9030010	18	Roper	Flying Fox Station -Judy Xng	26/08/2014	119	1560	94	8.285	8.35	20.9	2.3	0.002	0.001	0.001	0.054	0.07	0.069	
G9030010	18	Roper	Flying Fox Station -Judy Xng	28/08/2014	119	1560	95	8.31	8.3	21.2	2.0					0.08	0.070	0.23
G9030010	18	Roper	Flying Fox Station -Judy Xng	16/09/2014	119	1500	79	7.98	8.24	25.5	2.2	0.001	0.001	0.001	0.061	0.17	0.067	
G9030010	18	Roper	Flying Fox Station -Judy Xng	18/09/2014	119	1500	87	7.17	8.205	24.6	2.2	0.001	0.001	0.001	0.075	0.1	0.083	0.67
G9030010	18	Roper	Flying Fox Station -Judy Xng	14/10/2014	119	1570	91	6.85	8.02	29.6	2.5					0.26	0.014	
G9030010	18	Roper	Flying Fox Station -Judy Xng	16/10/2014	119	1580	89	6.77	8.06	28.6	2.5	0.008	0.002	0.004	0.008	0.13	0.015	0.68
G9030010	18	Roper	Flying Fox Station -Judy Xng	28/10/2014	119	1540	89	6.92	8.27	27.9	2.3	0.001	0.003	0.001	0.001	0.13	0.005	
G9030010	18	Roper	Flying Fox Station -Judy Xng	14/11/2014	119	1510	87	6.64	8.12	30.5	3.0	0.004	0.002	0.001	0.002	0.17	0.005	
G9030010	18	Roper	Flying Fox Station -Judy Xng	19/05/2015	119	941			8.2	22.2	6.5	0.004	0.002	0.001	0.009	0.18	0.011	
G9030010	18	Roper	Flying Fox Station -Judy Xng	31/10/2015	119	1430	82	6.12	7.44	30.3	2.9	0.007	0.001	0.001	0.006			
G9035068	19	Roper	11 km d/s Judy Crossing	27/06/2008	130	1246	92	8.13	8.03	21.3	0.1							
G9035068	19	Roper	12 km d/s Judy Crossing	4/09/2008	130	1340	90	7.23	8.26	26.2	0.1	0.001	0.001	0.001	0.022	0.1	0.025	
G9035068	19	Roper	13 km d/s Judy Crossing	23/10/2008	130	1431	69	5.23	8.12	29.2	3.0							
G9035068	19	Roper	14 km d/s Judy Crossing	19/09/2012	130	1448	84	6.86	8.11	25.0	5.9		0.001	0.001	0.008	0.14	0.015	29
G9035409	20	Roper	40M U/S Flying Fox Crk	26/06/2008	155	670	95	8.56	8.02	20.5	0.1							
G9035409	20	Roper	40M U/S Flying Fox Crk	3/09/2008	155	1320	89	7.32	8.21	24.8	5.1							
G9035409	20	Roper	40M U/S Flying Fox Crk	22/10/2008	155	1424	67	5.16	8.21	28.6	5.5							
G9035410	20	Roper	Big River Station	26/06/2008	156	1225	89	8.07	8.05	20.3	3.8							
G9035410	20	Roper	Big River Station	3/09/2008	156	1324	79	6.52	8.17	25.0	5.1							
G9035410	20	Roper	Big River Station	22/10/2008	156	1436	59	4.52	8.18	28.8	3.9							
G9030028	21	Roper	Mcminn Station Main Channel	18/09/2012	170	1331	99	8.03	8.19	25.2								
G9030028	21	Roper	Mcminn Station Main Channel	16/07/2014	170							0.004	0.020	0.004	0.014	0.125	0.020	0.69
G9030028	21	Roper	Mcminn Station Main Channel	26/08/2014	170	1510	111	9.675	8.44	21.7	1.6	0.002	0.002	0.003	0.045	0.1	0.064	

#STATION	Site No	River	Name	Date	Distance from confi	Conductivity field	Dissolved oxygen %	Dissolved oxygen membrane electrode	pH field measure	Temperature	Turbidity field	Ammonia as Nitrogen (Lower DL)	Nitrate as N (Low DL)	Nitrite as N(Lower DL)	Phosphorous reactive (P)	Nitrogen - Total	Phosphorus - Total	Chlorophyll a
G9030028	21	Roper	Mcminn Station Main Channel	27/08/2014	170													2.6
G9030028	21	Roper	Mcminn Station Main Channel	28/08/2014	170	1510	97	8.57	8.37	20.9	1.6	0.004	0.003	0.001	0.065	0.09	0.073	0.18
G9030028	21	Roper	Mcminn Station Main Channel	16/09/2014	170	1453	109	8.795	8.305	25.2	1.8	0.003	0.002	0.001	0.07	0.1	0.076	
G9030028	21	Roper	Mcminn Station Main Channel	17/09/2014	170													1.8
G9030028	21	Roper	Mcminn Station Main Channel	18/09/2014	170	1453	88	7.26	8.23	24.4	1.5	0.002	0.001	0.001	0.058	0.1	0.073	0.6
G9030028	21	Roper	Mcminn Station Main Channel	14/10/2014	170	1590	95	7.18	8.06	29.5	1.9					0.13	0.012	
G9030028	21	Roper	Mcminn Station Main Channel	15/10/2014	170	1590	79	6.05	8.02	27.9	1.7	0.011	0.002	0.003	0.007	0.17	0.013	1.1133
G9030028	21	Roper	Mcminn Station Main Channel	16/10/2014	170	1590	91	6.91	8.06	28.6	2.3	0.011	0.002	0.001	0.003	0.15	0.011	0.86
G9030028	21	Roper	Mcminn Station Main Channel	17/10/2014	170	1480	85	6.65	7.67	27.3	1.7	0.018	0.054	0.003	0.007	0.13	0.013	
G9030028	21	Roper	Mcminn Station Main Channel	14/11/2014	170	496	4	0.28	7.19	29.3								
G9030028	21	Roper	Mcminn Station Main Channel	20/05/2015	170	791	101	8.54	8.30	23.5		0.002	0.001	0.002	0.007	0.165	0.012	
G9030028	21	Roper	Mcminn Station Main Channel	16/06/2015	170	1075	91	7.48	8.64	24.5		0.006	0.001	0.001	0.0145	0.17	0.016	0.885
G9030028	21	Roper	Mcminn Station Main Channel	14/07/2015	170	1232	98	8.55	8.36	21.6		0.002	0.001	0.001	0.001	0.1	0.005	0.515
G9030028	21	Roper	Mcminn Station Main Channel	12/08/2015	170	1267	109	11.19	8.23	22.2	2.0	0.001	0.001	0.001	0.006	0.105	0.007	0.405
G9030028	21	Roper	Mcminn Station Main Channel	23/09/2015	170	1396	90	7.375	8.46	24.5	2.4	0.002	0.001	0.001	0.004	0.13	0.005	0.64
G9030028	21	Roper	Mcminn Station Main Channel	14/10/2015	170	1422	103	7.865	8.20	28.6	2.2							
G9030028	21	Roper	Mcminn Station Main Channel	15/10/2015	170							0.005	0.001	0.002	0.005	0.15	0.005	0.66
G9030028	21	Roper	Mcminn Station Main Channel	11/11/2015	170	1495	84	6.735	8.09	30.5	1.4	0.007	0.001	0.003	0.0055	0.155	0.007	0.815
G9030250	22	Roper	Red Rock Gauge Station	25/06/2008	189	1019	95	8.21	8.06	22.4	0.1							
G9030250	22	Roper	Red Rock Gauge Station	2/09/2008	189	1171	97	7.86	8.28	25.8	0.1	0.001	0.001	0.001	0.017	0.13	0.020	
G9030250	22	Roper	Red Rock Gauge Station	21/10/2008	189	1297	98	7.22	8.31	31.4	0.4							
G9030250	22	Roper	Red Rock Gauge Station	6/08/2010	189	1236	102	8.51	8.44	24.4	4.0							
G9030250	22	Roper	Red Rock Gauge Station	29/09/2010	189	1360	94	7.14	5.95	29.3	1.0							
G9030250	22	Roper	Red Rock Gauge Station	1/09/2011	189	1254	100	8.52	7.33	23.4	7.0							
G9030025	22	Roper	Red Rock Gauge Station	18/09/2012	189	1323	96	7.85	8.16	25.6	1.1							
G9030250	22	Roper	Red Rock Gauge Station	25/10/2013	189	1454	99	7.32	8.04	31.2	1.3	0.013	0.003		0.009	0.18		
G9030250	22	Roper	Red Rock Gauge Station	28/05/2014	189	1137	103	8.07	7.99	27.5	1.9	0.001	0.004	0.001	0.004	0.26	0.030	
G9030250	22	Roper	Red Rock Gauge Station	27/10/2014	189	1560	101	7.79	8.23	28.7	1.5	0.010	0.022	0.001	0.001	0.15	0.005	
G9030250	22	Roper	Red Rock Gauge Station	18/05/2015	189	677			7.53	23.1	3.8	0.001	0.001	0.001	0.007	0.2	0.011	
G9030250	22	Roper	Red Rock Gauge Station	30/10/2015	189	1393	90	6.67	7.73	31.1	1.2	0.055	0.002	0.002	0.004	0.16	0.008	
G9035300	23	Roper	Roper Bar Crossing	25/06/2008	200	1000	99	8.37	8.06	23.4	0.1							
G9035300	23	Roper	Roper Bar Crossing	2/09/2008	200	1165	105	8.42	8.36	26.4	0.1	0.001	0.003	0.001	0.021	0.12	0.025	
G9035300	23	Roper	Roper Bar Crossing	21/10/2008	200	1272	75	5.65	8.24	30.1	0.1							
G9035300	23	Roper	Roper Bar Crossing	17/09/2012	200	1318	98	7.79	8.20	26.4	1.9		0.001	0.002	0.006	0.18	0.015	1

12.3 Appendix 3: Loads

Table 4. Nutrient loads in the early and late dry seasons of 2014 and 2015 (kg/d).

Site	Name	Month	FRP		NH3		NO2		NO3		TN		TP	
			2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
G9035212	Bitter Springs	May		1.5		0.2		0.1		26.1		27.1		1.75
		Oct	0.1	0.6	0.2	0.3	0.1	0.2	19.2	19.9	19.2	23.2	0.3	0.75
G9035092	RainbowSprings	May	0.1	0.6	0.0	0.04		0.04	5.6	5.9	8.1	6.7	0.8	0.74
		Oct	0.1	0.3	0.03	0.1	0.03	0.03	5.5	5.5	5.6	6.1	0.2	0.44
G9035085	Little Roper@Mat H/steadXing	May	1.3	3.0	1.3	0.2	0.5	0.2	33.7	36.3	55.2	50.6	2.5	3.14
		Oct	0.1	1.4	0.5	0.9	0.4	0.15	19.6	30.6	28.1	40.0	0.7	1.69
G9035157	FigTreeSpring-RoperRiver EleyPark	May		0.175		0.006		0.012		0.423		1.028		0.200
		Oct	0.002	0.029	0.002	0.003	0.002	0.002	0.135	0.109	0.225	0.311	0.009	0.029
G9030176	Roper-D/S Mat Homestead	May	1.4	4.7	1.9	3.3	0.6	0.5	20.5	33.6	63.8	132.3	4.7	9.45
		Oct	0.6	1.3	2.8	3.1	0.4	0.8	5.7	11.5	20.7	32.5	0.9	2.48
G9030013	Roper-Eley Homestead	May	2.6	9.2	2.6	15.4	2.1	0.8	14.3	23.8	58.2	92.3	13.8	16.15
		Oct	0.3	2.3	0.3	0.3	0.3	0.3	1.0	0.3	27.7	56.8	1.7	2.67
G9030022	Roper 10.5kmD/S EleySite17	May	4.3	9.1	2.1	0.8	2.1	1.5	6.4	8.3	96.3	90.8	12.3	23.46
		Oct	0.5	3.0	0.5	0.4	1.4	0.4	0.5	0.8	32.7	37.9	2.8	4.64
G9030023	Roper River 12.5km D/s Eley (site18)	May	3.4	8.9	1.4	0.7	0.7	1.5	6.2	2.2	143.5	103.9	17.1	17.81
		Oct	0.5	1.6	0.5	0.3	1.4	0.3	0.5	30.9	72.9	31.9	3.2	4.46
G9030010	RoperRiver at JudyCrossing	May	2.6	6.0	1.3	2.7	2.6	0.7	1.7	1.3	90.9	120.4	6.9	7.36
		Oct	0.2	1.4	0.2	1.6	0.2	0.2	0.7	0.2	30.2	37.3	1.2	1.87
G9030250	RoperRiver-RedRock	May	1.7	5.1	0.4	0.7	0.4	0.7	1.7	0.7	108.5	146.5	12.5	8.06
		Oct	0.2	0.7	1.8	9.7	0.2	0.4	4.0	0.4	27.0	28.3	0.9	1.42
G9035200	Eley Ck at Roper Highway	May	0.4	1.3	0.3	1.3	0.4	0.2	0.4	1.1	20.7	22.2	1.4	2.31
		Oct	0.03	0.3	0.1	0.2	0.03	0.1	0.1	0.04	5.0	7.4	0.2	0.47

12.4 Appendix 4: Diurnal measurements of dissolved oxygen, temperature and pH

