

MAC Phase 4:

Marillana Creek Baseline Aquatic Ecosystem Survey

Dry 2021 & Wet 2022

Biologic Environmental Survey

Report to BHP Western Australia Iron Ore

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EXECUTIVE SUMMARY

Biologic Environmental Survey (Biologic) was commissioned by BHP Western Australia Iron Ore (WAIO) to undertake a two-season baseline aquatic ecosystem survey of an upper reach of Marillana Creek (hereafter referred to as the Study Area), located within the Upper Fortescue River Catchment. This constitutes the second round of sampling, with previous surveys undertaken in the dry season of 2020 (Dry 2020) and wet season of 2021 (Wet 2021) (Biologic, 2022b). Aquatic ecosystem surveys were undertaken at 12 sites, six within the Study Area, and six reference sites located outside the Study Area. Sampling was undertaken in October 2021 (Dry 2021 survey) and April 2022 (Wet 2022 survey). Surveys included habitat assessments and sampling of water quality, wetland flora (submerged and emergent macrophytes) and dominant riparian vegetation, zooplankton, hyporheos, macroinvertebrates and fish. Methods followed those used in similar surveys, including the Pilbara Biological Survey (PBS), National Monitoring River Health Initiative, and recent surveys undertaken by Biologic within the Study Area and for other BHP projects nearby. Given the Study Area was largely dry at the time of sampling in the Dry 2021, sediment samples were collected and rehydrate-emergence trials conducted in the laboratory.

Although the sampling site pools were previously considered permanent or to semi-permanent (noting MarC6 has dried from time to time in the past), all previous sampling locations along the creek were dry at the time of the Dry 2021 survey. A pool approximately 120 m downstream of MarC3 was present, however, and able to be sampled. The drying of the creek occurred after a relatively good wet season, with above average rainfall recorded from the Flat Rocks gauging station (near MarC6) in February and April 2021. The lowering water levels in the creek may be associated with drawdown impacts from nearby mining, especially those in the more downstream extent of the Study Area. This should be investigated further.

The Study Area supports numerous species of groundwater dependent vegetation (GDV), including the obligate phreatophyte *Melaleuca argentea*. This species is a very high-level key mesophytic/hydrophytic indicator species (Rio Tinto, 2021), and indicates the presence of groundwater close to, and expressing at, the surface. In addition, other high level mesophytic/hydrophytic indicator species (*Eucalyptus camaldulensis*, *Acacia ampliceps,* and *Melaleuca bracteata*) and moderate-level indicators (*Eucalyptus victrix*, *Cyperus vaginatus*, *Eleocharis geniculata* and *Schenoplectus subulatus*) occur within the Study Area. Study Area pools also support numerous submerged macrophytes in-stream, including *Chara* sp., *Chara fibrosa*, *Chara globularis*, *Vallisneria nana*, *Potamogeton tepperi*, and *Najas tenuifolia*, all of which are considered to be moderate hydrophytic indicators. Overall, the Study Area was found to support a high richness of macrophyte taxa (submerged and emergent) in comparison to sites sampled as part of the Pilbara Biological Survey (PBS), including the Priority 1 Priority Ecological Community (PEC) Weeli Wolli Spring. However, the flora and vegetation showed signs of water stress, particularly in the lower extent of the reach, with emergent macrophytes observed to be in poor condition. In addition, declines in tree canopy health and average foliage cover were also

observed during this survey and by Biologic (2022d) during tree health monitoring at sites located near MarC2 and MarC5.

Water quality within the Study Area was characterised by fresh to brackish, well buffered, clear waters, with wide-ranging dissolved oxygen saturation, slightly basic to circum-neutral pH, low concentrations of nitrogen nutrients but high total phosphorus, and generally low concentrations of dissolved metals. This is consistent with the previous survey (Biologic, 2022b). While water quality was generally within ANZG (2018) default guideline values (DGVs) for the protection of lowland river systems of tropical north Australia, there were some exceedances (i.e., dissolved oxygen, electrical conductivity, total nitrogen, total phosphorus, and dissolved boron at some sites). Several dissolved metals were also recorded in significantly greater concentrations from the Study Area compared with reference sites, including dAs, dB, dU and dV.

A diverse range of aquatic fauna was recorded across the Study Area despite the dry conditions in the Dry 2021, including 87 zooplankton taxa, 208 macroinvertebrate taxa, and two freshwater fish species. While most invertebrates recorded from the Study Area were common, widespread species, several species were of conservation significance and/or appear to be restricted or are known from few records. Information relating to these taxa is provided in Table 6.1.

Zooplankton richness within the Study Area has showed a significant linear increase over time (over the four sampling events). There was also a significant difference in zooplankton richness between the Study Area and nearby creeklines/reaches when compared to other studies in the area. Average zooplankton richness recorded from the Study Area was greater than all other creeks/reaches included in the analysis (Marillana Creek Downstream of the Study Area, Munjina Creek, Yandicoogina Creek, Weeli Wolli Spring, Weeli Wolli Creek, and the Davis River), although this difference was not significant (the Tukey's post-hoc test failed to locate the significant difference).

The hyporheic zone generally recorded a high richness of hyporheos and groundwater-dependent fauna, especially at MarC2, including several potentially restricted taxa. An additional reach of Marillana Creek, downstream of the Study Area, was sampled in the Wet 2022. This reach also supports a rich hyporheos fauna, comprising potentially restricted species, particularly MC4H and MC10H. Of the invertebrate fauna recorded within the hyporheic zone of the Study Area and the additional reach downstream, 15% are directly dependant on groundwater for persistence (8% stygobites and 3% permanent hyporheos stygophiles). The percentage of stygobitic taxa was greater than that reported previously for Pilbara hyporheic zones (i.e., 5% stygobitic fauna recorded in Halse *et al*. 2002). This highlights the strong connection to groundwater beneath Marillana Creek.

Macroinvertebrate richness was generally high throughout the Study Area, especially at MarC2 and MarC3. Interestingly, the average richness recorded from the Study Area during the Dry 2021, when only two sites held water, was greater than the previous Wet 2021 or Dry 2020 sampling events (although this difference wasn't significant). It is likely that aerial and mobile aquatic invertebrates moved to the remaining, refuge pools, as others receded and dried, leading to high richness within the two remnant pools. Also of particular note within the Study Area, was the considerably high richness of odonates at MarC4 (12 taxa in the Wet 2022). The high richness of odonates likely reflects the fact that the Study Area supports good, intact riparian vegetation and a high abundance and diversity of submerged and macrophytes.

When compared statistically to other aquatic surveys undertaken in the area, macroinvertebrate richness from the Study Area was significantly greater than that recorded from Weeli Wolli Creek (pools upstream of the spring), but statistically similar to all other creeklines/reaches included in the analysis, including the Weeli Wolli Spring PEC (as sampled during the PBS prior to any disturbance or mining impact), and the Davis River. This is notable given that Weeli Wolli Spring is a recognised Priority 1 PEC, while SS and RW on the Davis River are both known for their particularly high richness of aquatic invertebrate fauna (Kendrick & McKenzie, 2001). Multivariate analyses of the same dataset (current and previous other surveys) indicated that macroinvertebrate assemblages of the Study Area were statistically similar to those from groundwater-fed, spring systems, including Ben's Oasis, Munjina Spring and the Davis River

Two freshwater fish species were recorded from Marillana Creek within the Study Area, spangled perch (*Leiopotherapon unicolor*) and Pilbara tandan (*Neosilurus* sp.). Although this is the same richness as previously recorded from the Study Area (Biologic, 2022b), the abundance and distribution of spangled perch recorded in the Wet 2022 was markedly reduced from previous surveys. It appears that the drying of pools within the Study Area in the Dry 2021 resulted in a loss of fish from this reach, with re-colonisation only occurring at a small subset of pools by the Wet 2022 survey. Further surveys in the future will assess the success of re-colonisation throughout this reach of Marillana Creek.

The Study Area has been shown to support GDEs of varying levels of significance (Biologic, 2022a, 2022b), with considerable ecological value. In arid regions such as the Pilbara, such GDEs are important as they provide a refuge during periods of drought. Therefore, the fact that pools within the Study Area appear to be showing signs of declining groundwater levels, surface water levels and water stress is of concern. The cause of the declining water levels should be investigated.

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GLOSSARY

BOM	Bureau of Meteorology
DBCA	Department Biodiversity, Conservation and Attractions
DGV	Default Guideline Value
DO	Dissolved oxygen
DPaW	Department of Parks and Wildlife
DPIRD	Department of Primary Industry and Regional Development
DRF	Declared Rare Flora
EC	Electrical conductivity
EPA	Western Australian Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EWR	Ecological Water Requirements
GDE	Groundwater dependent ecosystem
GDV	Groundwater dependent vegetation
GS	Gauging station/s
IUCN	International Union for the Conservation of Nature
LOD	Limit of detection
LWD	Large woody debris
MNES	Matters of National Environmental Significance
NATA	National Association of Testing Authorities
PBS	Pilbara Biological Survey
PEC	Priority Ecological Community
SRE	Short-range endemic
WAM	Western Australian Museum

1 INTRODUCTION

1.1 Background

Biologic Environmental Survey (Biologic) was commissioned by BHP Western Australia Iron Ore (WAIO) to undertake a two-season baseline aquatic ecosystem survey for the Mining Area C (MAC) Phase 4 Project. A reach within Marillana Creek, located upstream of BHP WAIO Yandi operations on non-BHP WAIO tenure, was targeted for survey (hereafter referred to as the Study Area; Figure 1.1). The Study Area is located north of the current BHP WAIO MAC operation, within the East Pilbara region of Western Australia (WA). The overarching objective of the two-season survey was to identify the aquatic fauna found in perennial and semi-permanent pools associated with the target reach of Marillana Creek, and to determine the associated ecological values of aquatic fauna and habitats that may need to be considered during any future environmental approvals across the area.

Previous aquatic surveys undertaken in the dry season of 2020 (Dry 2020) and wet season of 2021 (Wet 2021) identified the presence of a groundwater dependent ecosystem (GDE) and associated permanent and semi-permanent pools within the Study Area (Biologic, 2022b). The GDE was found to be characterised by an open overstorey of *Eucalyptus camaldulensis*, *Melaleuca argentea* and *Melaleuca glomerata* over various *Acacia* species, with reeds and rushes along the waterline (*Cyperus vaginatus, Eleocharis geniculata*, *Schoenoplectus subulatus* and *Typha domingensis*). Biologic (2022b) found the GDE provided important habitat for aquatic fauna, and supported high ecological values, including:

- Invertebrates with potentially restricted distributions
- A high diversity of Pilbara endemic aquatic invertebrate taxa, especially at three sites (MarC2, MarC4 and MarC5)
- An exceptionally high richness of odonates at two sites (MarC5 and MarC6)
- Conservation significant species listed on the International Union for the Conservation of Nature (IUCN) Redlist of Threatened Species (i.e., *Eurysticta coolawanyah* and *Hemicordulia koomina*)
- A diversity of mesic flora species
- Two species of freshwater fish (Biologic, 2022b).

While the previous survey was comprehensive (Biologic, 2022b), it does not provide a sufficient baseline with which to detect change in water quality and aquatic fauna assemblages associated with potential future developments in the area. ANZG (2018) recommends sampling seasonally (wet and dry) over a period of at least three years to develop an appropriate dataset to cover the range in natural variability present within the aquatic ecosystem. As such, BHP commissioned Biologic to undertake an aquatic survey within the Study Area in the dry season of 2021 (Dry 2021) and wet of 2022 (Wet 2022) to complement the baseline dataset (this report). The scope of works included:

- A two-season aquatic survey at all previously established sampling sites, including reference sites

- Identification of any significant ecological values related to aquatic fauna and their habitats within the Study Area
- An assessment of the seasonal, temporal and spatial variation in water quality and aquatic fauna, including data from this and the previous survey, i.e., Dry 2020 and Wet 2021 (Biologic, 2022b).

1.2 Compliance

The survey was carried out in accordance with the Western Australian Environmental Protection Authority (EPA) and BHP WAIO guidelines. There is currently (November 2022) no technical guidance applicable to the Inland Waters Environmental Factor; however, this survey was carried out in a manner consistent with the following:

- Environmental Factor Guideline, Inland Waters (EPA, 2018).
- Australian & New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018).
- Technical Guidance, Sampling of Short-Range Endemic Invertebrate Fauna (EPA, 2016a).
- Technical Guidance, Terrestrial Fauna Surveys (EPA, 2016b).
- BHP WAIO's Aquatic Fauna Assessment Methods Procedure (0098594) (BHP, 2020).
- Similar surveys, including the Pilbara Biological Survey (Pinder *et al.*, 2010), National Monitoring River Health Initiative (Choy & Thompson, 1995), and recent surveys undertaken by Biologic for this and other BHP projects nearby (Biologic, 2020, 2022b, 2022f, 2022g, 2023a).

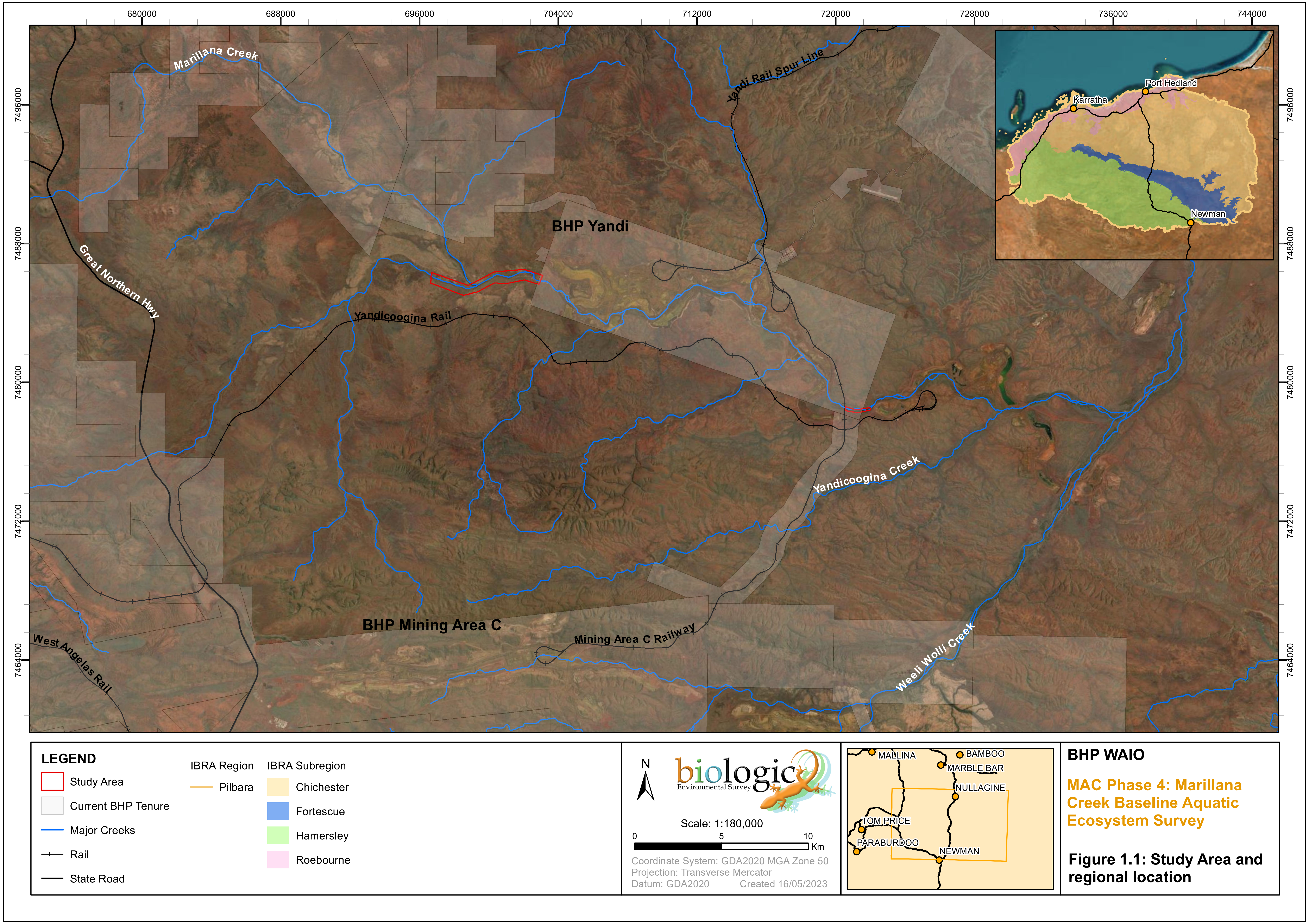


Figure 1.1: Study Area and regional location

2 ENVIRONMENT

2.1 Biogeographical Regionalisation of Australia

The Study Area falls within the Pilbara biogeographical region as defined by the Interim Biogeographic Regionalisation of Australia (IBRA) (Thackway & Cresswell, 1995). The Pilbara bioregion is characterised by vast coastal plains and inland mountain ranges with cliffs and deep gorges (Thackway & Cresswell, 1995). Vegetation is predominantly mulga low woodlands or snappy gum over tussock and hummock grasses (Bastin, 2008).

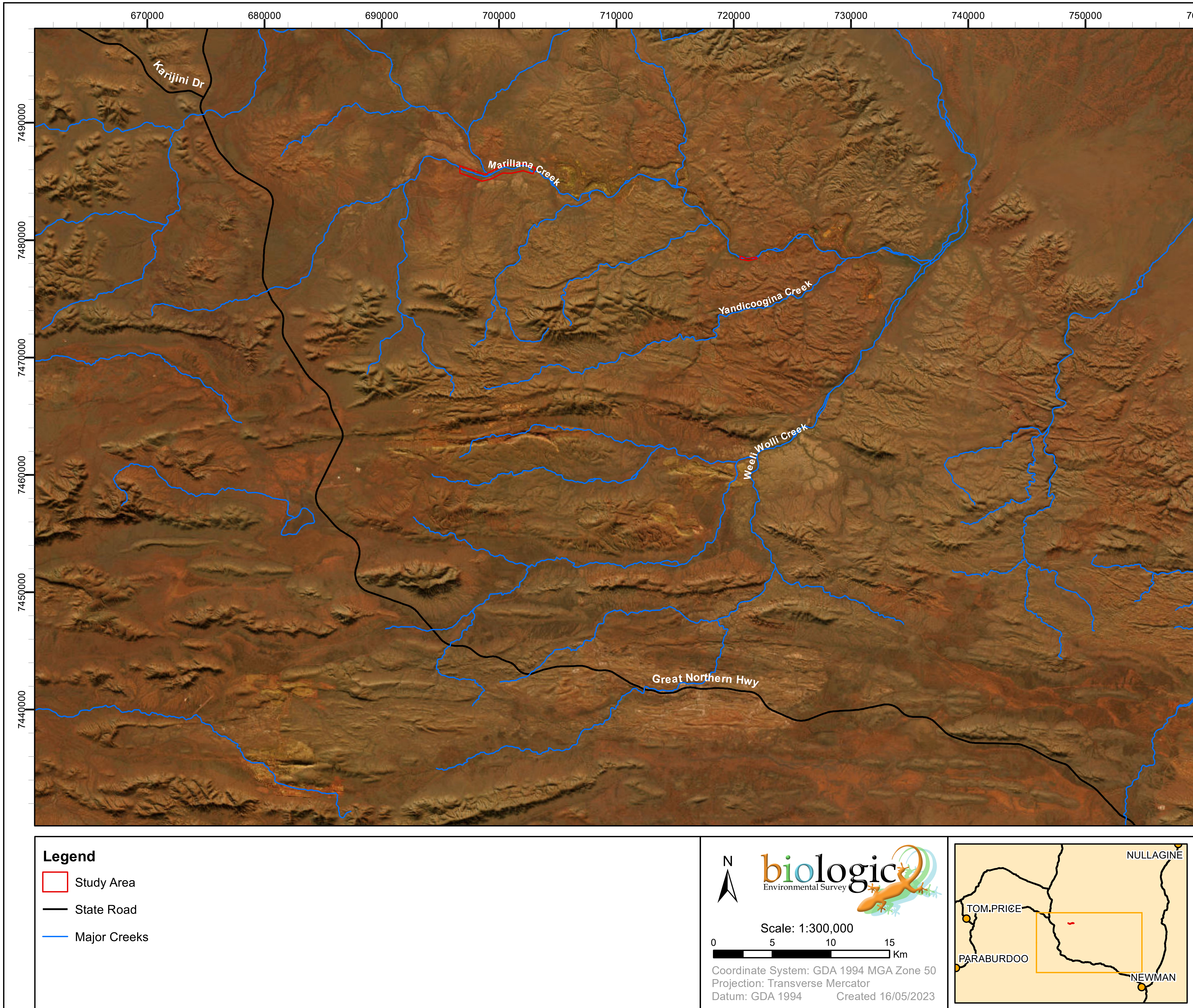
The Pilbara bioregion is classified into four separate subregions, Chichester (PIL01), Fortescue (PIL02), Hamersley (PIL03) and Roebourne (PIL04), of which the Study Area is located within the Hamersley subregion (Figure 1.1). This subregion contains the southern section of the Pilbara Craton and comprises a mountainous area of Proterozoic sedimentary ranges and plateaux, dissected by basalt, shale and dolerite gorges (Kendrick, 2001). The Hamersley contains extensive open snappy gum woodland and hummock grassland communities on ranges and plateaus, with low mulga woodlands over tussock grasses on fine textured soils in lower areas and valley floors (Kendrick, 2001).

The significant and dominant feature of this subregion is the Hamersley Range. This prominent range feature is a mountainous plateau, some 450 km in length, which receives considerably higher rainfall than the surrounding subregion. The plateau is dissected by deeply incised gorges, containing extensive permanent spring-fed streams and pools (Kendrick, 2001). Drainage is into the Fortescue River to the north, the Ashburton River to the south, or the Robe River to the west.

2.2 Hydrology

MAC is mostly located within the Weeli Wolli Spring catchment, with northern parts of the mining lease extending into the Yandicoogina Creek catchment. The current study focussed on Marillana Creek, as it is an option for discharge of excess groundwater.

Marillana Creek is a major tributary of Weeli Wolli Creek (Figure 2.1). The Marillana Creek catchment covers an area of approximately 2,050 km^2 (Johnson & Wright, 2001). Its headwaters rise from the Hamersley Range, and flow in an east and north-easterly direction into the Munjina Claypan (Rio Tinto, 2012). When the internal holding capacity of the claypan is exceeded, surface water flows south-east into the lower Marillana Creek catchment (Rio Tinto, 2012). The upper catchment is characterised by a broad alluvial plain with large areas of calcrete, while lower in the catchment, in the vicinity of the Study Area, the drainage is well defined (Johnson & Wright, 2001). Marillana Creek supports several natural permanent and semi-permanent pools, including one named pool (Flat Rocks). This pool is located within the Study Area, upstream of current BHP and Rio Tinto mining operations. Several tributaries contribute flows to Marillana Creek, including Lamb Creek, Phil's Creek, Yandicoogina Creek and many smaller, un-named creeks (Figure 2.1). Marillana Creek flows into Weeli Wolli Creek, 40 km downstream of the Study Area.



BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 2.1: Surface hydrology of the Study Area and surrounds

Marillana Creek is currently affected by mining operations downstream of the Study Area. The BHP Yandi mine currently dewater developing pit areas and discharge into Marillana Creek, approximately 23 km downstream of the Study Area. The Rio Tinto Yandicoogina mine lies downstream of BHP, and undertakes dewatering, with discharge of surplus groundwater into the creek around 38 km downstream of the Study Area, just upstream of the confluence with Weeli Wolli Creek.

2.3 Groundwater Dependent Ecosystems (GDE)

Groundwater-Dependent Ecosystems (or GDEs) are ecosystems that rely upon groundwater for their continued existence (BoM, 2021). GDEs can be represented by many different assemblages of biota which rely on groundwater, and as a result come in many forms. For terrestrial ecosystems there are three key types of GDE:

1. Aquatic ecosystems: that rely on the surface expression of groundwater – this includes surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs
2. Terrestrial ecosystems: that rely on the subsurface presence of groundwater–this includes all vegetation ecosystems or Groundwater Dependent Vegetation (GDV)
3. Subterranean ecosystems: this includes cave and aquifer ecosystems (BoM, 2021).

Above-ground terrestrial GDEs are typically characterised by the presence of flora species that rely on groundwater (i.e., phreatophytes). Phreatophytes may be classified as either obligate or facultative phreatophytes depending on their reliance on groundwater:

- Obligate phreatophytes are flora species confined to habitats with access to groundwater.
- Facultative phreatophytes are flora species that can utilise groundwater to satisfy a proportion of their ecological water requirement (EWR) when it is available. However, some individuals may also satisfy their EWR by relying solely on uptake from upper unsaturated soils layers where groundwater is inaccessible (Eamus *et al.*, 2016).

Groundwater originates from direct infiltration by rainfall and from surface water flows. Groundwater occurs throughout the Pilbara but is most easily located and accessed near surface water drainage lines (alluvial channels). The most significant aquifers can be grouped into three types: alluvial aquifers that are either unconsolidated sedimentary aquifers or chemically deposited aquifers, consolidated sedimentary (or sedimentary rock) aquifers and fractured rock aquifers. Broadly, the groundwater associated with the Survey Area is located within fractured and weathered rock aquifers. Groundwater is stored in fractures and voids in the rocks and therefore tends to be localised. Groundwater recharge is also episodic and affected by direct infiltration of rainfall over areas where the rocks are fractured. As a result, GDEs are subject to impacts resulting from changes in water table levels (above and below surface soil). The rate at which groundwater levels change (depth, rate of recharge, etc.) determines the presence or absent of groundwater dependent vegetation (GDV).

2.3.1 Groundwater Dependent Species

Above-ground GDEs are typically characterised by the presence of flora species that rely on groundwater (i.e., phreatophytes). Of the two types of phreatophytes described above, obligate phreatophytes are confined to habitats with continual, seasonal, or episodic access to groundwater due to their complete (or high) reliance on groundwater (Eamus *et al.*, 2016). They can only inhabit where they have access to groundwater in order satisfy at least some proportion of their ecological water requirement (EWR) (Eamus *et al.*, 2016). This means that obligate phreatophytes are highly sensitive to changes in groundwater regime and respond negatively to rapid groundwater drawdown. As such, obligate phreatophytes provide a good indicator of consistently shallow groundwater tables, or permanent surface water presence in the Pilbara. Not all phreatophytic species display the same degree of dependency on groundwater and the dependency within species has been shown to vary both spatially and temporally (Eamus *et al.*, 2016).

Facultative phreatophytes are plants that can access groundwater but are not totally reliant on it for their water requirements. Facultative phreatophytes use groundwater opportunistically, particularly during times of drought when moisture reserves in the unsaturated (vadose) zone of the soil profile become depleted. Facultative phreatophytes can use groundwater to satisfy a proportion of their EWR when it is available. However, some individuals may also satisfy their EWR by relying solely on uptake from upper unsaturated soils layers where groundwater is inaccessible (Eamus *et al.*, 2016). . Facultative phreatophytes are therefore generally associated with the subsurface presence of groundwater, rather than surface expression of groundwater. Most facultative phreatophytes are large woody trees and shrubs with deep root systems capable of accessing the capillary fringe of the water table which may occur at considerable depth within the soil profile.

Marillana Creek is known to support both obligate phreatophytic flora, in particular *Melaleuca argentea*, and facultative phreatophytic species (e.g., *Eucalyptus camaldulensis* subsp. *obtusa* and *Eucalyptus victrix*) (Biologic, 2022b). A substantial amount of literature and knowledge on groundwater and environmental water requirements is known for *Melaleuca argentea* (Graham *et al.*, 2003; Landman *et al.*, 2003; McLean, 2014; O'Grady *et al.*, 2006) and *Eucalyptus camaldulensis* subsp. *obtusa* (Collof, 2014; Gibson *et al.*, 1994; Marshall *et al.*, 1997; Morris & Collopy, 1999), while comparatively less information is known on the groundwater use strategies of understorey species. A regional study of Pilbara GDEs has provided a list of species found to be correlated with shallow groundwater, and representative of GDEs, with varying mesophytic and/or hydrophytic[1] indicator levels (Rio Tinto, 2021). Many of these species are known to occur within the Study Area (Table 2.1), and their presence indicates groundwater persists at, or just below, the surface.

[1] Mesophyte – A plant that grows in an environment that has a moderate supply of water. Growing in, or adapted to, a moderately moist environment.

Hydrophyte – A plant that grows in either partially or totally submerged in water, including waterlogged soil.

Table 2.1: Mesophytic and hydrophytic indicators (after Rio Tinto, 2021).

Indicator type	Indicator species	Presence in the Study Area
Very high-level	*Melaleuca argentea*	✓
	Sesbania formosa	
	Imperata cylindrica	
	Cladium procerum	
	Baumea juncea	
	Juncus krausii	
	Fimbristylis feruginea	
	Nymphaeaceae spp.	
High-level	*Eucalyptus camaldulensis*	✓
	Acacia ampliceps	✓
	Melaleuca bracteata	✓
	Ficus aculeata (common abundance)	
	Gymnanthera cunninghamii (abundant)	
	Schoenus falculatus (abundant)	Recorded by (Biologic, 2022a)
	Fimbristylis littoralis	
	Fimbistylis sieberiana	
	Eleocharis dulcis	
	Stylidium weeliwolli	
	Ammannia baccifera (abundant)	✓ but not abundant
	Ruppia polycarpa	*Ruppia* sp. present
	Potamogeton spp. (abundant, likely baseflow indicator)	✓
Moderate-level	*Eucalyptus victrix*	✓
	Gossypium sturtianum	
	Cyperus vaginatus (abundant)	✓
	Eleocharis geniculata	✓
	Stylidium fluminense	
	Schoenoplectus laevis	
	Ammannia baccifera	✓
	Chara spp.	✓
	Najas spp. (abundant)	✓

Although GDEs only cover a comparatively small proportion of the land surface, they provide specific ecosystem functions supporting unique and important biological diversity at both local and regional scales (Biologic, 2022b; Boulton & Hancock, 2006; Humphreys, 2006; Murray *et al.*, 2006; Thurgate *et al.*, 2001). In addition to environmental benefits, GDEs often have significant social, economic, and spiritual values (Murray *et al.*, 2006). Protection of GDEs is commonly considered an important criterion in sustainable water resource management, particularly when human water management is in competition with environmental water demands.

2.3.2 GDE Atlas

A national dataset of Australian GDEs was developed by the Bureau of Meteorology (BoM) to inform groundwater planning and management (BoM, 2021). This dataset is referred to as the Groundwater Dependent Ecosystems Atlas (GDE Atlas) and is the first and only national inventory of GDEs in Australia. The GDE Atlas contains information about the three key types of ecosystems described above (Aquatic; Terrestrial; and Subterranean). Importantly, the GDE Atlas also includes the national inflow-dependent landscapes layer which is derived from remotely sensed data. This layer indicates the likelihood that a landscape is accessing water in addition to rainfall (such as soil moisture, surface water or groundwater), and generally represents a potential GDE dataset for all areas not yet studied or investigated in any detail.

Mapping in the GDE Atlas comes from two broad sources:

- National assessment – national-scale analysis based on a set of rules that describe potential for groundwater/ ecosystem interaction and available GIS data.
- Regional studies – more detailed analysis undertaken by various State and regional agencies using a range of different approaches including field work, analysis of satellite imagery and application of rules/conceptual models.

The GDE Atlas indicates that the Marillana Creek Study Area has moderate potential to support GDEs based on the terrestrial and inflow dependent ecosystem (IDE) assessment (IDE likelihood classification of 9). However, no specific aquatic GDEs were highlighted within the Study Area in the GDE Atlas. Interestingly, Weeli Wolli Creek, which is a known terrestrial and aquatic GDE, is only classified as having a moderate potential to support GDEs on the GDE Atlas. This may be due to the national-scale level of analysis which is based on remote sensing and follows a specific set of rules (Doody *et al.*, 2017). Therefore, the GDE Atlas alone is not completely accurate and ground-truthing is important. Follow-up surveys and investigations are required to confirm the Atlas and identify the presence of any actual GDEs.

2.4 Climate

The Pilbara region has a semi-desert to tropical climate, with relatively dry winters and hot summers. Rainfall is highly variable and mostly occurs during the wet season (summer). It tends to be associated with convective thunderstorms, low pressure systems and tropical cyclones that generate ephemeral flows and occasional flooding in creeks and rivers (Leighton, 2004). Winter (dry season) rainfall is generally lighter and the result of cold fronts moving north-easterly across the state (Leighton, 2004). Due to the nature of cyclonic events and thunderstorms, total annual rainfall in the region is highly unpredictable and individual storms can contribute several hundred millimetres of rain at one time. The average annual rainfall over the broader Pilbara area ranges from 200 to 400 millimetres (mm), although rainfall may vary widely from year to year (van Etten, 2009).

Nearby rainfall gauging stations (GS) for the Study Area include the Department of Water and Environmental Regulation (DWER) Marillana Creek - Flat Rocks (#505011; length of record 1988 to current), located within the Study Area close to Biologic's current sampling site MarC6, and the DWER Marillana Creek - Munjina Station (#505004; length of record 1985 to current), located approximately 20 km west of the Study Area. Long-term average annual rainfall ranged from 410 mm at Flat Rocks to 435 mm at Munjina (DWER, 2021). Temperatures vary considerably throughout the year, with average maximum wet season temperatures reaching 30 °C to 40 °C, and dry season temperatures generally fluctuating between 22 °C and 30 °C.

3 METHODS

3.1 Field Survey and Laboratory Teams

Field surveys were conducted by Biologic aquatic ecologists Jessica Delaney (Principal Aquatic Ecologist | Manager of Aquatic Ecology), Kim Nguyen (Senior Aquatic Ecologist) and Alex Riemer (Senior Aquatic Ecologist); all with extensive experience undertaking aquatic ecosystem surveys throughout the Pilbara region of Western Australia. The field team also included Courtney Wilkins (Aquatic Ecologist), Siobhan Paget (Aquatic Ecologist) and Isabelle Johansson (Invertebrate Zoologist).

Fauna sampling was conducted under DBCA Fauna Taking (Biological Assessment Regulation 27) Licence BA27000290-2, and Department of Primary Industries and Resource Development (DPIRD) Instrument of Exemption to the *Fish Resources Management Act 1994 Section 7 (2)* numbers: 3266 and 250976722, both issued to Jessica Delaney. Flora was collected under DBCA Flora Taking (Biological Assessment) Licence FB62000095, issued to Jessica Delaney.

Macroinvertebrate specimens were identified in-house by Alex Riemer, Kim Nguyen, Giulia Perina, Isabelle Johansson, Siobhan Paget, and Vanessa Nici. Flora samples (submerged and emergent macrophytes) were identified by Biologic's Flora Team, including Samuel Coultas, Kaylin Geelhoed and Clinton van den Bergh, in conjunction with Alex Riemer and Morgan Lythe. Zooplankton samples were processed and identified by Dr Robert Walsh (Australian Water Life).

3.2 Survey Timing, Weather, and River Conditions

The field survey comprised two sampling events. The dry season survey (Phase 1; hereafter referred to as Dry 2021) was undertaken between the 18th and 21st of October 2021. Average maximum temperature (33.7°C) in October 2021 was 1.5 °C cooler than the long-term average maximum for the month. There was no rainfall in the three months preceding the survey, but in the month following (November 2021), Newman received a greater amount of rainfall than the November long-term average (Figure 3.1).

The wet season survey (Phase 2; Wet 2022) was undertaken between the 11th and 14th of April 2022, when average maximum daytime temperatures (32.1 °C) were similar to the April long-term average maximum temperature (32.2 °C). Total rainfall in March 2022 reached 37.0 mm, compared to the long-term average of 40.8 mm (Figure 3.1). While January 2022 (21.8 mm) recorded rainfall well below the long-term average (68.2 mm), rainfall for February and March (73.0 mm and 37.0 mm, respectively) were comparable to the average of 72.3 mm (February) and 40.8 mm (March). The Flat Rocks GS on Marillana Creek, located approximately 18 km north-west of the Survey Area, also reported low rainfall for January 2022 (49.4 mm recorded in comparison to the average of 184.4 mm), but well above the long-term average rainfall for February (296.6 mm recorded in comparison to the average of 189.7 mm) (DWER, 2022) (Figure 3.2).

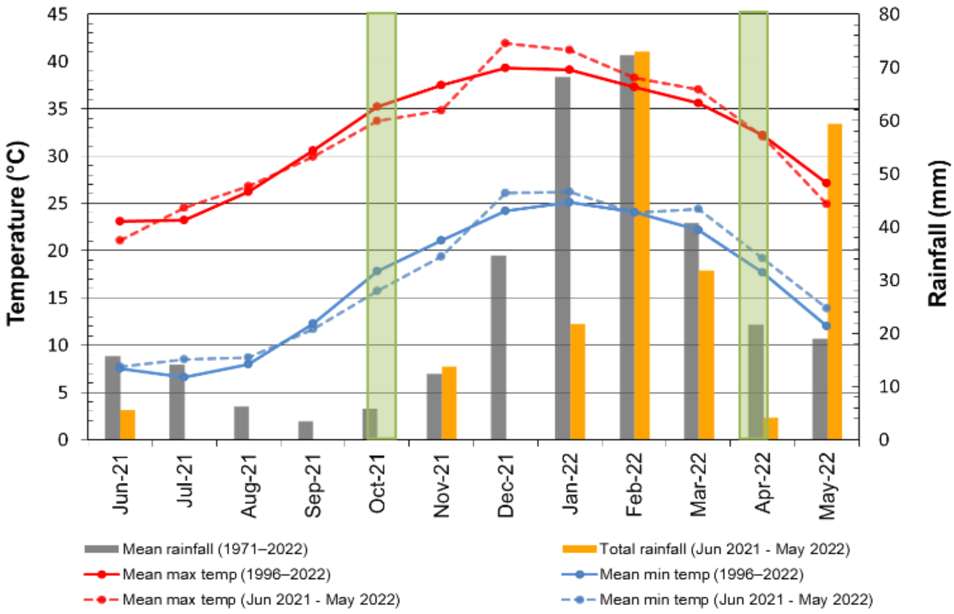


Figure 3.1: Total and long-term average monthly temperature (°C) and rainfall (mm) recorded from the Newman BoM gauging station in the months preceding the Marillana Creek aquatic survey.

Green bars indicate wet and dry season survey timing.

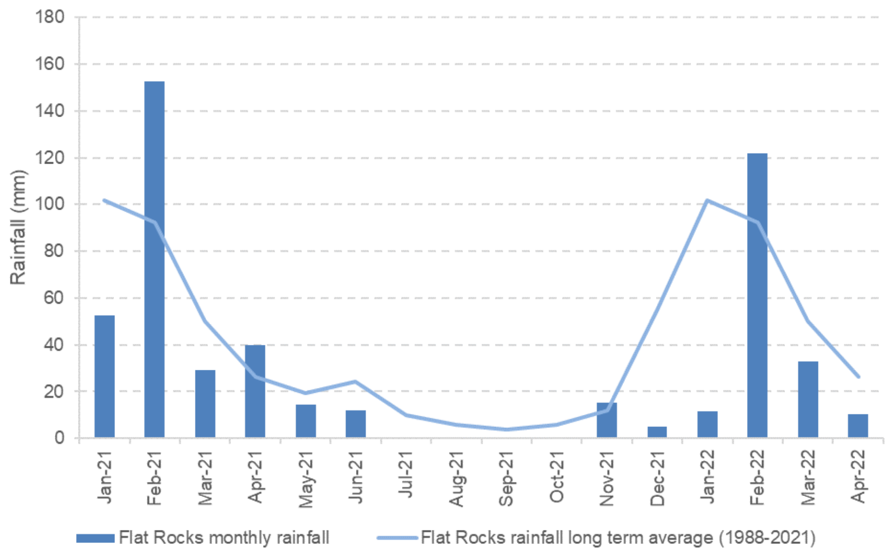


Figure 3.2 Monthly rainfall data (mm) at the DWER Flat Rocks GS on Marillana Creek, including monthly totals between Jan-21 and Apr-22 and long-term averages (1988-2021).

Long-term average annual streamflow recorded from Flat Rocks GS (streamflow station number 708001) on Marillana Creek is 6,995.97 ML. Streamflow in the Pilbara occurs as a direct response to rainfall. Monthly flows are typically highest in January and February, before receding over the course of the year. The relationship between rainfall and streamflow within Marillana Creek (Flat Rocks GS station) is shown in Figure 3.3, where high flows are recorded during years of heavy rainfall. Rainfall and flows have been considerably lower since 2000, in comparison to the previous 12-year period (Figure 3.3). The streamflow gauging station at Flat Rocks was damaged during a major flood and has not provided information since February 2021. The relationship between rainfall and streamflow within Marillana Creek prior to this time can be seen in Figure 3.3, based on annual rainfall and streamflow. High flows were recorded during years of heavy rainfall.

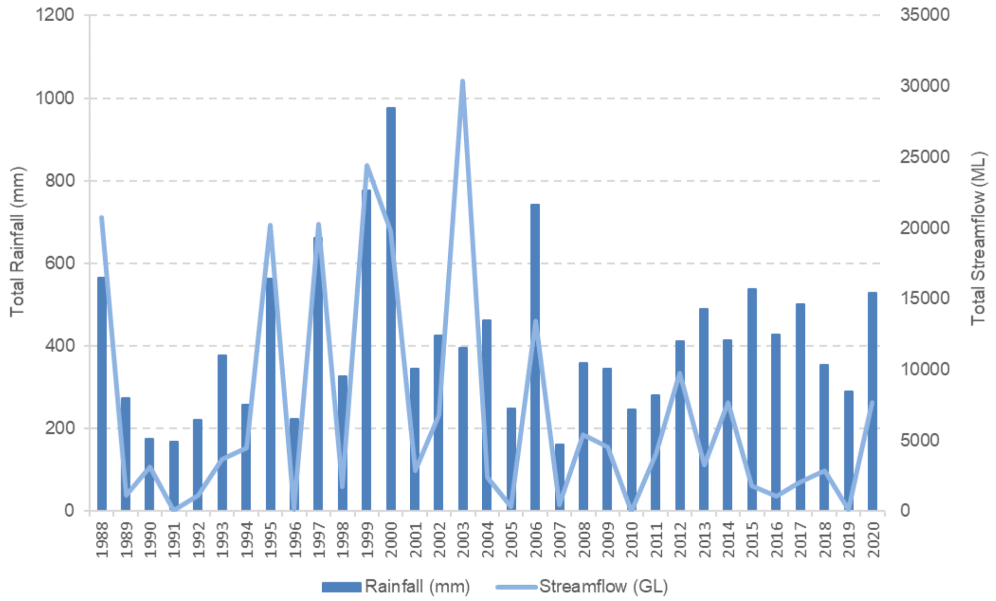


Figure 3.3: Annual rainfall (mm) and streamflow (ML) at the DWER Flat Rocks GS on Marillana Creek.

Although March 2022 recorded just below the long-term average rainfall, a tropical low (30U) produced heavy rainfall in the fortnight prior to the Wet 2022 survey, with over 76 mm of rain recorded at the Newman GS in four days (29th March – 1st April). The high rainfall days prior to the survey led to flooding in many creeks and river systems in the East Pilbara. The pools in Marillana Creek were likely flushed and filled at this time, but had settled following flooding by the time of the Wet 2022 sampling event.

3.3 Site Selection

A total of 12 sites were sampled in both seasons; six sites within the Study Area, and six reference sites. Table 3.1 provides information on the sites sampled and their locations are shown in Figure 3.4. All previously sampled Study Area sites, except MarC3, were dry at the time of the Dry 2021 survey. However, pools within 500 m of MarC6 were present, and therefore the full suite of sampling was able to be undertaken (named MarC6a to distinguish it from the original sampling site). At all other Study Area locations (except MarC3), sediment samples were collected in the Dry 2021, and rehydrate-emergence trials undertaken in the laboratory.

One reference site was located just outside the Study Area, on Marillana Creek, upstream of the confluence with the un-named tributary (Figure 3.4). All other reference sites were located on creeks and systems well outside the Study Area. The aim of reference site selection was to choose sites most similar to Marillana Creek, with respect to hydrology, persistence, morphology, and riparian vegetation, as well as being relatively close by and within the same climatic area. Reference sites included MACREF1 (located on a tributary of Yandicoogina Creek), MACREF2 (located on Marillana Creek, upstream of the confluence with the un-named tributary), Ben's Oasis (BENS) and Weeli Wolli Spring (WWS; both located on Weeli Wolli Creek), Skull Springs (SS on the Davis River) and Munjina Spring (MUNJS on Munjina Creek). A brief description of each site is provided below:

Study Area Sites

- Tributary of Marillana Creek (MarC1): One pool located on a tributary which flows into Marillana Creek, downstream of the potential discharge location.
- Marillana Creek: Five pools (MarC2, MarC3, MarC4, MarC5 and MarC6), located downstream of the confluence with the un-named tributary (Figure 3.4).

Reference Sites

- MAC Reference 1 (MACREF1): permanent pools and riffle sequences located on a tributary of Yandicoogina Creek, between the BHP WAIO MAC operations to the southwest and BHP WAIO Yandi operations to the north. Located approximately 11 km southeast of the Study Area.
- MAC Reference 2 (MACREF2): series of permanent pools and riffles located on Marillana Creek, upstream of the confluence with the un-named tributary and just outside the Study Area.
- Weeli Wolli Spring (WWS): spring site on Weeli Wolli Creek, within the Weeli Wolli Spring Priority 1 Priority Ecological Community (PEC). Located 31 km to the southeast of the Study Area.
- Ben's Oasis (BENS): spring site on Weeli Wolli Creek which represents the second occurrence of the Weeli Wolli Spring Priority 1 PEC. Located 41 km southeast of the Study Area.
- Munjina Spring (MUNJS): a spring site located on Munjina Creek, within the Priority 2 PEC: *Riparian flora and plant communities of springs and river pools with high water permanence of the Pilbara*.
- Skull Spring (SS): spring site on the Davis River. Designated a wetland of subregional significance by Kendrick and McKenzie (2001) due to the presence of permanent springs, large permanent pools, large fish fauna, waterbird use and richness of aquatic vegetation. Skull Springs lies approximately 228 km to the northeast of the Study Area.

In the Wet 2022, additional hyporheic sampling locations were included in the program. These sites were located on Marillana Creek, approximately 23 km downstream of the Study Area (Figure 3.4). They were located close to pits associated with BHP's Yandi mine, and were included in the current program to provide further information on the distribution of stygal species across the area.

Table 3.1: Site details, indicating site type and sampling effort.

	Creek/System	Site	Site Code	Latitude	Longitude	Sampling effort	
						Dry 2021	Wet 2022
Study Area	Marillana Creek	Marillana Creek 1	MarC1	-22.7242	118.9254	×	✓
		Marillana Creek 2	MarC2	-22.7258	118.9421	×	✓
		Marillana Creek 3	MarC3	-22.7219	118.9471	✓	✓
		Marillana Creek 4	MarC4	-22.7201	118.9505	×	✓
		Marillana Creek 5	MarC5	-22.7198	118.9618	×	✓
		Marillana Creek 6	MarC6	-22.7188	118.9704	×	✓
		Marillana Creek 6a	MarC6a	-22.7223	118.9742	✓	-
Additional Hyporheic Sampling Site	Marillana Creek	Marillana Creek Hypo 1	MC1H	-22.7864	119.1485	-	*
		Marillana Creek Hypo 2	MC2H	-22.7870	119.1499	-	*
		Marillana Creek Hypo 3	MC3H	-22.7876	119.1516	-	*
		Marillana Creek Hypo 4	MC4H	-22.7876	119.1519	-	*
		Marillana Creek Hypo 5	MC5H	-22.7879	119.1527	-	*
		Marillana Creek Hypo 9	MC9H	-22.7880	119.1529	-	*
		Marillana Creek Hypo 10	MC10H	-22.7882	119.1561	-	*
Reference	Marillana Creek	Marillana Creek Reference 2	MACREF2	-22.7235	118.9363	^	✓
	Tributary of Yandicoogina Creek	Marillana Creek Reference 1	MACREF1	-22.8647	119.1145	^	^
	Weeli Wolli Creek	Weeli Wolli Spring	WWS	-22.9181	119.1994	✓	✓
		Bens Oasis	BENS	-23.0558	119.1509	✓	✓
	Munjina Spring	Munjina Spring	MUNJS	-22.5373	118.7046	✓	✓
	Davis River	Skull Springs	SS	-21.8600	121.0114	✓	✓
					Total sites sampled (full suite)	**6**	**11**
					Rehydration-emergence samples	**6**	**0**

✓ Full suite of methods completed
× Dry at time of sampling, sediments collected, and rehydration-emergence trials undertaken
^ No hypo due to substrate
* Hypo only
- Not sampled

There are no fish present at reference site MUNJS and therefore fish were not sampled at this site.

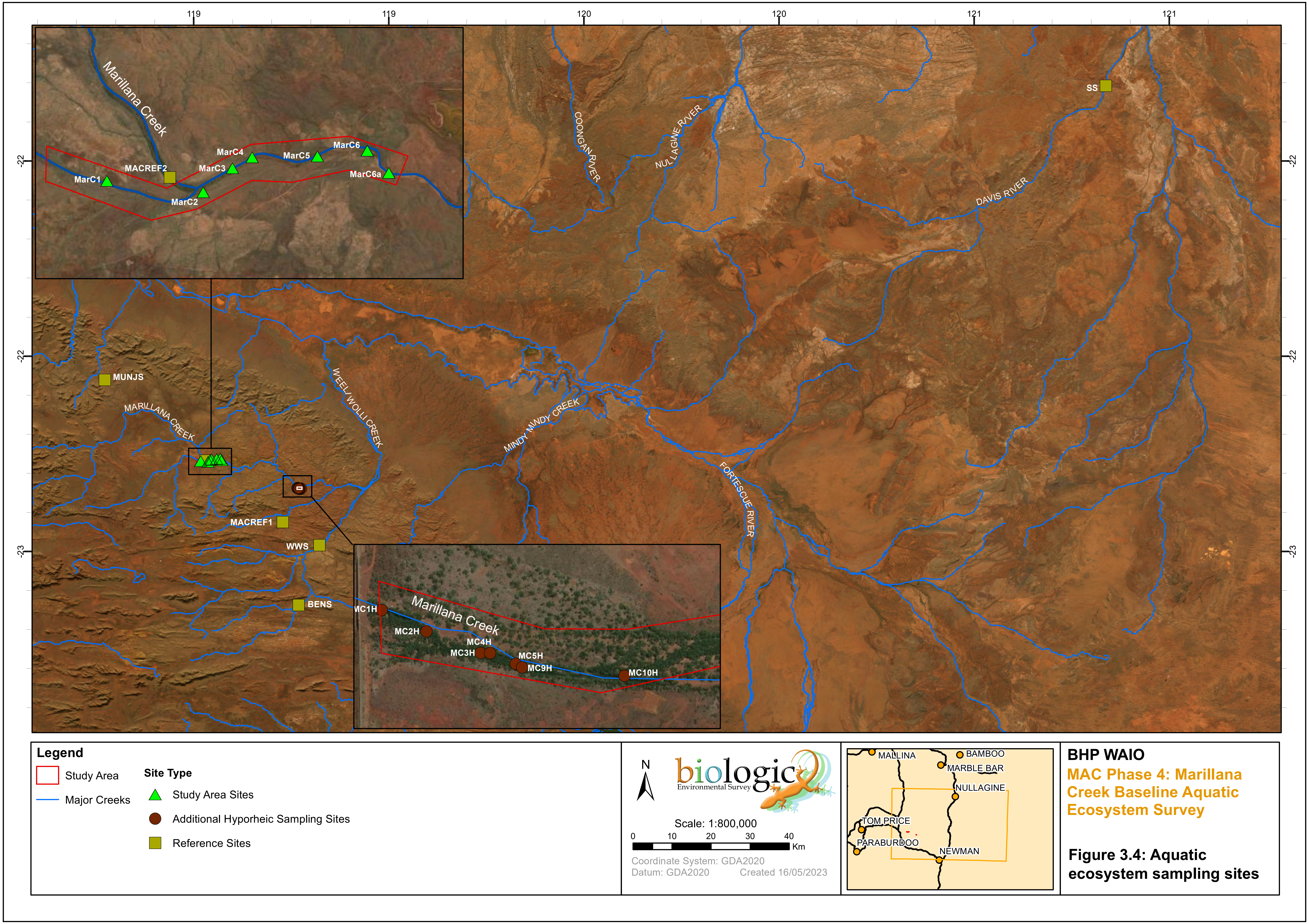


Figure 3.4: Aquatic ecosystem sampling sites

3.4 Habitat Assessment

Habitat characteristics were recorded at each site to provide information on the variability of aquatic habitat present, and to assist in explaining patterns in aquatic faunal assemblages. Details of in-stream habitat and sediment characteristics were recorded by the same team member at all sites to reduce the potential for habitat differences related to subjective recordings by different personnel. Habitat characteristics recorded included percent cover by inorganic sediment, submerged macrophyte, floating macrophyte, emergent macrophyte, algae, large woody debris (LWD), detritus, roots, and trailing vegetation. Details of substrate composition included percent cover by bedrock, boulders, cobbles, pebbles, gravel, sand, silt, and clay.

3.5 Water Quality

Water quality variables were recorded *in situ* at each site with a portable YSI Pro Plus multimeter. *In situ* variables included pH, electrical conductivity (EC), dissolved oxygen (DO), and water temperature. Undisturbed water samples were taken for laboratory analyses of ionic composition, nutrients, dissolved metals, and turbidity. All water quality analyses were undertaken by Australian Laboratory Services (ALS), a National Association of Testing Authorities (NATA) accredited chemical analysis laboratory.

All water quality variables measured included:

- *In situ* – pH, DO (% and mg/L), EC (µS/cm), water temperature (°C) and redox (mV);
- Ionic composition - Ca, K, Mg, Na, HCO_3, Cl, SO_4, CO_3, alkalinity and hardness (mg/L);
- Water clarity – turbidity (NTU);
- Nutrients – nitrite (N_NO_2), nitrate (N_NO_3), nitrogen oxides (N_NOx), ammonia (N_NH_3), total nitrogen (total N) and total phosphorus (total P) (all in mg/L); and
- Dissolved metals – aluminium (dAl), arsenic (dAs), boron (dB), barium (dBa), cadmium (dCd), cobalt (dCo), chromium (dCr), copper (dCu), iron (dFe), manganese (dMn), molybdenum (dMo), nickel (dNi), lead (dPb), selenium (dSe), uranium (dU), vanadium (dV) and zinc (dZn) (all mg/L).

Samples collected for dissolved metals were filtered through 0.45 µm MF-Millipore™ nitrocellulose filters in the field. Nutrient samples were filtered by ALS in the laboratory as part of their analytical methods. Following best practice and to minimise any potential for contamination, all water samples were collected using clean Nalgene sample bottles, and clean/new filters and syringes (Ahlers *et al.*, 1990; Batley, 1989; Madrid & Zayas, 2007). All water quality sampling equipment was stored in polyethylene bags, and samplers wore polyethylene gloves whilst sampling water quality (Plate 3.1). All water samples were kept on ice in an esky whilst in the field, and either refrigerated (ions, dissolved metals, nutrients, general water), or frozen (total nutrients) as soon as possible for subsequent transport to the ALS laboratory.

Plate 3.1: Taking water samples for laboratory analysis at MarC2 in the Wet 22 (photo by Biologic ©).

3.5.1 Macrophytes

Macrophytes (submerged and emergent) and dominant riparian vegetation specimens were collected from each site, where present. Submerged macrophytes were hand collected and placed in sample containers with sufficient water from the site to ensure the collected material did not dry out or degrade. Roots, stem and flowering/fruiting bodies from emergent and riparian sedges and rushes were hand collected, ensuring sufficient material to allow confident identification. The emergent and riparian flora samples were assigned a unique number and pressed in the field. All specimens collected were processed as per WA Herbarium guidelines and identified in the Biologic laboratory.

3.5.2 Zooplankton (Microinvertebrate Fauna)

Zooplankton samples were collected by gentle sweeping over an approximate 15 m distance with a 53 μm mesh pond net. The net was thoroughly cleaned between sites to avoid cross contamination. Samples were preserved in 95% ethanol in the field and sent to Dr Robert Walsh (Zooplankton taxonomist; Australian Waterlife).

In the laboratory, zooplankton samples were sorted using a Greiner tray under a low power dissecting microscope. All micro-crustacea were removed from samples and identification made under a compound microscope, to the lowest possible level of taxonomy (genus or species). Rotifera were identified from a 1 ml aliquot taken from the sample, using a Sedgwick rafter counting tray on a compound microscope.

3.5.3 Hyporheos Fauna

At each site, the hyporheic zone was sampled using the Karaman-Chappuis (Karaman) method (Chappuis, 1942; Karaman, 1935). This involved digging a hole (approximately 20 cm deep, 40 cm diameter) in alluvial sediments adjacent to the water's edge (Plate 3.2). The hole was swept at three-time intervals with a modified 110 µm mesh plankton net; (i) immediately once it had filled with water, (ii) after approximately 30 minutes, and (iii) then again at the completion of sampling at that site. The net was thoroughly cleaned between sites to avoid cross contamination. Although Bou-Rouch (Bou, 1974) sampling has widely been used to sample the hyporheic zone, the Karaman method has been found to be more effective, with a greater diversity of taxa collected (Canton & Chadwick, 2000; Strayer & Bannon-O'Donnell, 1988).

Hyporheic samples were preserved in 95% ethanol in the field and returned to the Biologic laboratory where they were stored in the freezer prior to processing. Hyporheos[2] fauna present were removed by sorting under a low power dissecting microscope. Specimens were identified in-house to the lowest possible level (genus or species level) and enumerated to log_{10} scale abundance classes (i.e., 1 = 1 individual, 2 = 2 - 10 individuals, 3 = 11 - 100 individuals, 4 = 101-1000 individuals, 5 = >1000). Molecular analysis was used to complement morphological taxonomy for identification of some of the more difficult groups, such as ostracods, syncarids, and amphipods.

Plate 3.2: Sampling the hyporheos using the Karaman methodat MarC3a (photo by Biologic ©).

3.5.4 Macroinvertebrates

Macroinvertebrate sampling was conducted with a 250 µm mesh D-net across as many habitats as possible, including open water, macrophyte beds, LWD, leaf litter and edge habitat. The kick-sweep method was used in open areas, riffles and along edge habitat, whereby the sediments were disturbed

[2] Fauna residing in the hyporheic zone with intent. Surface water species utilising the zone for protection against perturbations in the river environment and obligate groundwater species, are collectively known as hyporheos fauna (Brunke & Gonser, 1997).

(kicked) and the water column immediately swept with the dip net. Each sample was washed through a 250 μm sieve to remove fine sediment. Leaf litter and other coarse debris were removed by hand. The net was thoroughly cleaned between sites to avoid cross contamination.

Samples were preserved in 95% ethanol in the field and transported to the Biologic laboratory for processing. Sorting was conducted under a low power dissecting microscope. Specimens were identified to the lowest possible level (genus or species level) and enumerated to log_{10} scale abundance classes (i.e., 1 = 1 individual, 2 = 2 - 10 individuals, 3 = 11 - 100 individuals, 4 = 101-1000 individuals, 5 = >1000). All macroinvertebrate groups were identified using in-house expertise.

3.5.5 Rehydrate emergence trials

Sediments were collected from dry sites (i.e., MarC1, MarC2, MarC4, MarC5 and MarC6 in the Dry 2021) to enable rehydration and emergence trials to be conducted in the Biologic laboratory. The aim of these trials was to obtain information on the types of resident fauna the creek supports by identifying those which emerge from desiccation-resistant resting stages following inundation and rehydration. This provides information on aquatic ecosystem values in the absence of surface water.

In the field, sediment samples were collected from areas with low elevation in relation to surrounding topography, i.e., areas that likely hold water after a rainfall event. Approximately 2 kg of surficial sediment was collected from the top 5-10 mm, and samples placed in labelled, breathable calico bags. Each sample was kept in a cool, dark place.

In the Biologic laboratory, each sediment sample was rehydrated in tanks flooded with 7 L of dechlorinated filtered water. Rehydration was undertaken in a controlled temperature room maintained at a temperature comparable to conditions in the field at the time of collection, with a 12-hour light/12-hour dark cycle. Samples were examined every 24 to 48 hours for emergent fauna for up to 58 days after rehydration, or until no new fauna emerged. As cues for emergence and colonisation rates are different for different species, samples were allowed to dry after 28 days and re-wetted, to simulate a second flooding event. Animals were fed algal pellets for the duration of the emergence trials.

Emergent fauna was identified to species level (where possible) under high-powered magnification, and abundance recorded on a log^{10} abundance scale. The conservation status of emergent taxa was determined. Macrophytes which germinated were also identified to as low as level as possible.

Water quality was measured every few days over the course of the trial to ensure the water temperature and DO were appropriate for emergence/germination. The EC of surficial waters in rehydration tanks also reflects the dissolution of salts stored in the creek bed sediments, and so provides an indication of the salinity of the creeks when inundated.

3.5.6 Fish

Fish sampling included a variety of methods to collect as many species and individuals as possible. Methods included light-weight fine mesh gill nets (10 m net, with a 2 m drop, using 10 mm, 13 mm, 19 mm and 25 mm stretched mesh; Plate 3.3) set across the creek/pool, seine netting (10 m net, with a 2 m drop and 6 mm mesh) and direct observation. The seine was deployed in shallow areas with little vegetation or LWD, and up to three seine hauls were undertaken per site. Fish were identified in the field and standard length (SL[3]) measured (Plate 3.4). All fish were released alive to the site where they were collected.

Plate 3.3: Fish sampling using gill nets at MarC6a in the Dry 2021 (photo by Biologic ©).

Plate 3.4: Measuring a spangled perch to SL (mm) at MarC6a in the Dry 2021 (photo Biologic ©).

[3] Standard length (SL) - measured from the tip of the snout to the posterior end of the last vertebra or to the posterior end of the midlateral portion of the hypural plate (i.e., this measurement excludes the length of the caudal fin).

3.5.7 Other Aquatic Fauna

Other vertebrate fauna (i.e., turtles, olive pythons, frogs) observed over the course of the aquatic survey were recorded for each site. Any introduced species captured were also processed and recorded. This included the redclaw crayfish (*Cherax quadricarinatus*). Any redclaw crayfish captured were sexed and carapace length (CL) measurements taken. As per DPIRD licencing exemption conditions, all introduced species were anaesthetised using AQUI-S® (AQUI-S New Zealand Ltd.), before being euthanised humanely in an ice slurry. Locations of introduced redclaw were reported to DPIRD in accordance with licence conditions.

3.6 Data Analysis

3.6.1 Water Quality

In the absence of site-specific guideline values (SSGVs) for the Study Area, water quality data were compared against the ANZG (2018) default water quality guideline values (DGVs) for the protection of aquatic ecosystems in the tropical north-west of Western Australia (see Appendix B for default values). For this purpose, sites sampled in the current study were classified as lowland rivers (< 150 m elevation). DGVs are provided for a range of parameters designed to protect aquatic systems at a low level of risk but are not designed as pass or fail compliance criteria. Exceedances of DGVs provide a trigger which can be used to inform managers and regulators that changes in water quality are occurring and may need to be investigated (ANZG, 2018).

Differing levels of protection are provided within the guidelines, depending on the condition of the ecosystem:

- High conservation/ecological value systems – where the goal is to maintain biodiversity with no (or little) change to ambient condition. 99% species protection DGVs for toxicants apply[4].
- Slightly to moderately disturbed systems – where aquatic biodiversity has already been adversely impacted to a small but measurable degree by human activity. The aquatic ecosystem remains in a healthy condition and ecological integrity is largely retained. The aim is to maintain current biodiversity and ecological function. 95% species protection DGVs for toxicants apply.
- Highly disturbed systems – are measurably degraded and of lower ecological value. Guideline aims for these systems may be varied and more flexible, ranging from maintenance of the current yet modified ecosystem that supports management goals, to

[4] For toxicants, DGVs were derived using the species sensitivity distribution (SSD) approach; methods are described in ANZECC & ARMCANZ (2000). Refer to Warne *et al.* (2018) or updated DGVs. Where the SSD approach could not be used, the less preferred 'assessment-factor approach' was used, following methods detailed in ANZECC & ARCMANZ (2000). For toxicants, DGVs relate to differing levels of species protection, i.e., the 99% DGVs protect 99% of species, the 95% DGVs protect 95% of species present, and so on.

continual improvement in ecosystem condition. For toxicants, the 90% or 80% species protection DGVs may be applied.

For stressors (pH, DO, EC and turbidity), the ANZG (2018) provide DGVs for slightly disturbed ecosystems only, which are equivalent to the 95% DGVs described above. For analytes which have a lower threshold as well as an upper limit, such as pH and DO, an upper and lower DGV is provided. This is because adverse ecological impacts can occur at low pH and DO levels, as well as high. Two DGVs relating to nutrient concentrations are provided within the guidelines:

- A toxicity DGV above which direct toxic effects to aquatic biota can be expected (ammonia and nitrate); and
- A eutrophication DGV (stressor), above which nutrient concentrations are such that algal blooms and eutrophic conditions can be expected (nitrogen oxides, total nitrogen, and total phosphorus).

All sites sampled in the current study show evidence of varying levels of impact from pastoral use, human activity and introduced species. Therefore, they were classified as slightly to moderately disturbed systems and the 95% toxicity DGVs applied. However, where appropriate, the 99% DGVs were also included in water quality plots for comparative purposes, i.e., where 95% DGVs were considerably greater than the maximum value recorded in the current study (and therefore outside the range of the y-axis in plots).

3.6.2 Macrophytes

Data on wetland vegetation of the Pilbara is limited, with varied sampling effort and taxonomic resolution across studies. However, macrophytes were sampled as part of the Pilbara Biological Survey (PBS), with a paper discussing conservation significance and distribution information due for publication (Mike Lyons, DBCA, unpub. data). To compare species lists with the current study, the DBCA provided Biologic with macrophyte and dominant riparian flora data from appropriate PBS sites. Sites included in this comparison were Weeli Wolli Spring (PSW026), Kalgan Pool (PSW066), and Homestead Creek (PSW093). Flora data from these PBS sites were amalgamated with the current dataset, and a histogram produced displaying overall macrophyte richness recorded from each site.

3.6.3 Invertebrates

All taxa recorded from hyporheic samples were classified using Boulton (2001) categories:

- stygobite – obligate groundwater species, with special adaptations to survive such conditions;
- permanent hyporheos stygophiles - epigean species (living on or near the surface of the ground) which can occur in both surface- and groundwaters, but is a permanent inhabitant of the hyporheos;
- occasional hyporheos stygophiles – use the hyporheic zone seasonally or during early life history stages; and

- stygoxene – species that appear rarely and apparently at random in groundwater habitats (there by accident or seeking refuge during spates or drought; not specialised for groundwater habitat).

Additionally, one further hyporheic classification was imposed:

- possible hyporheos stygophile – likely to be hyporheos fauna, but due to taxonomic resolution or a lack of ecological information we are unable to say this with certainty.

All invertebrates collected were compared against appropriate threatened and priority species lists including the *Biodiversity Conservation Act 2016* (BC Act), the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the IUCN, Australian Society for Fish Biology Conservation List 2016, and Priority Fauna recognised by the DBCA (see Appendix A). In addition, species were assigned to one of the following categories based on species' distributions:

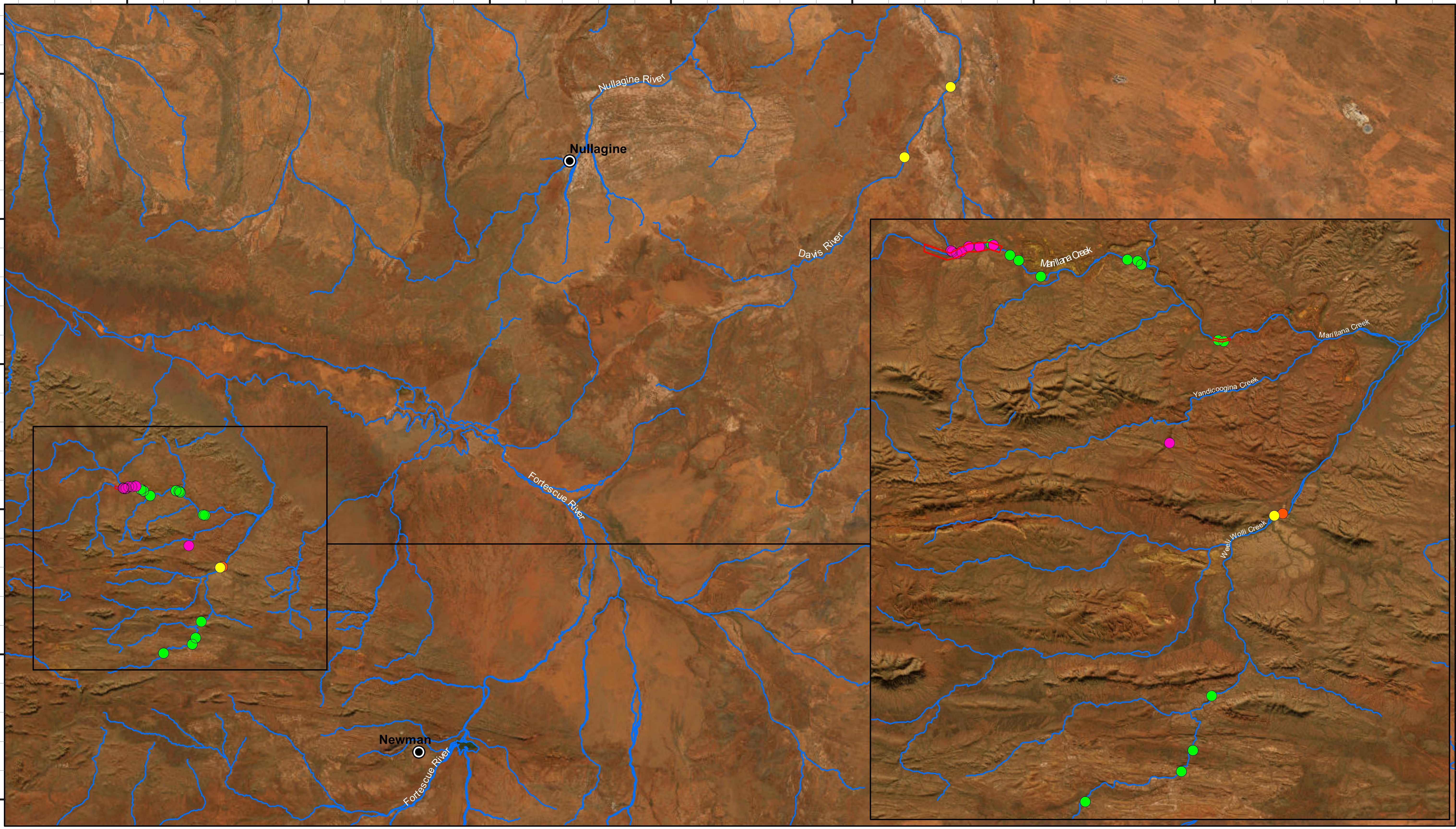
- Cosmopolitan – displays a worldwide distribution;
- Australasian – distributed across Australia, New Guinea and neighbouring islands, including those of Indonesia;
- Australian endemic –found only in Australia;
- Northern Australia – species with distributions across the northern, tropical regions of Australia;
- Northwestern Australia – recorded across northern WA, including the Pilbara and Kimberley regions;
- Western Australian endemic – known only from WA;
- Pilbara endemic - restricted to the Pilbara region;
- Short range endemic (SRE) – occupies an area of less than 10,000 km^2 (Harvey, 2002). Such species have traits which make them vulnerable to disturbance and changes in habitat, and affords them high conservation value; and
- Indeterminate distribution – taxa could not be assigned to one of the above categories, as there is currently insufficient knowledge on either its distribution or taxonomy to assess its level of endemism.

Invertebrate data was compared to the previous MAC Phase 4 aquatic survey data using two-way ANOVA to test for difference in richness (taxa richness for hyporheos fauna, zooplankton, and macroinvertebrates) between sampling events (Dry 2020, Wet 2021, Dry 2021, Wet 2022) and site type (Study Area vs Reference sites). Equality of variances was assessed using the Levene's test. Invertebrate data was also compared in this way to nearby sites sampled during the PBS, using the sites outlined above for macrophytes (Weeli Wolli Spring, Kalgan Pool, and Homestead Creek), and previous aquatic surveys by Biologic and others (see Table 3.2). To undertake this comparison, the dataset was amalgamated, and taxonomy aligned, to ensure any differences in taxonomic knowledge between samplers and years was appropriately accounted for. All univariate analyses were undertaken in SPSS (subscription build 1.0.0.1447).

Macroinvertebrate assemblage data was also analysed using multivariate techniques in PRIMER v7 (Clarke & Gorley, 2015), including cluster analysis and ordination. Ordination was by non-metric Multi-Dimensional Scaling (nMDS), which, unlike other ordination techniques uses rank orders, and therefore can accommodate a variety of different types of data. Ordination was based on the Bray-Curtis similarity matrix (Bray & Curtis, 1957). Differences in assemblages between sampling events and site type were investigated using Two-way Analysis of Similarity (ANOSIM). Multivariate analysis was undertaken on the complete amalgamated dataset which included other surveys from nearby sites (PBS and others listed in Table 3.2). Locations of sites sampled in previous studies which were used in these analyses are shown in Figure 3.5.

Table 3.2: Data used in analysis comparing the Marillana Creek Study Area to nearby sites sampled previously.

Creek/Area	Description	Sampling events	Reference
Marillana	Upper Marillana Creek, upstream of BHP's Yandi (in the vicinity of Flat Rocks and upstream, i.e. previous MAC survey).	Wet 2014 (Flat Rocks) Dry 2014 (Flat Rocks)	(WRM, 2015)
		Wet 2017 Dry 2017	(WRM, 2018)
		Dry 2020 Wet 2021	Biologic (2022b)
Marillana Downstream	Marillana Creek from downstream of the pools in and around Flat Rocks, to just downstream of Rio Tinto's Yandicoogina Oxbow Deposit	Wet 2014 Dry 2014	WRM (2015)
		Wet 2017 Dry 2017	WRM (2018)
Weeli Wolli Spring	The main Priority 1 PEC spring system comprising approximately 2 km of flowing creeklines	Dry 2003 Wet 2005	Pinder *et al.* (2010)
		Dry 2019 Wet 2020	Biologic (2020)
		Dry 2020 Wet 2021	Biologic (2022f)
		This study (reference site)	
Weeli Wolli Creek	Semi-permanent and permanent pools located upstream of Bens Oasis on Weeli Wolli Creek (i.e., Wunna Munna, etc).	Wet 2014 Dry 2014	WRM (2015)
		Wet 2017 Dry 2017	WRM (2018)
Davis River	Permanent flowing spring pools on the Davis River, including Running Waters and Skull Springs	Dry 2019 Wet 2020	Biologic (2020)
		Dry 2020	Biologic (2022f)
		This study (reference site)	



LEGEND

- Study Area
- Major Creeks

Previous Sampling Sites

- Biologic (2020)
- Biologic (2020c)
- Pinder et al. (2010)
- WRM (2015, 2018)

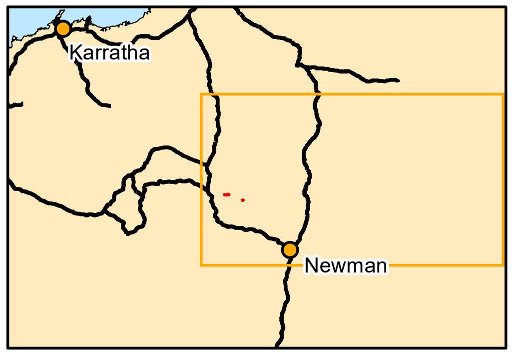
N

biologic
Environmental Survey

Scale: 1:1,000,000

0 20 40 60 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 16/05/2023



BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 3.5: Previous sampling sites used in comparisons with the current study

Using macroinvertebrate data from the Marillana Creek Study Area from MAC Phase 4 surveys only (across all four sampling events to-date), the relationship between macroinvertebrate assemblages and environmental characteristics (water quality and habitat) was assessed in PERMANOVA using a distance-based linear model (DistLM) (Anderson *et al.*, 2008). This model finds linear combinations of the environmental variables that best predict patterns in the biotic data set (Anderson *et al.*, 2008). Prior to analysis, environmental data was examined using draftsman plots to assess whether the distributions of covariables were skewed. Transformations (natural log) were made where appropriate. Percentage data was transformed using arcsin transformations on proportions. Once all appropriate transformations had been undertaken, the environmental data was normalised in PRIMER prior to analysis.

3.6.4 Fish

Length-frequency analysis was undertaken for each fish species recorded, whereby each species was classified into four age classes based on body size (SL mm). Age classes were determined from the literature (Allen *et al.*, 2002; Puckridge & Walker, 1990) (Table 3.3).

Table 3.3: Standard lengths used for each age class for each species recorded.

	Standard Length (mm)		
Age class	**Western rainbowfish**	**Spangled perch**	**Pilbara tandan**
New recruit	≤ 30	≤ 30	≤ 30
Juvenile	31-40	31-50	31-70
Sub-adult	41-50	51-70	71-90
Adult	≥ 51	≥ 71	≥ 91

4 RESULTS

4.1 Habitat Assessment

A summary of the overall habitat assessment is provided in Table 4.1 and all raw data in Appendix C. Riparian vegetation throughout the Study Area comprised an open overstorey of *Eucalyptus camaldulensis*, *Melaleuca argentea* and *M. glomerata* over *Cyperus vaginatus*. Weeds were sporadic throughout the Study Area, but were not present in high diversity, density, or abundance. Impacts of cattle were apparent throughout the Study Area, including grazing of sedges and trampling of banks. No other major disturbances were noted, other than potential drawdown impacts from dewatering. Although the Study Area is located upstream of current mining, and the current study was undertaken to characterise baseline aquatic ecosystem conditions, several sites within the downstream end of the Study Area may be experiencing some impact from drawdown currently. For example, MarC6 (also known as Flat Rocks) has been thought previously to be affected by dewatering from BHP WAIO Yandi operations (WRM, 2018). Overall, riparian vegetation within the Study Area was considered to be in good condition, with several GDV taxa present. However, stands of *M. argentea* showed signs of water stress, particularly at MarC4, MarC5 and MarC6a in the dry season.

While most sites in the Study Area were dominated by transmissive substrates such as pebbles and gravel, bedrock was more dominant at MarC3 and MarC6a (while MarC6 had comparatively low levels of bedrock). Clay was also more dominant at MarC6 (with no clay present at MarC6a). Most sites recorded some sand and silt. At reference sites, bedrock was dominant at MACREF1, MACREF2 and MUNJS, while all other sites generally recorded high contributions of transmissive sediments.

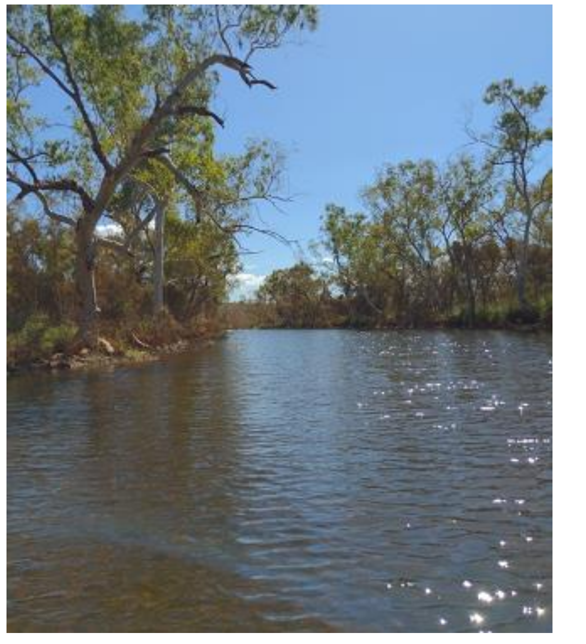
In-stream habitat diversity was high throughout the Study Area, and comprised complex heterogenous substrates with which to support aquatic fauna, such as submerged and emergent macrophytes, LWD, algae and detritus. Cover of submergent macrophytes was particularly high at MarC6 while emergent macrophytes were most prominent at MarC1 in the Wet 22. Macrophyte cover was comparatively higher at Study Area sites in comparison to reference sites, with the exception of MACREF2 in the Dry 21. Some seasonal change was evident, with emergent macrophyte cover generally increasing, and algal cover decreasing at most Study Area and reference sites. MACREF2 and BENS were exceptions, with algae cover increasing between the Dry 21 and Wet 22.

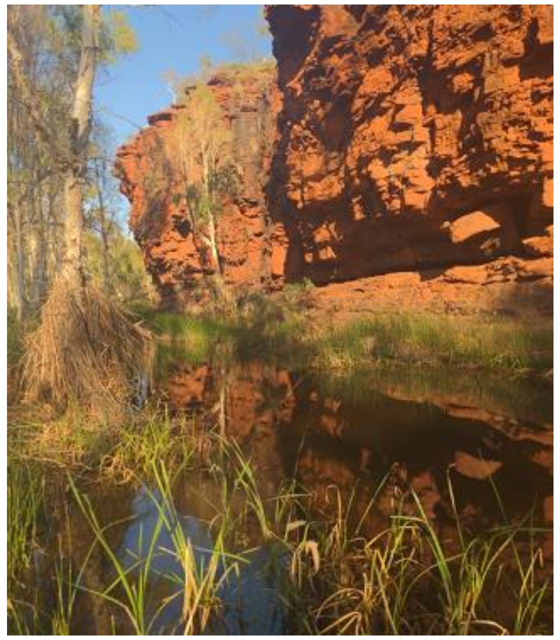
Table 4.1: Summary of aquatic habitats sampled, including site photos.

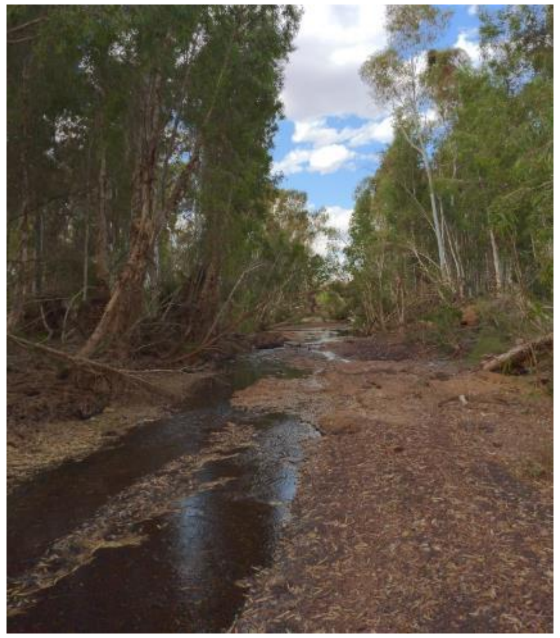
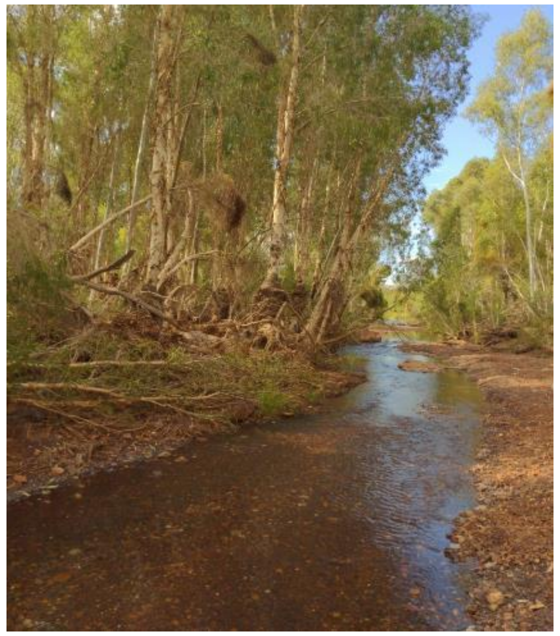
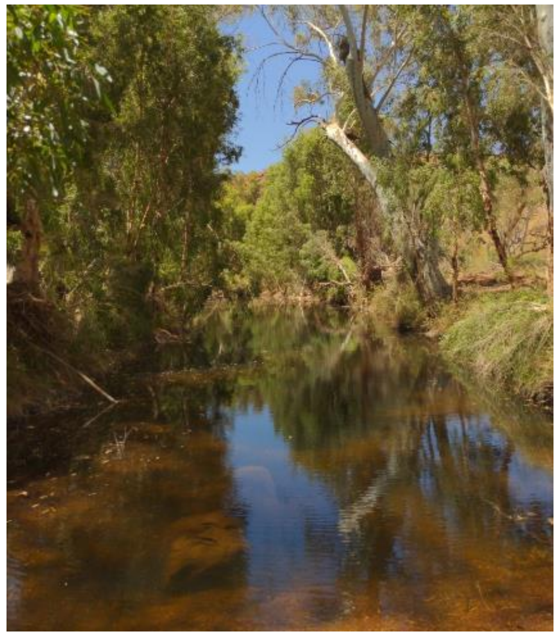
Site	Habitat	Description	Site Photo Dry 2021 Survey	Site Photo Wet 2022 Survey
MarC1 (tributary)	**Semi-permanent pools**	Series of semi-permanent, shallow pools and riffles located on an un-named tributary of Marillana Creek. Pool size: Dry 2021 = dry Wet 2022 = 200 m x 4 m. Maximum water depth: Dry 2021 = dry. Wet 2022 = 0.4 m. Open overstorey of *Melaleuca argentea, M. glomerata, M. bracteata* and *Acacia* spp. In-stream habitat comprising emergent macrophytes (*Cyperus vaginatus, C. ixiocarpus, Schoenoplectus subulatus, Eleocharis geniculata* and *Typha domingensis*), algae, LWD, trailing vegetation, detritus, and root mats, as well as open sediment. Mineral substrate dominated by pebbles and gravel, with small amounts of bedrock, cobbles, sand, and silt.		
MarC2	**Semi-permanent pools**	Series of semi-permanent, shallow pools located on the main channel of Marillana Creek, downstream of the confluence with the un-named tributary. Pool size: Dry 2021 = dry. Wet 2022 = 100 m x 4 m. Maximum water depth: Dry 2021 = dry. Wet 2022 = 0.5 m. Riparian vegetation comprising *Eucalyptus camaldulensis*, *Melaleuca argentea, M. glomerata*, *M. bracteata*, *Acacia ampliceps* and *A. bivenosa*. In-stream habitat comprising submerged charophytes (*Chara* spp.) and emergent macrophyte (*Typha domingensis, Cyperus vaginatus* and *Schoenoplectus subulatus*), detritus, algae, LWD, roots and trailing vegetation. Mineral substrate predominately comprised of pebbles and gravel, with some sand and cobbles also present.		

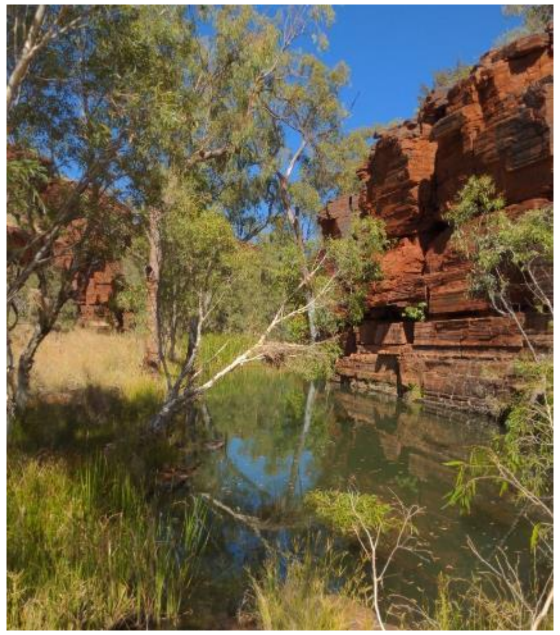
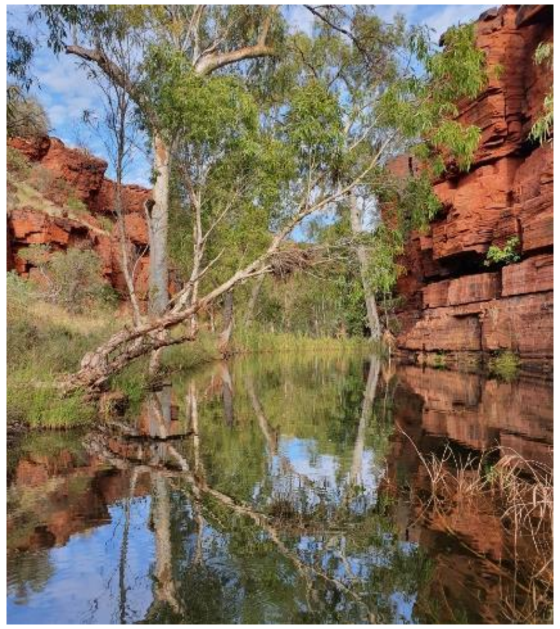
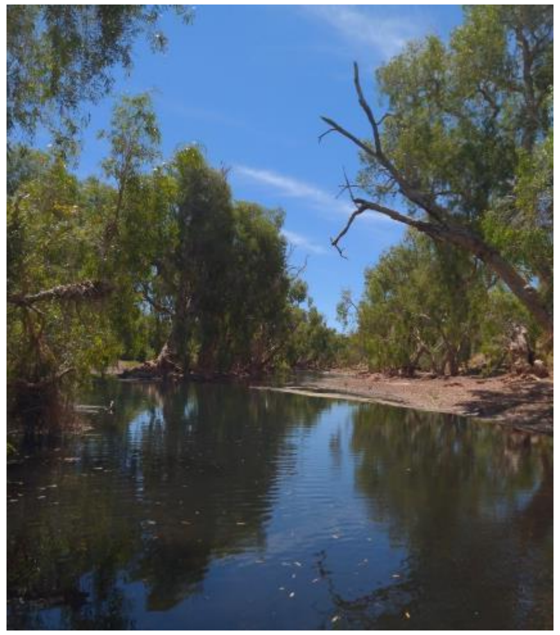
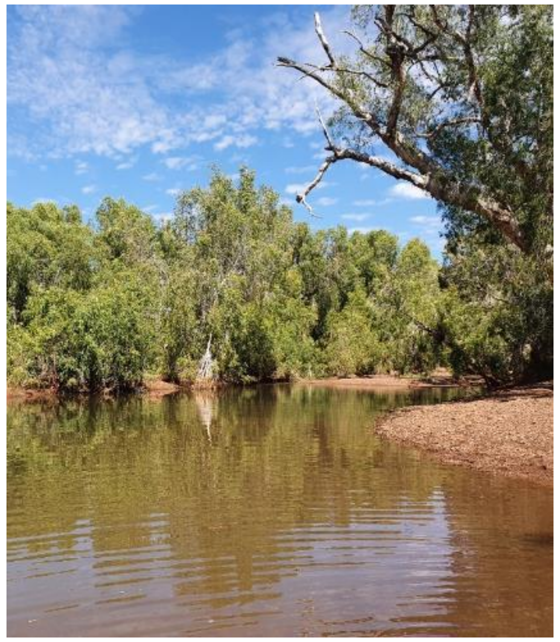
			Site Photo	
Site	**Habitat**	**Description**	**Dry 2021 Survey**	**Wet 2022 Survey**
MarC3	**Ephemeral pools**	Long open pool over bedrock. Pool size: Dry 2021 = main pool was dry at the time of sampling, but a pool approximately 21 m x 9 m located 140 m downstream was present and able to be sampled. Wet 2022 = 220 m x 18 m. Maximum water depth: Dry 2021 = Downstream pool was 0.6 m deep. Wet 2022 = 1 m. *Eucalyptus camaldulensis*, *E. victrix*, *Melaleuca argentea, M. glomerata, M. bracteata* and *Acacia coriacea* subsp. *pendens* and sedges present (*Schoenoplectus subulatus, Typha domingensis, Cyperus vaginatus* and *Eleocharis geniculata)*. High amounts of algae present, as well as some submerged macrophyte (*Vallisneria nana*), LWD, detritus, roots, and trailing vegetation. Substrate dominated by bedrock with some gravel.	Main pool (dry)  Pool 140 m downstream 	

Site	Habitat	Description	Site Photo: Dry 2021 Survey	Site Photo: Wet 2022 Survey
MarC4	**Small semi-permanent pool**	A small semi-permanent pool. Pool size: Dry 2021 = dry. Wet 2022 = 40 m x 13 m. Maximum water depth: Dry 2021 = dry. Wet 2022 = 1.2 m. Riparian vegetation comprising *Eucalyptus camaldulensis*, *Melaleuca argentea, M. bracteata* and *M. glomerata*. In-stream habitat comprising submerged macrophyte (*Potamogeton tepperi* and *Vallisneria nana*) and charophytes (*Chara* spp.), with some algae, detritus, LWD, emergent macrophytes (*Typha domingensis*, *Cyperus vaginatus* and *Schoenoplectus subulatus*) and open sediment. Mineral substrate primarily gravel, with pebbles, clay, and silt. *Melaleuca argentea* trees appeared to be in poor condition in the Wet 2022.		
MarC5	**Semi-permanent pool**	Series of semi-permanent, shallow pools. Pool size: Dry 2021 = dry. Wet 2022 = 180 m x 10 m. Maximum water depth: Dry 2021 = dry. Wet 2022 = 1.5 m. Riparian vegetation comprising *Eucalyptus camaldulensis*, *Melaleuca argentea, M. bracteata* and *Acacia* spp. In-stream habitat predominantly open sediment, with some submerged macrophyte (*Najas tenuifolia*), emergent macrophytes (*Typha domingensis* and *Cyperus vaginatus*), algae, detritus, LWD and roots. Mineral substrate dominated by gravel and pebbles. *Melaleuca argentea* trees appeared to be in poor condition in the Wet 2022.		

			Site Photo	
Site	**Habitat**	**Description**	**Dry 2021 Survey**	**Wet 2022 Survey**
MarC6	**Semi-permanent pool**	Semi-permanent pool colloquially referred to as Flat Rocks (Streamtec, 2004). Likely was permanent historically. Though located upstream of current mining operations, this site is thought to be impacted by drawdown from the nearby BHP WAIO Yandi operations (WRM, 2018). Pool size: Dry 2021 = dry. Wet 2022 = 250 m x 20 m. Maximum water depth: Dry 2021 = dry (MarC6a sampled instead. See below). Wet 2022 = 1.5 m. Riparian vegetation comprising *Eucalyptus camaldulensis*, *Melaleuca argentea, M. glomerata, M. bracteata* and *Acacia coriaceae* subsp. *pendens*. In-stream habitat dominated by open sediment and cover from emergent (*Cyperus vaginatus*, *Schoenoplectus subulatus* and *Typha domingensis*), submerged macrophytes (*Vallisneria* spp., *Potamogeton tepperi, Najas tenuifolia* and *Ruppia* spp.) and charophytes (*Chara* spp.). Small amounts of detritus, LWD roots and algae also present. Substrate comprising clay, gravel, cobbles, sand, and silt.		
MarC6a		Permanent bedrock pool. Pool size: Dry 2021 = 300 m x 15 m. Wet 2022 = not sampled. Maximum water depth: Dry 2021 = 2.0 m. Wet 2022 = not sampled. *Eucalyptus camaldulensis* and *Melaleuca argentea* over sedges (*Typha domingensis*, *Schoenoplectus subulatus* and *Cyperus vaginatus*). *Melaleuca* in poor condition with dead trees present. In-stream habitat comprising submerged macrophyte (*Potomogeton* spp. and *Ruppia* spp.), charophyte (*Chara* spp.) and algae. Predominently bedrock substrate with small amounts of detritus, pebbles and gravel. Cattle and dewatering impacts evident.		Not sampled as the original site, MarC6, held water at this time (see above).

			Site Photo	
Site	**Habitat**	**Description**	**Dry 2021 Survey**	**Wet 2022 Survey**
MACREF1	**Permanent pools**	Series of permanent pools and riffles on a tributary of Yandicoogina Creek. Main pool size: Dry 2021 = 180 m x 10 m. Wet 2022 = 180 m x 11 m. Maximum water depth: Dry 2021 = 0.4 m. Wet 2022 = 1.0 m. *Eucalyptus camaldulensis*, *Melaleuca argentea*, *M. glomerata, M. bracteata* and *Acacia* spp. over sedges (*Typha domingensis*, *Schoenoplectus subulatus* and *Cyperus vaginatus*) and fringing *Lobelia arnhemiaca*. In-stream habitat comprising submerged macrophyte (*Vallisneria nana*) and charophyte (*Chara* spp.), LWD, detritus, roots and trailing vegetation. Predominantly bedrock substrate, with small amounts of gravel, sand and silt. *Typha domingensis* rushes appeared to be in poor condition in the Wet 2022, likely due to recent wet season flooding, with the short-lived high flows knocking plants along the bank down. The highly invasive weed *Bidens bipinnata* was also present.		
MACREF2	**Permanent pools**	Long series of permanent pools and riffles sequences on Marillana Creek, located upstream of the confluence with the un-named tributary. Pool size: Dry 2021 = 300 m x 5 m. Wet 2022 = 150 m x 10 m. Maximum water depth: Dry 2021 = 0.5 m. Wet 2022 = 0.5 m. Riparian vegetation comprising *Eucalyptus camaldulensis*, *E. victrix*, *Melaleuca argentea, M. bracteatea*, and *M. glomerata* as well as several *Acacia* species and shrubs. Complex in-stream habitat comprising submerged macrophyte (*Vallisneria nana* and *Potamogeton tepperi*), emergent macrophytes (*Typha domingensis*, *Cyperus vaginatus, Eleocharis geniculata* and *Schoenoplectus subulatus*), charophytes (*Chara* spp.), algae, root mats, trailing veg, detritus and LWD. Mineral substrate comprising bedrock, pebbles, gravel, sand, silt, and clay.		

Site	Habitat	Description	Site Photo: Dry 2021 Survey	Site Photo: Wet 2022 Survey
WWS	**Spring**	Permanent spring comprising a series of pools and interconnecting riffles. Located within Rio Tinto's HD1 discharge area – surface flows maintained by discharge from spurs currently. WWS is a Priority 1 PEC. Pool size: Dry 2021: 100 m x 12 m Wet 2022: 100 m x 11 m Maximum water depth: Dry 2021: 1.2 m Wet 2022: 1.2 m. Overstorey vegetation comprising *Melaleuca argentea* and *Eucalyptus camaldulensis* over a dense shrub layer. Emergent macrophyte comprising *Cyperus vaginatus, Schoenoplectus subulatus* and *Typha domingensis*. Fringing *Stylidium weeliwolli* (P3) and *Lobelia arnhemiaca* present in the dry season. Algal bloom in the dry. Substrate comprising primarily gravel, pebbles, sand, and cobbles, with the pool infilled with sediment in the Wet 2022.		
BENS	**Spring**	Series of creek pools. Pool size: Dry 2021: 100 m x 10 m Wet 2022: 110 m x 15 m. Maximum water depth: Dry 2021: 1.2 m Wet 2022: 1.6 m. Second occurrence of the WWS PEC, located upstream on Weeli Wolli Creek. Riparian vegetation consisting of *Eucalyptus camaldulensis* and *Melaleuca argentea* woodland over *Acacia coriacea* subsp. *pendens.* shrubland, and sparse sedges (*Cyperus vaginatus* and *Schoenoplectus subulatus*). *Stylidium weeliwolli* (P3) fringing on banks during the dry season, but not the wet season. Submerged macrophyte *Vallisneria annua* present. Detritus and LWD present in-stream. Mineral substrate dominated by transmissive gravel and pebbles, with some sand, silt, bedrock, and boulders. Obvious impacts by cattle, with sedges grazed, and erosion of banks.		

Site	Habitat	Description	Site Photo: Dry 2021 Survey	Site Photo: Wet 2022 Survey
MUNJS	**Permanent creek pools**	A series of long permanent pools, with numerous riffle sections Pool size: Dry 2021: 400 m x 15 m Wet 2022: 400 m x 15 m. Maximum water depth: Dry 2021: 3.4 m Wet 2022: 4.5 m. Riparian vegetation comprising *Eucalyptus camaldulensis* and *Melaleuca argentea* with *Acacia* spp. understory. Emergent macrophyte comprising *Typha domingensis, Cyperus vaginatus*, *C. cunninghamii* subsp. *cunninghamii*, *Machaerina juncea, Eleocharis geniculata* and *Shoenus falcatus*. Submerged charophyte *Chara* spp. and submerged macrophytes *Vallisneria annua* and *Potamogeton tepperi* present in-stream. No fish. No obvious signs of disturbance. *Stylidium fluminense* and *Lobelia arnhemiaca* present throughout in the dry. Mineral substrate almost exclusively bedrock overlain by silt and organics.		
SS	**Spring**	Permanent spring flowing into a series of pools via a braided channel. Pool size: Dry 2021: 200 m x 22 m Wet 2022: 250 m x 22 m Maximum water depth: Dry 2021: 1.2 m Wet 2022: 1.2 m. Riparian vegetation comprising *Melaleuca argentea, Acacia coriacea* subsp. *pendens* and sedges (*Cyperus vaginatus, Schoenoplectus subulatus, Typha domingensis* and *Eleocharis geniculata*). Charophyte *Chara globularis* and submerged macrophyte *Potamogeton tepperi* present with fringing *Lobelia arnhemiaca.* P2 Priority flora (ground creeper *Ipomoea racemigera*) present. Mineral substrate heterogenous, dominated by gravel, pebbles, and sand. Disturbances included cattle impacts and introduced vegetation (such as Mexican poppy *Argemone ochroleuca* subsp. *ochroleuca* and *Cenchrus ciliaris*).		

4.2 Water Quality

All raw water quality data are provided in Appendix D.

4.2.1 In situ

Electrical conductivity (EC) of surface waters within the Study Area were fresh to brackish[5], ranging from 2,517 µS/cm (at MarC6a) to 3,187 µS/cm (at MarC3) in the Dry 2021, and from 1,088 µS/cm (at MarC6) to 2,172 µS/cm (at MarC2) in the Wet 2022 (Figure 4.1). All sites recorded EC in excess of the ANZG (2018) DGV (> 250 µS/cm), and most within the Study Area also exceeded the point of ecological stress (~1,500 µS/cm) (Hart *et al.*, 1991). However, the DGV for EC is known to be conservative and not necessarily applicable to Pilbara waters, which are known to experience wide-ranging EC. All reference sites were fresh (Figure 4.1). Although few Study Area sites held water in both seasons to assess seasonal variation, greater EC was generally recorded in the dry season (Figure 4.1).

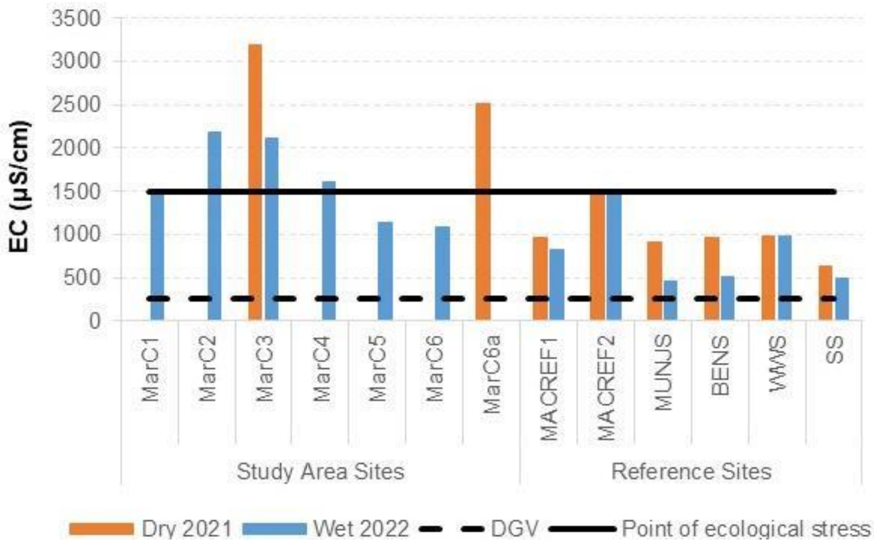


Figure 4.1: Electrical conductivity (EC; µS/cm) recorded from all sites, in comparison to the ANZG (2018) DGV and point of ecological stress.

Dissolved oxygen (DO) concentrations were variable and ranged from 35.2% (at SS) to 147.9% (at MarC3) in the Dry 2021, and 19.2% (at MarC1) to 128.2% (at MarC6) in the Wet 2022 (Figure 4.2). Several sites recorded low DO below the lower DGV, across both Study Area and reference sites, in at least one season (Figure 4.2). Two sites (MarC1 and BENS) recorded values below the point of ecological stress (~30%) (Butler & Burrows, 2007). Two sites recorded DO in excess of the upper ANZG (2018) DGV including MarC3 (147.9%) in the dry season and MarC6 (128.2%) in the wet.

[5] Salinity categories are based on the Department of Water and Regulation (DWER) classification system, where fresh/marginal < 1,000 mg/L (~1,500 µS/cm), brackish = 1,000 mg/L – 2,000 mg/L (~1,500 µS/cm to 3,000 µS/cm), saline = 2,000 mg/L – 10,000 mg/L (~ 3,000 µS/cm – 15,000 µS/cm), and hypersaline > 10,000 mg/L (> 15,000 µS/cm).

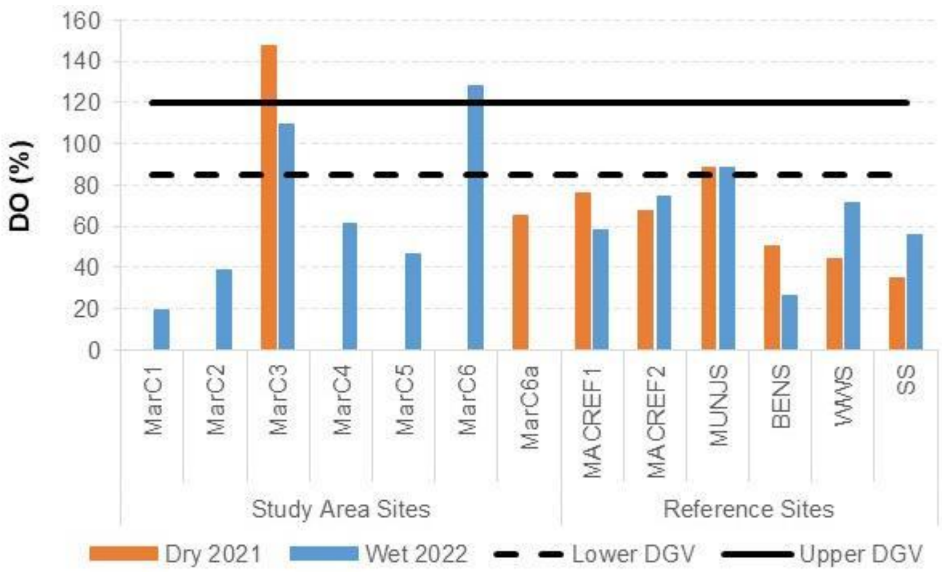


Figure 4.2 Dissolved oxygen (DO; percentage) recorded from all sites, in comparison to the ANZG (2018) upper and lower DGVs.

Surface waters within the Study Area were circum-neutral to basic, with pH ranging from 7.43 (at MarC2 in the wet) to 9.05 (at MarC6a in the dry). Most sites recorded pH within the ANZG (2018) DGVs, with the exception of three sites which exceeded the upper DGV; MarC6 (in both seasons), and reference sites MUNJS (slight exceedance in both seasons), and SS (in the Dry 2021). Despite this, no pH values were considered to be of ecological concern or out of the ordinary for Pilbara waters.

4.2.2 Turbidity

Turbidity was low and within the DGV at all Study Area and reference sites, indicating high water clarity and light penetration at all sites in both seasons. In the Dry 2021, turbidity ranged from 0.5 NTU (at WWS) to 4.6 (at MarC6a and MACREF1). Turbidity varied from values below the limit of detection (<0.1 NTU at WWS) to 5.8 NTU (at SS) in the Wet 2022.

4.2.3 Ionic composition

There was minimal change in ionic dominance of surface waters within the Study Area between site and season. Generally, all sites were dominated by sodium (Na) cations and hydrogen carbonate (HCO_3) anions. The only exceptions to this were MarC1 and MarC6, with the former being dominated by calcium (Ca) cations in the Wet 2021, and the latter being dominated by chloride (Cl) anions (in both seasons). Generally, there was a longitudinal decrease in Na, Ca, HCO_3 and Cl concentrations along Marillana Creek.

Reference sites did experience some seasonal and spatial variation in ionic composition. MACREF1 (Dry 2021), MACREF2 (both seasons), and MUNJS (Dry 2021) were all similar to the Study Area and were dominated by Na and HCO_3. However, in the Wet 2022 MACREF1 was dominated by Na and Cl, while MUNJS was dominated by potassium (K) and HCO_3. WWS (both seasons), SS (both seasons) and BENS (Wet 2022) were dominated by Ca and HCO_3 in both seasons. In the dry, BENS was dominated by magnesium (Mg) and HCO_3.

4.2.4 Alkalinity

Alkalinity measures the capacity of the water to resist sudden changes in pH, i.e., it is the buffering capacity of the water. Alkalinity of less than 20 mg/L is considered low, and the system would have limited ability to buffer against rapid changes in pH. Alkalinity recorded in the current study was generally high, and ranged from 93 mg/L (MUNJS in the Wet 2022) to 670 mg/L (MarC3 in the Dry 2021). Within the Study Area, the lowest alkalinity was recorded from MarC6 in the Wet 2022 (204 mg/L), although this value was still high in comparison to the 20 mg/L threshold. This suggests waters within the Study Area have good buffering capacity.

4.2.5 Nutrients

Nitrogen nutrient concentrations within the Study Area were generally low. Nitrogen ammonia (N_NH_3) concentrations were below the limit of detection (LOD; i.e. < 0.01 mg/L) at all sites in the Dry 2021, and in the Wet 2022 ranged from 0.02 mg/L (at MarC4) to 0.04 mg/L (at MarC1) in the Study Area (Appendix D). At reference sites, the greatest N_NH_3 concentration was 0.07 mg/L, recorded from MACREF2. All concentrations were well below toxicity DGVs for the protection of 99% of species (0.32 mg/L). Similarly, nitrogen nitrate (N_NO_3) concentrations within both the Study Area and reference sites were low. Records were below the LOD at all sites in the dry season and ranged from below LOD to 0.29 mg/L (at SS) in the wet season. All Study Area sites recorded N_NO_3 concentrations either at or below the LOD (i.e., 0.01 mg/L or < 0.01 mg/L), in both seasons.

Nitrogen oxide (N_NOx) concentrations were variable, ranging from below the LOD to 0.29 mg/L (at SS in the Wet 2022; Figure 4.3). No N_NOx concentrations recorded from the Study Area exceeded the eutrophication DGV (0.01 mg/L). Reference sites recorded some exceedances of the eutrophication DGV, with N_NOx concentrations being elevated at MACREF2 (0.22 mg/L), MUNJS (0.02 mg/L), WWS (0.05 mg/L) and SS (0.22 mg/L) in the Dry 2021, and WWS (0.04 mg/L) and SS (0.29 mg/L) in the Wet 2022 (Figure 4.3).

Concentrations of total nitrogen (total N) within Study Area pools ranged from 0.07 mg/L (at MarC1 in the Wet 2022) to 2.43 mg/L (at MarC6a in the Dry 2021; Figure 4.3). Both Study Area sites which held water in the Dry 2021 exceeded the eutrophication DGV for total N, while in the Wet 2022, all Study Area concentrations were below the DGV. The majority of concentrations recorded from reference sites were below the DGV, with two exceptions; MACREF2 in the Dry 2021 (0.49 mg/L) and SS in the Wet 2022 (0.34 mg/L). Only one site within the Study Area (MarC6a in the Dry 2021) recorded total N notably in excess of the DGV. At this site, total N was more than eight times the DGV, and represented the greatest concentration recorded during the current study (Figure 4.3).

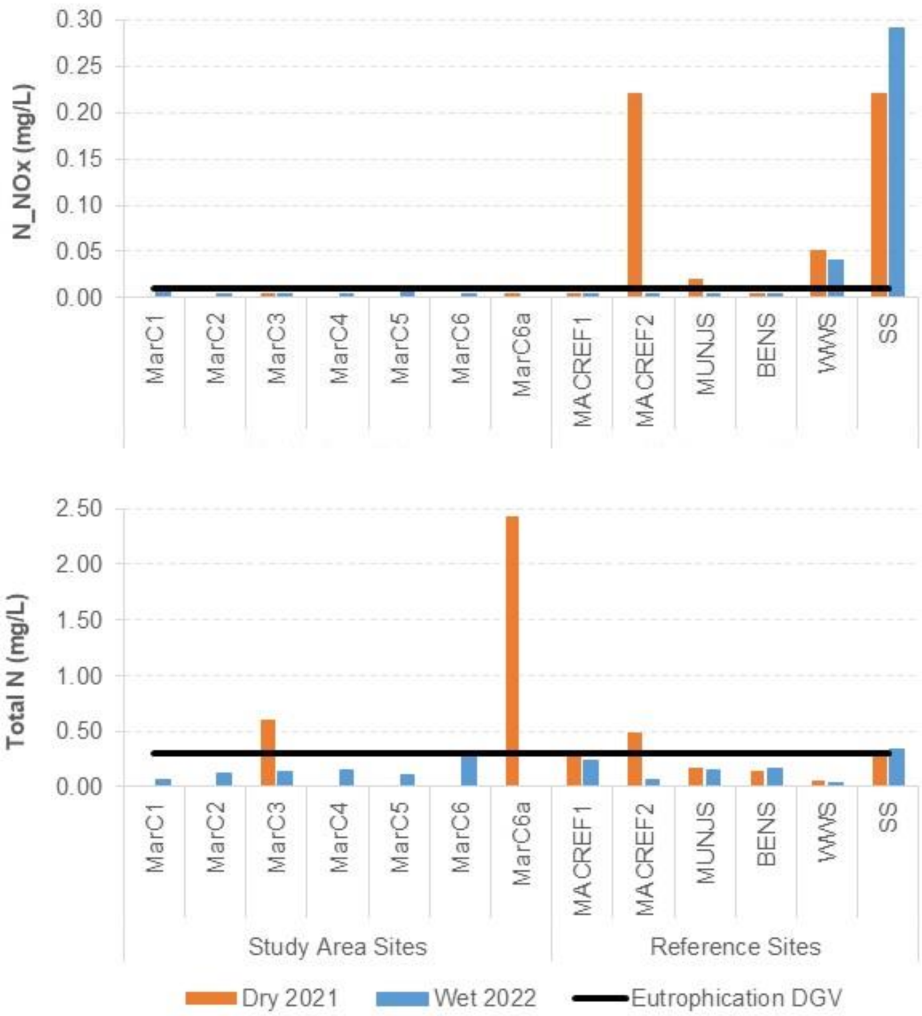


Figure 4.3: Nitrogen oxide (N_NOx; top) and total nitrogen (Total N; bottom) concentrations recorded from each site (mg/L), in comparison to ANZG (2018) eutrophication DGVs. NB: y-axis scales are different for each analyte.

Total phosphorus (total P) was high across all Study Area and reference sites, in comparison to DGVs (Figure 4.4). Within the Study Area, concentrations ranged from 0.04 mg/L (at MarC3) to 0.05 mg/L (at MarC6a) in the Dry 2021, and 0.01 mg/L (at MarC5) to 0.03 mg/L (at MarC1 and MarC2) in the Wet 2022. All sites, including reference sites, recorded elevated TP concentrations in excess of the eutrophication GV, in both seasons. Concentrations were notably high at MarC3, MarC6a, MACREF1 and MACREF2 in the Dry 2021, with total P recorded in concentrations up to five times the DGV. This reduced to around two times the DGV in the Wet 2022, following wet season flushing (Figure 4.4).

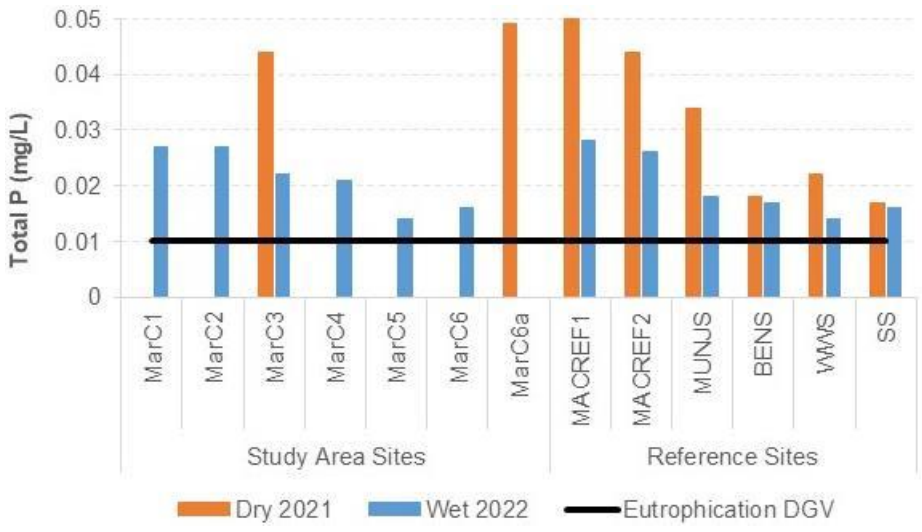


Figure 4.4 Total phosphorus (Total P) concentrations recorded from each site (mg/L), in comparison to the ANZG (2018) eutrophication DGV.

4.2.6 Dissolved metals

Dissolved metal concentrations within the Study Area were generally low, with many analytes recording concentrations below LODs at most, if not all sites in both seasons (i.e., dissolved cadmium, chromium, nickel, lead, and zinc). However, several dissolved metals were recorded in concentrations greater than toxicity DGVs at some sites (Figure 4.5). Elevated dissolved metals recorded from the Study Area included:

- Dissolved arsenic (dAs) concentrations exceeded the 99% toxicity DGV at MarC6a in the Dry 2021, but were still well below the 95% DGV (Figure 4.5).
- Dissolved boron (dB) concentrations exceeded the 95% toxicity DGV at four Study Area sites (MarC6a in the Dry 2021, MarC2 and MarC4 in the Wet 2022, and MarC3 in both seasons), and one reference site (MACREF2, also located on Marillana Creek, in both seasons) (Figure 4.5). All sites recorded dB concentrations in excess of the 99% toxicity DGV, with the exception of BENS (in the wet season) and SS (both seasons) (Figure 4.5).
- Dissolved manganese (dMn) was recorded in excess of the 99% toxicity DGV at SS in the Dry 2021. All other sites recorded low dMn concentrations, well below the 95% and 99% toxicity DGVs (Appendix D).

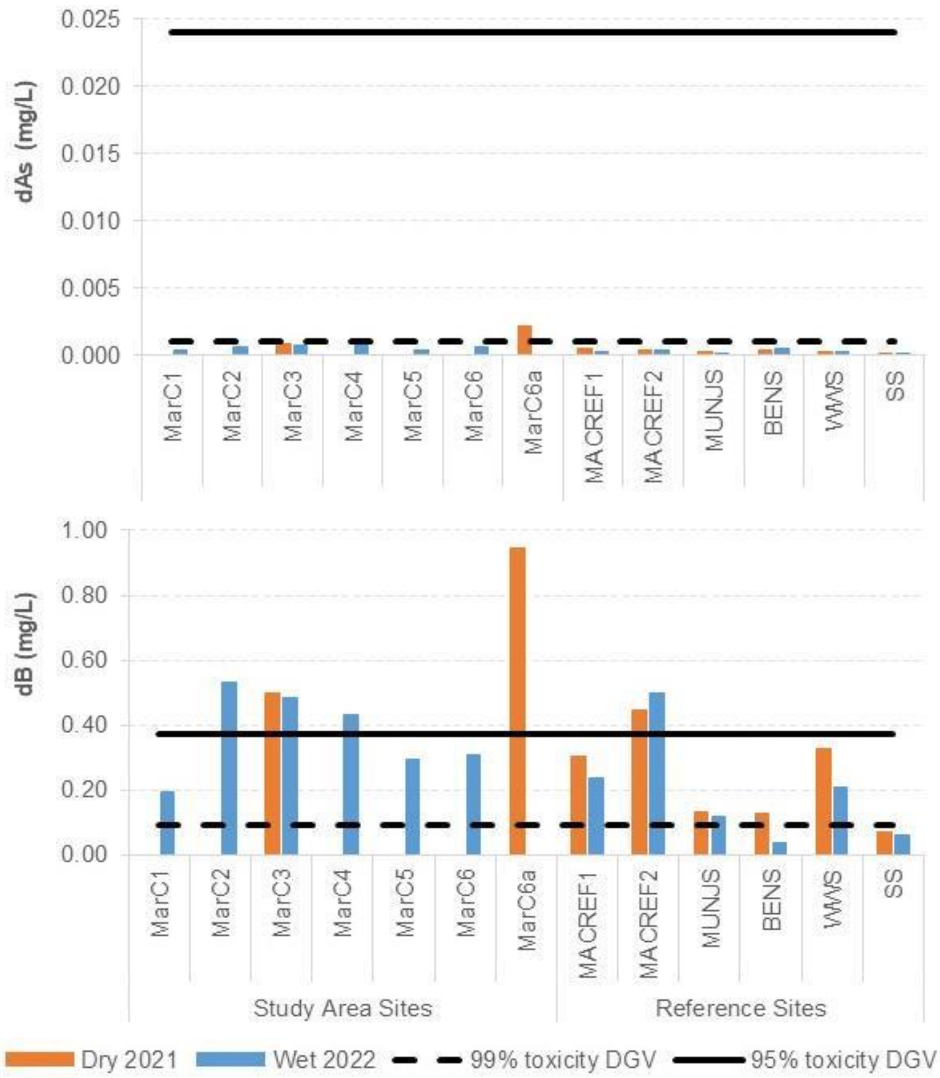


Figure 4.5: Concentrations of dAs (top) and dB (bottom), recorded from each site, in comparison to the ANZG (2018) default toxicity GVs. NB: y-axis scales are different for each analyte.

4.2.7 Water quality comparison with the previous surveys

In situ

Average EC recorded from surface waters within the Study Area has shown some variation over time, particularly in the Dry 2021 when considerably greater EC was recorded (Figure 4.6). At this time, Marillana Creek was largely dry and only two sites were successfully sampled. The greater EC recorded from these sites was likely a reflection of evapoconcentration as the pools receded due to drying. In contrast, EC recorded from reference sites has remained relatively consistent, with no major seasonal or temporal trends apparent (Figure 4.6). Overall, there was a significant difference in EC between sampling events and between site types (Two-way ANOVA; Table 4.2). Results indicated that EC recorded from the Study Area was significantly greater than reference sites (Figure 4.6). While the Tukey's post-hoc test failed to locate the significant difference between sampling events, greater average EC was recorded in the Dry 2021 compared to all other events (Figure 4.6).

pH has remained relatively stable over time, within both the Study Area pools and reference sites (Figure 4.6). The only major variation in average pH was recorded from the Study Area in the Dry 2021, when slightly higher (more basic pH was recorded) (Figure 4.6). Again, this was a reflection of the two remaining pools sampled at the time, which were likely receding at the time and exhibiting water quality changes associated with drying. Overall, there was no significant difference in average pH between sampling events, but there was between site types (Two-way ANOVA; Table 4.2). pH recorded from the Study Area was significantly higher than reference sites (Figure 4.6).

Average DO has shown considerable variation both within and between sampling events (Figure 4.6). Changes appear to be associated with seasonal variation, however, the pattern of change has been different in the Study Area in comparison to reference sites. Within Study Area pools, average DO was greater in the dry season and lower in the wet, while the reverse was true of reference pools (Figure 4.6). Overall, there was no significant difference in DO between sampling events or between site types (Two-way ANOVA; Table 4.2). However, in general, average DO was greater within the Study Area (average = 84.36%) in comparison to reference sites (average DO = 69.21%).

Average turbidity varied over time, and interestingly appeared to be generally greater in the dry season in both the Study Area and at reference sites (Figure 4.6). Although, seasonal variation within reference sites was marginal in comparison to the Study Area. Overall, there was a significant difference in average turbidity between sampling events (Table 4.2), with significantly greatest turbidity recorded in the Dry 2020 and significantly lowest in the Wet 2022 (Figure 4.6). While average turbidity was higher within Study Area pools (average = 3.07 NTU) compared to reference sites (average = 2.40 NTU), this difference was not significant (Two-way ANOVA; Table 4.2). There was also a significant interaction, suggesting that differences in turbidity between site type were not consistent across sampling events.

Table 4.2: Two-way ANOVA results, comparing in situ water quality analytes between sampling events and site type (Study Area vs reference). Significant *p*-values are shown in red.

Analyte	Source	df	F	*p*-value
EC	Sampling event	3	3.83	0.018
	Type	1	60.22	0.000
	Sampling event*type	3	2.10	0.118
	Corrected total	43		
DO	Sampling event	3	1.37	0.269
	Type	1	3.36	0.075
	Sampling event*type	3	2.62	0.066
	Corrected total	43		
pH	Sampling event	3	0.25	0.859
	Type	1	7.38	0.010
	Sampling event*type	3	0.93	0.434
	Corrected total	43		
Turbidity	Sampling event	3	3.77	0.019
	Type	1	4.01	0.053
	Sampling event*type	3	3.47	0.026
	Corrected total	43		

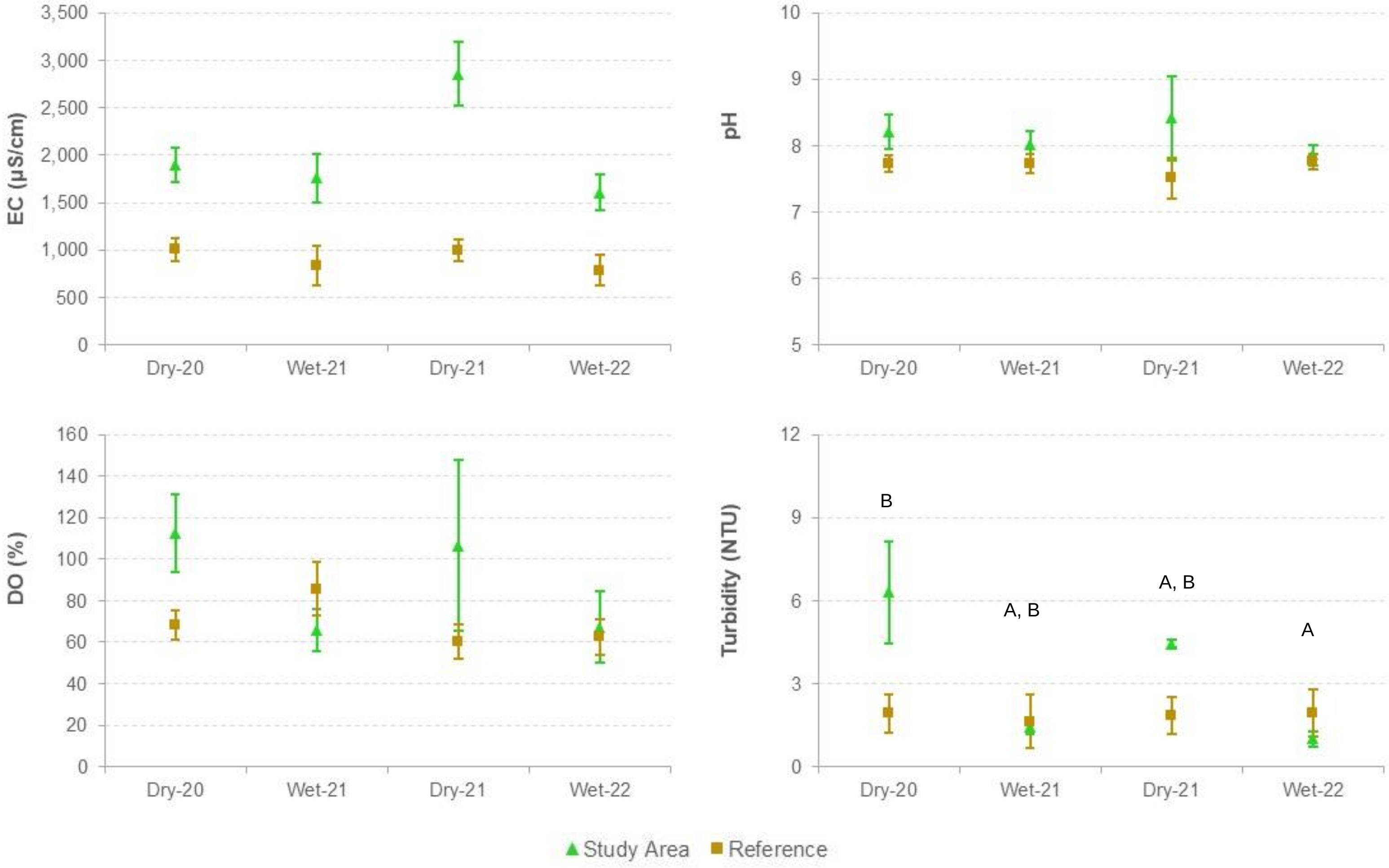


Figure 4.6: Comparison of in situ water quality analytes between sampling events(average ± standard error).

Letters denote equal means from the Tukey's post-hoc test results.

Ionic composition

Variation in the concentration of major ions was evident over time (Figure 4.7). In fact, there was a significant difference in average concentrations between sampling events for Na, Mg, K, HCO_3, Cl, and S_SO_4 (Two-way ANOVA; Table 4.3). In the case of HCO_3, significantly lowest concentrations were recorded in the Wet 2022, and greatest in the Dry 2020 (Figure 4.7). The Tukey's post-hoc test failed to locate the differences for the remaining ions, however, Na and Mg both recorded higher average concentrations in the Dry 2021 (Figure 4.7). Several ions also recorded a significant difference in average concentration between site type, including Na, Mg, K, HCO_3, Cl and S_SO_4 (Table 4.3). All were significantly higher within Study Area pools in comparison to reference sites (Figure 4.7).

Table 4.3: Two-way ANOVA results, comparing selected ion concentrations between sampling events and site type (Study Area vs reference). Significant *p*-values are shown in red.

Analyte	Source	df	F	*p*-value
Na	Sampling event	3	6.36	0.001
	Type	1	68.76	0.000
	Sampling event*type	3	4.07	0.014
	Corrected total	43		
Ca	Sampling event	3	0.81	0.497
	Type	1	2.19	0.147
	Sampling event*type	3	2.25	0.099
	Corrected total	43		
Mg	Sampling event	3	5.49	0.003
	Type	1	59.83	0.000
	Sampling event*type	3	2.56	0.070
	Corrected total	43		
K	Sampling event	3	2.63	0.065
	Type	1	26.19	0.000
	Sampling event*type	3	4.34	0.010
	Corrected total	43		
HCO_3	Sampling event	3	4.24	0.012
	Type	1	8.84	0.005
	Sampling event*type	3	0.27	0.845
	Corrected total	43		
Cl	Sampling event	3	3.12	0.038
	Type	1	74.26	0.000
	Sampling event*type	3	2.39	0.085
	Corrected total	43		
S_SO_4	Sampling event	3	0.60	0.622
	Type	1	38.20	0.000
	Sampling event*type	3	0.54	0.657
	Corrected total	43		

Nutrients

Average concentrations of N_NO_3 within the Study Area have remained stable over time (Figure 4.8). In contrast, concentrations within reference sites have been highly variable, both within and between sampling events (Figure 4.8). Notably high average N_NO_3 concentrations were recorded from reference sites in the Dry 2020. Overall, there was no significant difference in N_NO_3 concentration between sampling events or between site type (Two-way ANOVA; Table 4.4).

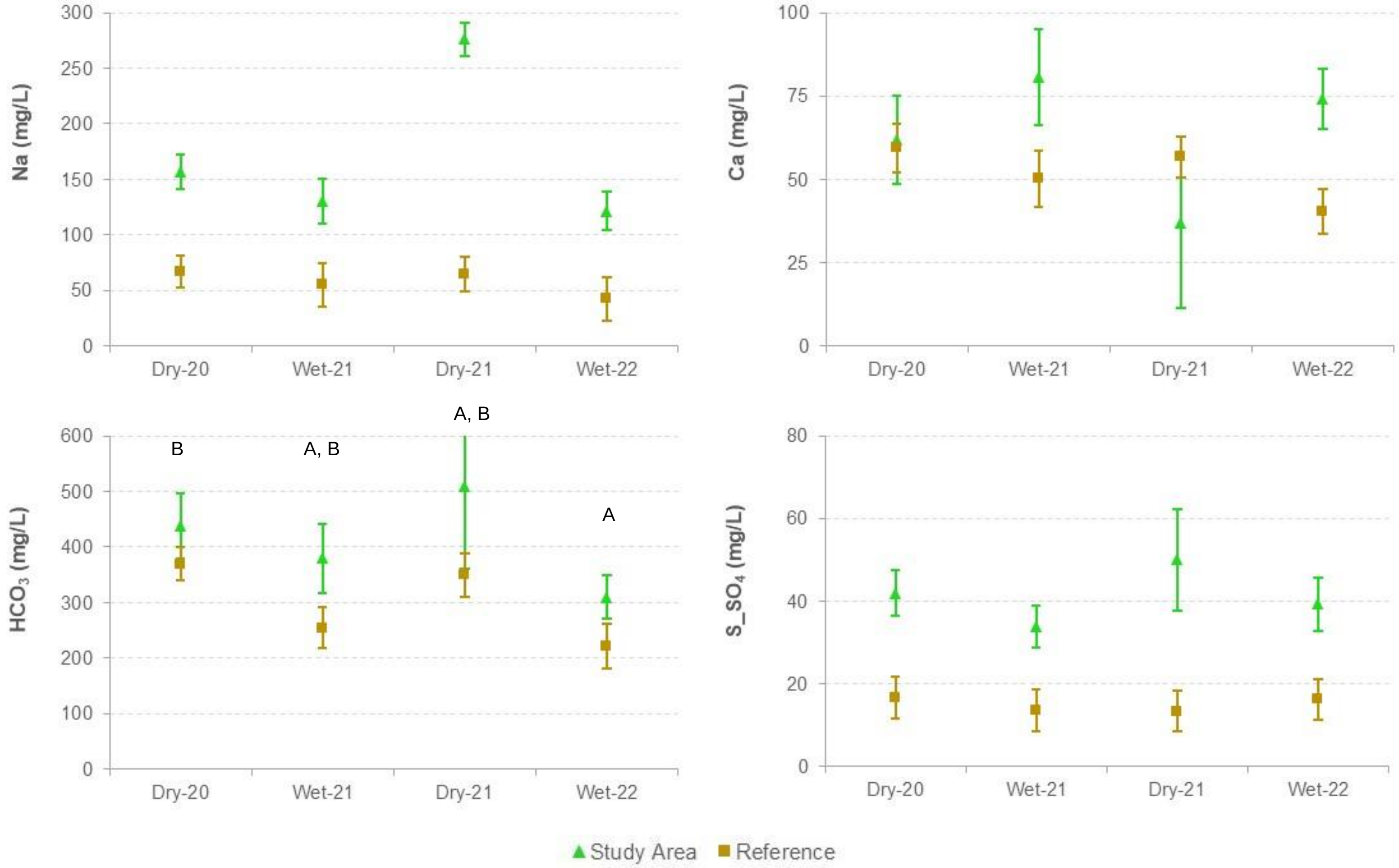


Figure 4.7: Comparison of selected ion concentrations between sampling events(average ± standard error).

Letters denote equal means from the Tukey's post-hoc test results.

Total nitrogen concentrations have varied over time in both the Study Area pools and at reference sites, although the magnitude of change was much greater within the Study Area (Figure 4.8). Similar seasonal patterns were evident between the Study Area and reference sites, with greater total N concentrations recorded in the dry season, and lower concentrations recorded in the wet (Figure 4.8). However, the average concentration recorded in the Dry 2021 from the remaining pools within the Study Area was considerably greater than all other average concentrations recorded. Overall, there was significant difference in average total N concentration between sampling event (Two-way ANOVA; Table 4.4), however, the Tukey's post-hoc test failed to locate the differences. There was also a significant difference in total N between site types, with significantly greater concentrations recorded from the Study Area in comparison to reference sites (Table 4.4, Figure 4.8). This was largely due to the high total N concentration recorded in the Dry 2021. Similar average concentrations were recorded from the Study Area and reference sites in the Wet 2021 and Wet 2022 (Figure 4.8). There was also a significant interaction, suggesting that changes in total N were not consistent between site types across events (Table 4.4).

Table 4.4: Two-way ANOVA results, comparing selected nutrient analytes between sampling events and site type (Survey Area vs reference). Significant *p*-values are shown in red.

Analyte	Source	df	F	*p*-value
Nitrate	Sampling event	3	0.78	0.513
	Type	1	2.49	0.123
	Sampling event*type	3	0.78	0.513
	Corrected total	43		
Total N	Sampling event	3	5.20	0.004
	Type	1	7.01	0.012
	Sampling event*type	3	3.66	0.021
	Corrected total	43		
Log Total P	Sampling event	3	2.25	0.099
	Type	1	3.59	0.066
	Sampling event*type	3	1.27	0.298
	Corrected total	43		

Total P showed some variation over time, and between site types (Figure 4.9). Generally, higher concentrations were recorded in the dry season in comparison to the wet. The average total P recorded from the Study Area in the Dry 2020 was notably higher than all other events. Overall, however, there was no significant difference in total P between sampling events, or between site types (Two-way ANOVA; Table 4.4).

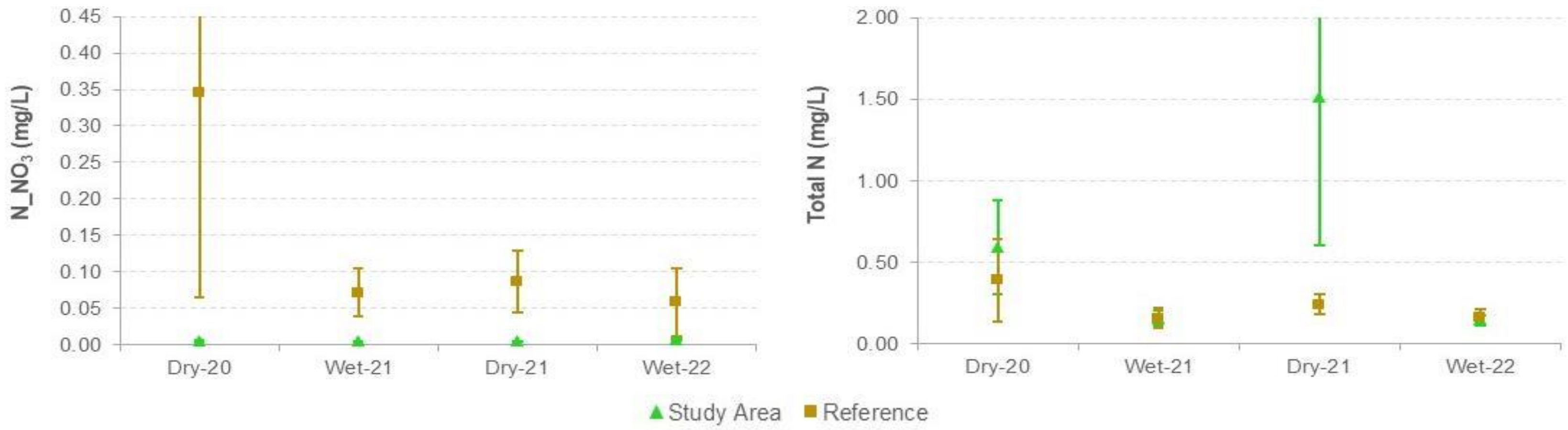


Figure 4.8: Comparison of nitrogen nutrient analytes between sampling events(average ± standard error).

Letters denote equal means from the Tukey's post-hoc test results.

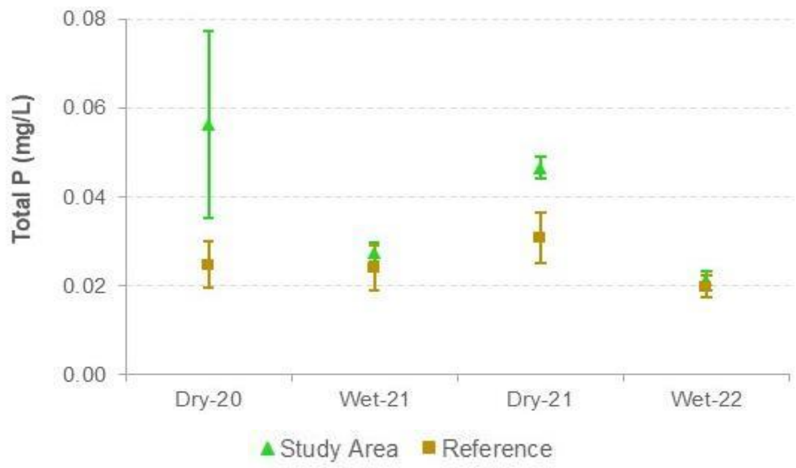


Figure 4.9: Comparison of total P between sampling events(average ± standard error).

Dissolved metals

Dissolved metals showed little variation over time, and there was no significant difference in average concentration between sampling events recorded for any analyte (Table 4.5). However, two dissolved metals, dAs and dB, did show an increase in concentration within the Study Area in the Dry 2021 (Figure 4.10). Several metals were recorded in significantly greater concentration from the Study Area pools in comparison to reference sites, including dAs, dB, dU and dV (Table 4.5, Figure 4.10).

Table 4.5: Two-way ANOVA results, comparing selected dissolved metal analytes between sampling events and site type (Survey Area vs reference). Significant *p*-values are shown in red.

Analyte	Source	df	F	*p*-value
Dissolved aluminium	Sampling event	3	1.45	0.243
	Type	1	1.00	0.323
	Sampling event*type	3	1.75	0.174
	Corrected total	43		
Log dissolved arsenic	Sampling event	3	1.59	0.209
	Type	1	43.36	0.000
	Sampling event*type	3	0.89	0.456
	Corrected total	43		
Dissolved boron	Sampling event	3	2.31	0.093
	Type	1	29.07	0.000
	Sampling event*type	3	1.46	0.242
	Corrected total	43		
Dissolved copper	Sampling event	3	0.52	0.670
	Type	1	3.15	0.084
	Sampling event*type	3	0.37	0.774
	Corrected total	43		
Dissolved iron	Sampling event	3	0.44	0.725
	Type	1	3.49	0.070
	Sampling event*type	3	2.47	0.077
	Corrected total	43		
Dissolved manganese	Sampling event	3	1.04	0.387
	Type	1	0.02	0.875
	Sampling event*type	3	1.03	0.389
	Corrected total	43		
Dissolved selenium	Sampling event	3	1.07	0.375
	Type	1	1.30	0.262
	Sampling event*type	3	1.04	0.385
	Corrected total	43		
Dissolved uranium	Sampling event	3	1.25	0.307
	Type	1	30.19	0.000
	Sampling event*type	3	0.15	0.932
	Corrected total	43		
Dissolved vanadium	Sampling event	3	1.23	0.315
	Type	1	8.32	0.007
	Sampling event*type	3	0.97	0.419
	Corrected total	43		
Dissolved zinc	Sampling event	3	1.714	0.181
	Type	1	0.000	1.000
	Sampling event*type	3	0.000	1.000
	Corrected total	43		

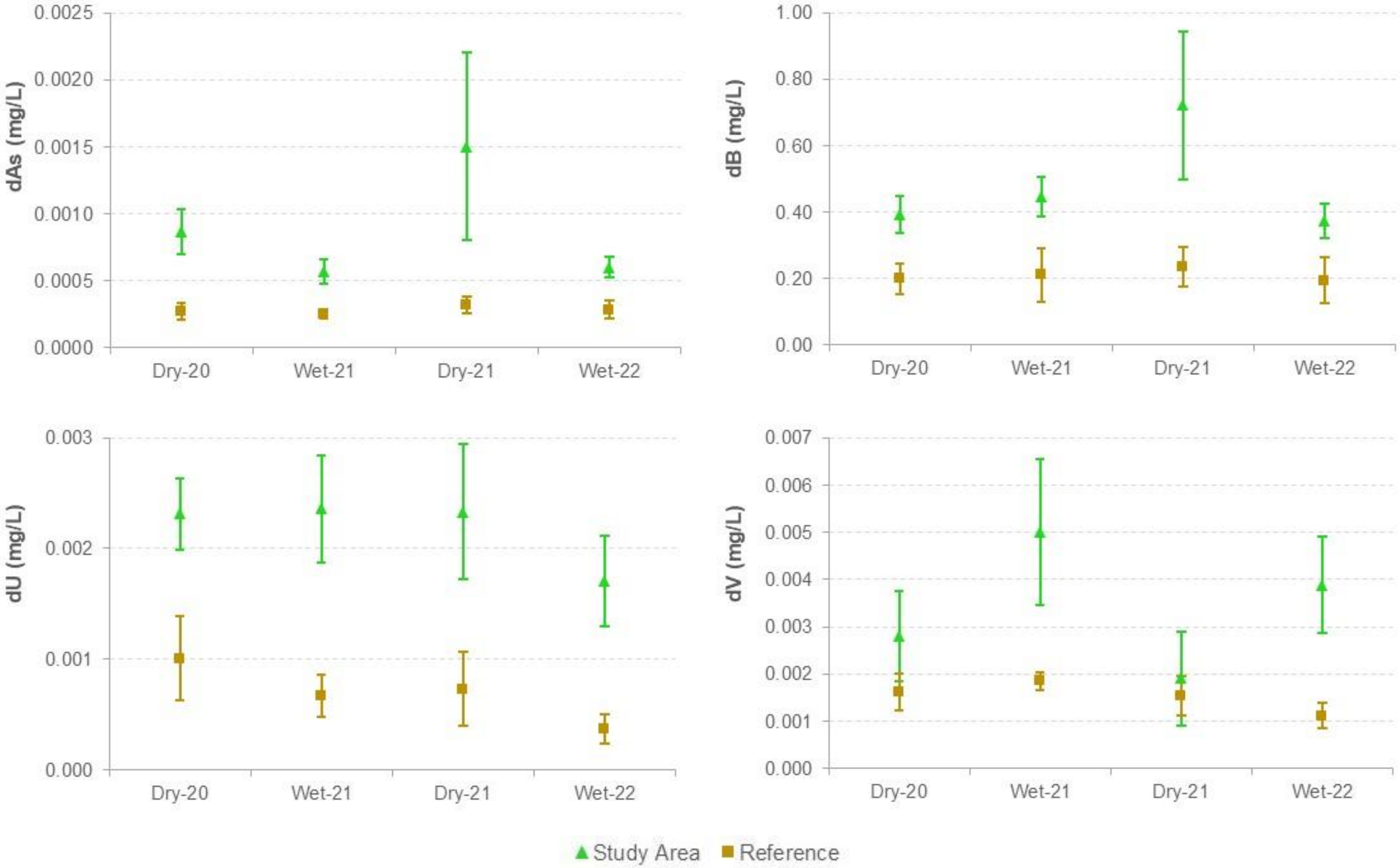


Figure 4.10: Comparison of selected dissolved metal concentrations between sampling events(average ± standard error).

Letters denote equal means from the Tukey's post-hoc test results.

4.3 Macrophytes

4.3.1 Taxa composition and richness

A total of twelve macrophytes were recorded from the Study Area, comprising four emergent macrophytes and eight submerged macrophytes (Table 4.6). An additional three emergent and one submerged macrophyte were recorded from reference sites (Table 4.6). Other riparian vegetation taxa recorded from the Study Area included the GDV species *Melaleuca argentea* and *Eucalyptus camaldulensis* as well as various herbs, shrubs, and grasses associated with creeks (i.e., *Acacia coriacea* var. *pendens, Melaleuca bracteata, Melaleuca glomerata, Pluchea rubelliflora*, *Stemodia grossa*, *Corchorus crozophorifolius*, and *Ammannia baccifera*) (Table 4.6).

Emergent macrophytes recorded from the Study Area included *Cyperus vaginatus, Eleocharis geniculata, Schoenoplectus subulatus,* and *Typha domingensis* (Table 4.6). *Typha domingensis* and *Cyperus vaginatus* were present at all Study Area sites and *Schoenoplectus subulatus* at all but one Study Area site (not present at MarC5), while *Eleocharis geniculata* was recorded from MarC1 and MarC3. The greatest diversity of emergent macrophytes recorded from the Study Area was four taxa, which was recorded from MarC1, MarC3, and MarC6. Three reference sites also recorded four emergent taxa (MACREF1, MACREF2 and SS). The greatest richness of emergent macrophytes within reference sites was six taxa (from MUNJS). Additional taxa recorded from reference sites, but not present within the Study Area, included *Machaerina juncea* and *Schoenus falculatus* (MUNJS), and *Imperata cylindrica* (MUNJS and MACREF1; Table 4.6).

Submerged macrophytes recorded from the Study Area comprised *Chara* sp., *Chara fibrosa*, *Chara globularis*, *Najas* sp., *Vallisneria* sp., *Vallisneria nana*, *Potamogeton tepperi*, and *Ruppia* sp. An additional submerged macrophyte was recorded from reference sites BENS and MUNJS; *Vallisneria annua* (Table 4.6). MarC6 and reference site MUNJS recorded the highest diversity of submerged macropyhte taxa (six taxa).

4.3.2 Conservation significant flora

Two species of conservation significant flora were recorded in the current study, neither of which was recorded from the Study Area. Both annual herb species, *Ipomoea racemigera* and *Stylidium weeliwolli*, are listed as DBCA Priority Species, P2 and P3, respectively. The former was recorded from SS and the latter from WWS and BENS. *Stylidium weeliwolli* is considered to be an indicator of soil moisture or semi-permanent to permanent surface water availability (Rio Tinto, 2020).

Table 4.6: Flora recorded during the current study.

			Study Area						Reference Sites					
Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF1**	**MACREF2**	**WWS**	**BENS**	**SS**	**MUNJS**
CHLOROPHYTA														
CHAROPHYCEAE														
Charales	**Characeae**	*Chara* spp.↓				X		X	X	X				X
		Chara fibrosa	R	X				R	X					X
		Chara globularis				R							X	X
PLANTAE														
MAGNOLIOPSIDA														
Asterales	**Asteraceae**	**Bidens bipinnata*							X					
		Pluchea rubelliflora^^	X		X			X				X	X	
		Pluchea dentex^	X	X		X				X				
		?Rhodanthe margarethae												X
		**Sonchus oleraceus*		X		X		X	X	X				
	Campanulaceae	*Lobelia arnhemiaca*^							X		X		X	X
	Goodeniaceae	*Goodenia lamprosperma*	X											
	Stylidiaceae	*Stylidium fluminense*^												X
		Stylidium weeliwolli^ (P3)									X	X		
Brassicales	**Capparaceae**	*Capparis spinosa* subsp. *nummularia*												X
	Cleomaceae	*Arivela viscosa*								X			X	
Fabales	**Fabaceae**	*Acacia ampliceps*	X	X			X			X				
		Acacia bivenosa							X					
		Acacia coriacea subsp. *pendens*^	X	X	X		X	X	X	X		X	X	X
		Acacia ?hamersleyensis												X
		Acacia pyrifolia var. *pyrifolia*							X					
		Acacia tumida var. *pilbarensis*	X	X			X		X	X				
		Crotalaria medicaginea var. *neglecta*										X		
		Cullen leucanthum											X	
		Glycine canescens										X		
		Petalostylis labicheoides		X						X		X	X	
		Rhynchosia minima										X		
		Senna artemisioides subsp. *filifolia*						X						
		Tephrosia rosea var. Fortescue creeks (M.I.H. Brooker 2186)					X		X					
		**Vachellia farnesiana*		X										
		Vigna lanceolata var. *lanceolata*^							X				X	
		Vigna sp. Hamersley Clay (A.A. Mitchell PRP 113)									X	X		
	Surianaceae	*Stylobasium spathulatum*							X					
Gentianales	**Gentianaceae**	*Schenkia australis*	X											
Lamiales	**Plantaginaceae**	*Stemodia grossa*	X	X	X	X	X	X	X				X	X
		Stemodia viscosa	X	X										
		Stemodia sp.									X	X		
	Scrophulariaceae	*Eremophila longifolia*							X					
Laurales	**Lauraceae**	*Cassytha filiformis*									X			
Malpighiales	**Euphorbiaceae**	*Adriana tomentosa*												
Malpighiales	**Phyllanthaceae**	*Nellica maderaspatensis*										X	X	
Malvales	**Malvaceae**	*Androcalva luteiflora*							X					
		Corchorus crozophorifolius^	X		X		X			X				
		Gossypium robinsonii	X	X					X	X		X		
		Gossypium sturtianum var. *sturtianum*										X		
		**Malvastrum americanum*					X	X						
Myrtales	**Lythraceae**	*Ammannia baccifera*^			X	X		X						
		Ammannia multiflora^											X	
		Ammania sp. indet.												
	Myrtaceae	*Eucalyptus* sp.												

Class/Order	Family	Lowest taxon	Study Area						Reference Sites					
			MarC1	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF1**	**MACREF2**	**WWS**	**BENS**	**SS**	**MUNJS**
		Eucalyptus camaldulensis^	X	X	X	X	X	X	X	X	X	X		X
		Eucalyptus victrix			X					X				
		Melaleuca argentea^	X	X	X	X	X	X	X	X	X	X	X	X
		Melaleuca bracteata^^	X	X	X	X	X	X	X	X				
		Melaleuca glomerata^	X	X	X	X		X	X	X				
Ranunculales	**Papaveraceae**	**Argemone ochroleuca* subsp. *ochroleuca*											X	
Rosales	**Moraceae**	*Ficus brachypoda*							X					X
Sapindales	**Sapindaceae**	*Atalaya hemiglauca*		X			X			X				X
		Dodonaea viscosa subsp. *mucronata*										X		
		Dodonaea pachyneura												X
Solanales	**Convolvulaceae**	*Ipomoea plebeia*										X		
		Ipomoea racemigera (P2)											X	
LILIOPSIDA														
Alismatales	**Hydrocharitaceae**	*Najas tenuifolia*↓				X	X	X						
		Vallisneria sp.↓					R	X	X	X				X
		Vallisneria annua↓										X		X
		Vallisneria nana↓			X	X			X	X				
	Potamogetonaceae	*Potamogeton tepperi*↓				X		X		X			X	X
	Ruppiaceae	*Ruppia* sp.↓						X						
Poales	**Cyperaceae**	*Cyperus cunninghamii* subsp. *cunninghamii*												X
		Cyperus sp.												
		Cyperus ixiocarpus^	X											
		Cyperus vaginatus^	X	X	X	X	X	X	X	X	X	X	X	X
		Eleocharis geniculata^	X		X					X			X	X
		Machaerina juncea^												X
		Schoenoplectus subulatus^	X	X	X	X		X	X	X	X	X	X	
		Schoenus falculatus^												X
	Poaceae	**Cenchrus ciliaris*											X	
		**Cenchrus setiger*				X								
		Chrysopogon fallax							X					
		Cymbopogon ambiguus												X
		**Echinochloa colona*				X								
		Eragrostis tenellula				X		X		X				
		Eriachne mucronata							X					X
		Imperata cylindrica^							X					X
		Sorghum plumosum var. *plumosum*	X					X		X				
		Themeda triandra	X	X					X					
	Typhaceae	*Typha domingensis*^	X	X	X	X	X	X	X	X	X		X	X
		Taxa richness	**23**	**20**	**15**	**19**	**15**	**22**	**30**	**25**	**10**	**19**	**20**	**27**

* Introduced species.

(P2) and (P3) Priority Flora Species.

^ Associated with creeks and/or sub-perennial surface water.

^^ Seasonal wet areas, claypans and rivers.

↓ submerged macrophyte.

R from rehydrates.

4.3.3 Introduced flora

Four introduced plant species were recorded from the Study Area, including:

- common cowthistle (**Sonchus oleraceus*) – recorded from MarC2, MarC4, and MarC6, as well as reference sites MACREF1 and MACREF2.
- mimosa bush (**Vachellia farnesiana*) – recorded from MarC2.
- spiked malvastrum (**Malvastrum americanum*) – MarC5 and MarC6.
- birdwood grass (**Cenchrus setiger*) - MarC4.
- awnless barnyard grass (**Echinochloa colona*) – MarC4 (Table 4.6).

Additional introduced species were recorded from reference sites; bipinnate beggartick (**Bidens bipinnata*; MACREF1), Mexican poppy (**Argemone ochroleuca* subsp. ochroleuca; SS), and buffel grass (**Cenchrus ciliaris*; SS).

None of these species are listed as Weeds of National Significance (WoNS) or Declared Pests under the *Biosecurity and Agriculture Management Act 2007*, and none are 'Priority Alert' weeds designated by Parks and Wildlife. However, **Sonchus oleraceus, *Echinochloa colona, *Argemone ochroleuca* subsp. *ochroleuca*, and **Bidens bipinnata* are all considered to be highly invasive and able to establish and spread rapidly (DBCA, 2013). Additionally, **Echinochloa colona* is considered to greatly impact the ecology of Pilbara ecosystems (DBCA, 2013).

4.3.4 Flora comparison with previous studies

Macrophyte richness recorded from the Study Area was generally high when compared to nearby sites sampled during the PBS, especially at MarC6 and MarC4 (Figure 4.11). Even the lowest richness from the Study Area (MarC2 and MarC5 = four taxa) was higher than the ephemeral PBS site on Homestead Creek (two taxa) (Figure 4.11).

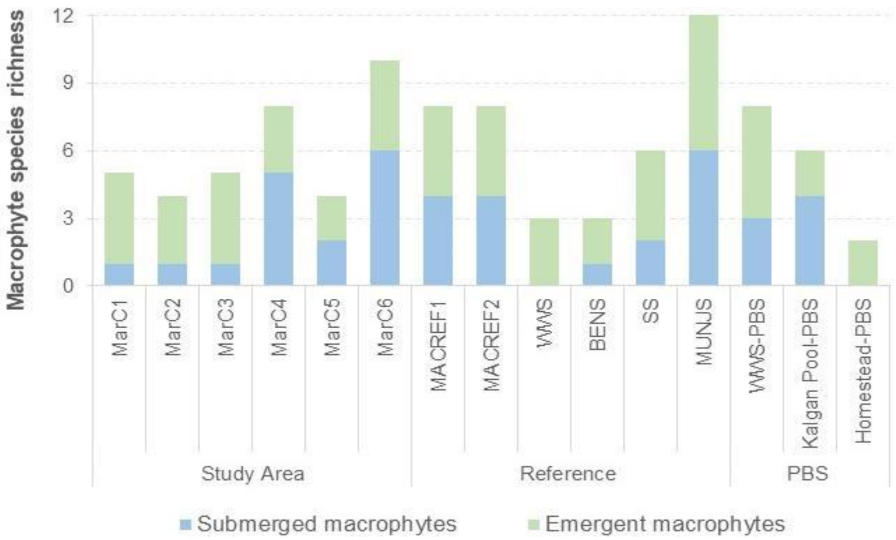


Figure 4.11: Macrophyte (emergent and submerged) richness recorded in the current study (dry and wet seasons combined), in comparison to the PBS from Homestead Creek headwaters (January 2006), Kalgan Pool (September 2004 and April 2005) and Weeli Wolli Spring (September 2003 and May 2005; Mike Lyons, unpub. data).

There was a notable reduction in macrophyte richness at WWS between the PBS and current survey, with no submerged macrophytes being recorded in the Dry 2021 or Wet 2022 (Figure 4.11). However, this area is currently impacted by dewatering and discharge operations from the Hope Downs 1 (HD1) mine, as well as more recently by the introduction of redclaw crayfish, which feed on submerged macrophytes, as well as detritus and zooplankton (DPIRD, 2020; Haubrock *et al.*, 2021; Marufu *et al.*, 2018). It should be noted that site locations at Weeli Wolli Spring also differed slightly between surveys, with the PBS site being located approximately 660 m downstream of the WWS site sampled during the current survey.

4.4 Zooplankton

4.4.1 Taxa composition and richness

A total of 87 zooplankton taxa[6] was recorded from the Study Area, with 35 recorded in the Dry 2021 and 68 in the Wet 2022. The zooplankton taxa list from the Study Area comprised:

- Protista (protists; two taxa),
- Ciliophora (ciliates; two taxa),
- Gastrotricha (hairy backs; one taxon),
- Rotifera (rotifers; 40 taxa),
- Cladocera (water fleas; 12 taxa),
- Maxillopoda (Copepoda; 14 taxa), and
- Ostracoda (seed shrimp; 16 taxa; see Appendix E for full taxa list).

Zooplankton composition was generally dominated by Rotifera and Maxillopoda (Figure 4.12). The diversity of Cladocera and Ostracoda was generally low at all sites, with some sites recording no individuals from these groups in one season. However, across both seasons, ostracods were recorded from all sites at least once. Cladocera were not recorded from reference site BENS in either season (Figure 4.12).

Within-site zooplankton richness was highly variable (Figure 4.12). In the Dry 2021, richness ranged from five (at reference site WWS) to 27 (at reference site (SS). In comparison, Study Area sites yielded 22 zooplankton taxa (at MarC6a) and 23 taxa (at MarC3). During the Wet 2022, richness ranged from nine (at three reference sites; MACREF1, BENS and WWS) to 37 (at Study Area site MarC6) (Figure 4.12). Aside from MUNJS and SS in the Dry 2021, reference sites generally recorded lower zooplankton richness than Study Area sites. WWS, in particular, has consistently recorded low zooplankton richness since the dry season of 2019 (Biologic, 2020, 2022b, 2022f).

Seasonal variation within the Study Area was difficult to assess given only two sites were successfully sampled in the Dry 2021, and one of these was located approximately 500 m downstream of the routine

[6] As not all specimens could be identified to species due to immaturity, damage, unknown or unresolved taxonomy and/or a lack of suitable keys, taxa refers to the lowest level of identification possible (generally genus).

sampling site (MarC6a). While richness at MarC3 was relatively stable between seasons, taxa composition was notably different at this site in the Wet 2022 compared to the Dry 2021 (Figure 4.12). Richness and taxa composition was highly seasonally variable within reference sites (Figure 4.12).

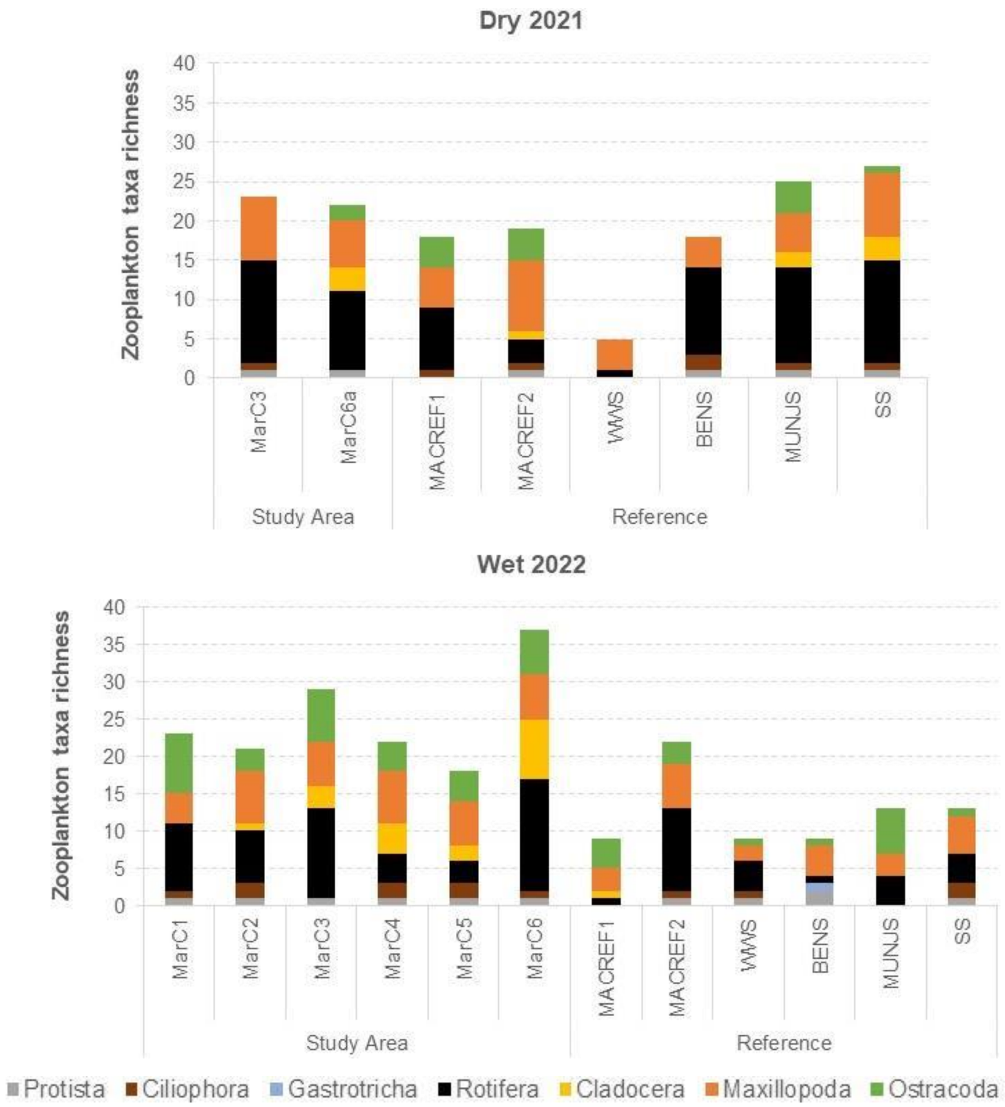


Figure 4.12: Zooplankton taxa richness recorded from each site in the Dry 2021 (top) and Wet 2022 (bottom).

4.4.2 Conservation significant zooplankton taxa

Most zooplankton taxa recorded from the Study Area are widely distributed across northern Australia or the world (cosmopolitan species), and none are listed for conservation significance. However, one ostracod species, *Vestalenula marmonieri*, recorded from MarC6a in the Dry 2021 is a Pilbara endemic. This species is known to occur in surface waters and hyporheic zones across the Pilbara.

Several ostracod specimens collected from MarC1 in the Wet 2022 were morphologically identified as *Bennelongia* sp. These were submitted for molecular analysis and the resulting sequences found to be nested within this genus. The sequences matched a previously known, undescribed OTU; *Bennelongia* \`sp. Biologic-OSTR026\` (Biologic, 2022c). This OTU was more than 15% different to all other *Bennelongia* species in the available genetic database, including *Bennelongia tirigie*. *Bennelongia* \`sp. Biologic-OSTR026\` was previously recorded from this same site (MarC1) in the Wet 2021, but has also been recorded from Gingianna Pool claypan in the Upper Fortescue River catchment, approximately 112 km southeast of the Study Area (Biologic, 2023b). Additional molecular work on ostracod specimens collected from the Pilbara may increase the known distribution of this taxon in the future, but given current records, it would not be considered a Potential SRE.

4.4.3 Zooplankton comparison with previous surveys

Average zooplankton taxa richness within the Study Area has appeared to increase over time, with an average of 15.5 taxa recorded in the Dry 2020, compared with 25 in the Wet 2022 (Figure 4.13). This increase was significant (Linear Regression; R = 0.98, p = 0.023). A similar increase in richness over time was not apparent at reference sites (R = 0.17, p = 0.832). Instead, average zooplankton richness within reference sites underwent a seasonal pattern of change over time, with greater richness recorded in the dry season, and lower in the wet (Figure 4.13).

Overall, there was no significant difference in zooplankton taxa richness between sampling events (Two-way ANOVA; df = 3, p = 0.309), but there was between site type (df = 1, p = 0.003). Average zooplankton taxa richness was significantly greater within the Study Area in comparison to reference sites (Figure 4.13).

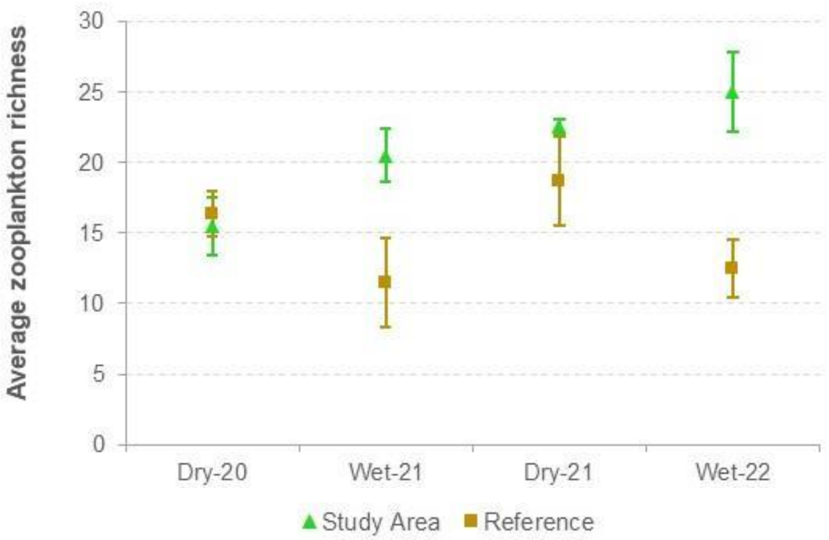


Figure 4.13: Average zooplankton taxa richness (± standard error) in the Study Area and reference sites recorded during each sampling event since the Dry 2020.

4.4.4 Zooplankton comparison with other studies

Zooplankton richness from the Study Area was compared with previous studies detailed in section 3.6.3 above, for those studies which sampled more than one replicate site within a creek system. Weeli Wolli

Creek sites were split into Weeli Wolli Spring (recorded from the historic spring area) and Weeli Wolli Creek (upper Weeli Wolli Creek river pools), to reflect differences in water permanence and hydrology between these two areas; factors which would influence zooplankton assemblages. Reference site BENS could not be included in this analysis due to a lack of replication. As detailed in the methods, the dataset was amalgamated, and taxonomy aligned, prior to analysis to ensure any differences in taxonomic knowledge between samplers and years was accounted for.

Average zooplankton richness from the Study Area was high in comparison to other nearby creeklines and a downstream reach of Marillana Creek (Figure 4.14). This was especially true in the wet season, with the average wet richness being greater than all other creeks and reaches, in either season (Figure 4.14). Variability in richness within the Study Area was generally low in comparison to other areas, with the exception of Yandicoogina Creek (Figure 4.14). Overall, there was no significant difference in average zooplankton taxa richness between season (Two-way ANOVA; df = 1, p = 0.725), but there was a significant difference between creeks (df = 6, *p* = 0.012). The Tukey's post-hoc test failed to locate the difference between creeks, perhaps due to the large variation within some creeks. However, the combined average richness (across seasons) was highest within the Marillana Creek Study Area (average = 18.63), in comparison to all other creeks and reaches included in the analysis. Weeli Wolli Spring recorded the lowest combined average zooplankton richness (average = 10.78), while Munjina Spring recorded the second highest after the Study Area (average = 15.60).

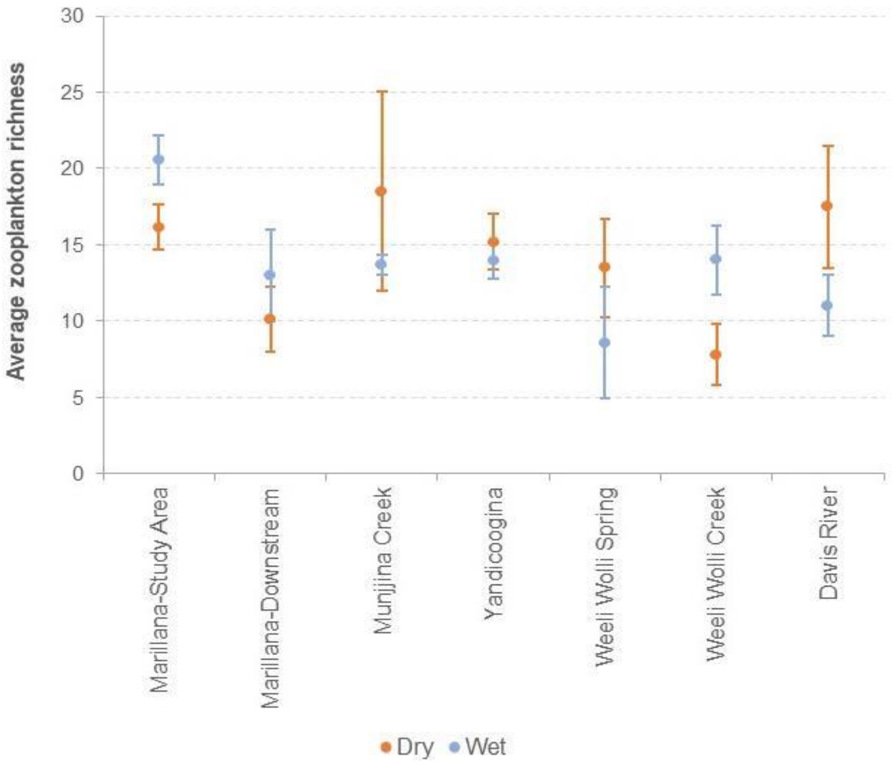


Figure 4.14: Average zooplankton taxa richness (± se) recorded from the Study Area, in comparison to other studies and nearby creeks and reaches, in both seasons.

4.5 Hyporheos Fauna

Despite there being no surface water present at MarC1 and MarC4 in the Dry 2021, sub-surface water was present beneath the creek bed, within the hyporheic zone, and samples were successfully collected. Overall, a total of eight hyporheic samples were collected in the Dry 2021, and 18 in the Wet 2022. Although it had been proposed to sample ten additional locations on Marillana Creek, downstream of the Study Area in the Wet 2022, the high prevalence of clay substrate throughout this reach made sampling difficult. Hyporheic samples were successfully collected from seven sites in this area, with locations surrounding MC6H, MC7H, and MC8H being unconducive to sampling. Of the reference sites, sediments were not appropriate for hyporheic sampling at MACREF1 or MACREF2, although, a sample was successfully collected from MACREF2 in the Wet 2022. This sample was collected beside bedrock and within predominantly clay substrate, but did fill with water.

4.5.1 Taxa composition and richness

A total of 151 invertebrate taxa was recorded from hyporheic zones along Marillana Creek, this included 41 taxa recorded from the Study Area in the Dry 2021, 76 taxa recorded from the Study Area in the Wet 2022, and 106 taxa recorded from the additional hyporheic sites on Marillana Creek, downstream of the Study Area in the Wet 2022 (see Appendix F for full taxa list). The taxa from Marillana Creek included specimens from 20 higher taxonomic orders, including:

- Cnidaria (freshwater polyp; one taxon),
- Platyhelminthes (flatworm; one taxon),
- Nematoda (roundworm; one taxon),
- Mollusca (freshwater snails; two taxa),
- Oligochaeta (aquatic segmented worm; 14 taxa),
- Acarina (water mites; 16 taxa),
- Copepoda (13 taxa),
- Ostracoda (seed shrimp; 10 taxa),
- Amphipoda (side swimmers; five taxa),
- Syncarida (three taxa),
- Collembola (springtails; two taxa),
- Coleoptera (beetles; 26 taxa),
- Diptera (two-winged flies; 38 taxa),
- Ephemeroptera (mayflies; six taxa),
- Hemiptera (aquatic true bugs; one taxon),
- Lepidoptera (moth larva; one taxon),
- Odonata (dragonflies and damselflies; three taxa),
- Thysanoptera (thrips; one taxon),
- Trichoptera (caddisflies; six taxa), and
- Symphyla (pseudocentipede; one taxon).

More than half of the taxa recorded from Marillana Creek hyporheic zones (including the additional locations downstream of the Study Area) were stygoxene (60%) and do not have specialised adaptations for groundwater habitats (Figure 4.15). Troglofauna comprised 1% of the taxa collected, and though terrestrial, were considered of interest and reported here to provide information on troglofauna diversity within the Study Area more generally (see section 4.5.3 below for further information). Hyporheos fauna, comprising stygobites, permanent hyporheos stygophiles, occasional hyporheos stygophiles and possible hyporheic taxa, made up the remaining taxa collected (i.e., 39%). A total of 15% of the taxa recorded from hyporheic zones of the Study Area are directly dependant on groundwater for their persistence (stygobites and permanent hyporheos stygophiles).

Hyporheos fauna recorded from the Study Area included:

Stygobites

- copepods *Pescecyclops* sp., *Elaphoidella* sp., *Parastenocaris* sp., *Parastenocaris* `sp. Biologic-HARP022`[7], and *Parastenocaris* `sp. Biologic-HARP037`;
- ostracods *Meridiescandona* `sp. Biologic-OSTR074`, *Gomphodella* sp., and *Vestalenula marmonieri*;
- amphipods Paramelitidae sp., Paramelitidae `sp. Biologic-AMPH024`; Paramelitidae `sp. Biologic-AMPH070`, *Chydaekata* sp. E and *Chydaekata* sp. MJ1-UM1; and,
- syncarids Bathynellidae sp., *Atopobathynella* `sp. Biologic-PBAT042` and *Atopobathynella* `sp. Biologic-PBAT044`.

Permanent stygophiles

- water mites *Guineaxonopsis* sp., *Guineaxonopsis* `sp. Biologic-ACAR011`, *Guineaxonopsis* `sp. Biologic-ACAR013`, *Rutacarus* sp., *Rutacarus* `sp. Biologic-ACAR006`, and *Hesperomomonia* sp.

Occasional hyporheos stygophiles

- oligochaetes *Allonais inaequalis*, *Allonais paraguayensis*, *Dero furcata*, *Nais variabilis*, *Pristina aequiseta*, *Pristina jenkinae* and *Pristina longiseta*;
- copepods *Microcyclops varicans* and *Paracyclops cf. fimbriatus*;
- ostracod *Candonopsis* cf. *tenuis*; and,
- beetles *Austrolimnius* sp., *Austrolimnius* sp. (L), *Hydraena* sp., Hydraenidae sp. (L), *Limnebius* sp., *Ochthebius* sp. and Scirtidae sp. (L).

Possible hyporheic taxa recorded included higher-level identifications for which taxa may have belonged to a stygal or hyporheos species, as well as OTU Harpacticoida `sp. Biologic-HARP038` and

[7] This identification was made following morphological and molecular analysis, and given it matched an already known OTU with a linear distribution of over 300 km it has not been discussed further here or in section 4.5.2. It does appear to have a disjunct distribution based on current records.

the Chironomidae (non-biting midge larvae) ?*Australopelopia* sp. The latter is an undescribed species commonly found in hyporheic zones in the Pilbara, and has a reduced eye typical of fauna that are adapted to interstitial environments. The Harpacticoida was morphologically distinct to known harpacticoids from groundwaters (Giulia Perina, Biologic, pers. comm). It was submitted for molecular sequencing and did not match any OTUs or described species within the database. It was therefore assigned a unique OTU (Harpacticoida `sp. Biologic-HARP038`) (Biologic, 2022c). This OTU was recorded from the hyporheic zone of MC1H.

Richness of hyporheos fauna varied between sites and seasons (Figure 4.15). The greatest richness of hyporheos fauna was recorded from MarC2 and MC9H in the Wet 2022 (both with 15 taxa), followed by MarC6a in the Dry 2021 and reference site SS (Wet 2022), each with 13 taxa (Figure 4.15). Almost all Study Area and additional Marillana Creek sites recorded stygobites in at least one season, except MarC6a. This site comprised predominately bedrock substrate, with the accessible banks being primarily clay and therefore not conducive to hyporheos fauna. Overall, the greatest number of groundwater dependent taxa (stygobites and permanent hyporheos stygophiles) was recorded from Study Area site MarC2 in the Wet 2022 (five taxa), followed by additional Marillana Creek sites MC4H and MC10H (Wet 2022), and reference sites WWS (Dry 2021) and SS (Wet 2022), all with four groundwater dependent taxa.

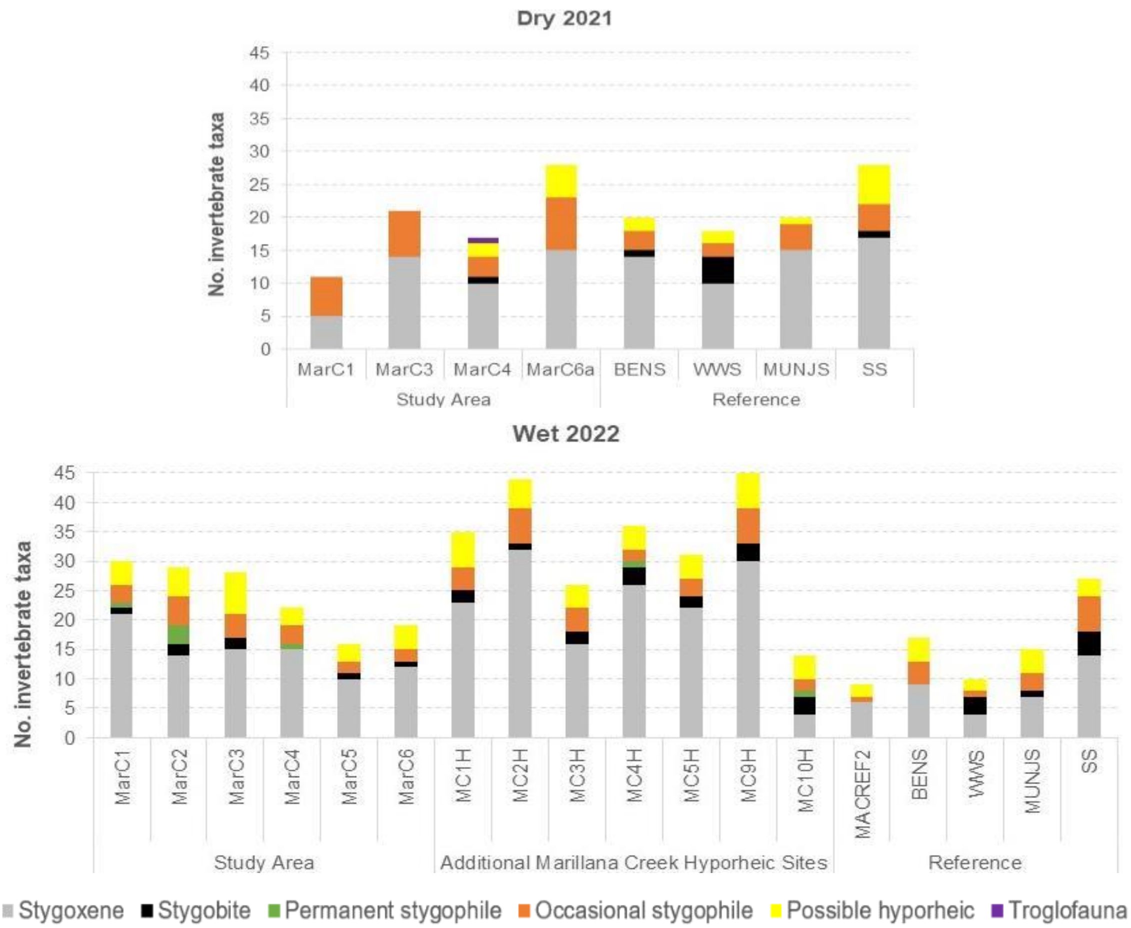


Figure 4.15: Hyporheic taxa richness recorded from each site.

4.5.2 Conservation significant hyporheos taxa

While most of the taxa recorded within hyporheic zones of the Study Area and additional Marillana Creek sites are generally common and ubiquitous across the Pilbara, a number are of interest (15 taxa) due to being are either locally restricted, rarely collected and/or representing potentially new species. Further information regarding these taxa is provided below.

Acari

Permanent hyporheos stygophile water mites of the genus *Guineaxonopsis* were recorded from the hyporheic zone of the Study Area. The *Guineaxonopsis* genus is not commonly recorded and is poorly understood, with only one species currently described from Tasmania. Two previous morphotypes are known from the Pilbara; *Guineaxonopsis* sp. S1 and *Guineaxonopsis* sp. P1. The former was recorded from Cangan Pool within the Yule catchment (approximately 136 km from the Survey Area) during the PBS (Pinder *et al.*, 2010) and several bores during the Pilbara Stygofauna Survey (PSS), including bores from the Robe and Fortescue River basins, Port Hedland coast and Great Sandy Desert. *Guineaxonopsis* sp. P1 was recorded from Minigarra Creek pools at Woodie Woodie (approximately 258 km from the Survey Area) during the PBS, but was not recorded during the PSS. It is not known whether the *Guineaxonopsis* from Marillana Creek match either of these Pilbara morphotypes as specimens were not available for morphological comparison and there is no accompanying genetic sequence information. However, given the large distance between the Study Area and these records, it seems unlikely.

Specimens from the current study were submitted for molecular analysis to provide further information on species' identities and distributions, and two distinct OTUs were recorded (Biologic, 2022c). One of these matched a previously known OTU, *Guineaxonopsis* `sp. Biologic-ACAR011`, which is currently known from Western Creek, the Fortescue River, and Weeli Wolli Spring, all within the Upper Fortescue River catchment (Biologic, 2022c, 2022i, 2022j). In the current study, *Guineaxonopsis* `sp. Biologic-ACAR011` was recorded from MarC2. Based on current information, this taxon has a linear range of 115 km (Figure 4.16). Other specimens from MarC2 and MarC4 formed a distinct OTU, but did not match any previously known species or OTUs, and therefore was assigned a unique code; *Guineaxonopsis* `sp. Biologic-ACAR013` (Biologic, 2022c). This OTU was more than 9% divergent from *Guineaxonopsis* `sp. Biologic-ACAR011`, its closest relative in the analysis (Biologic, 2022c). While its current distribution indicates a linear range of 1.1 km (Figure 4.16), it is likely that additional morphological and molecular work on Pilbara *Guineaxonopsis* will find it to be more widespread. Unfortunately, the remaining specimens from MarC1 failed to record an appropriate sequence (represented contamination) and therefore it is not known whether these specimens represent one of the aforementioned OTUs or a different taxon.

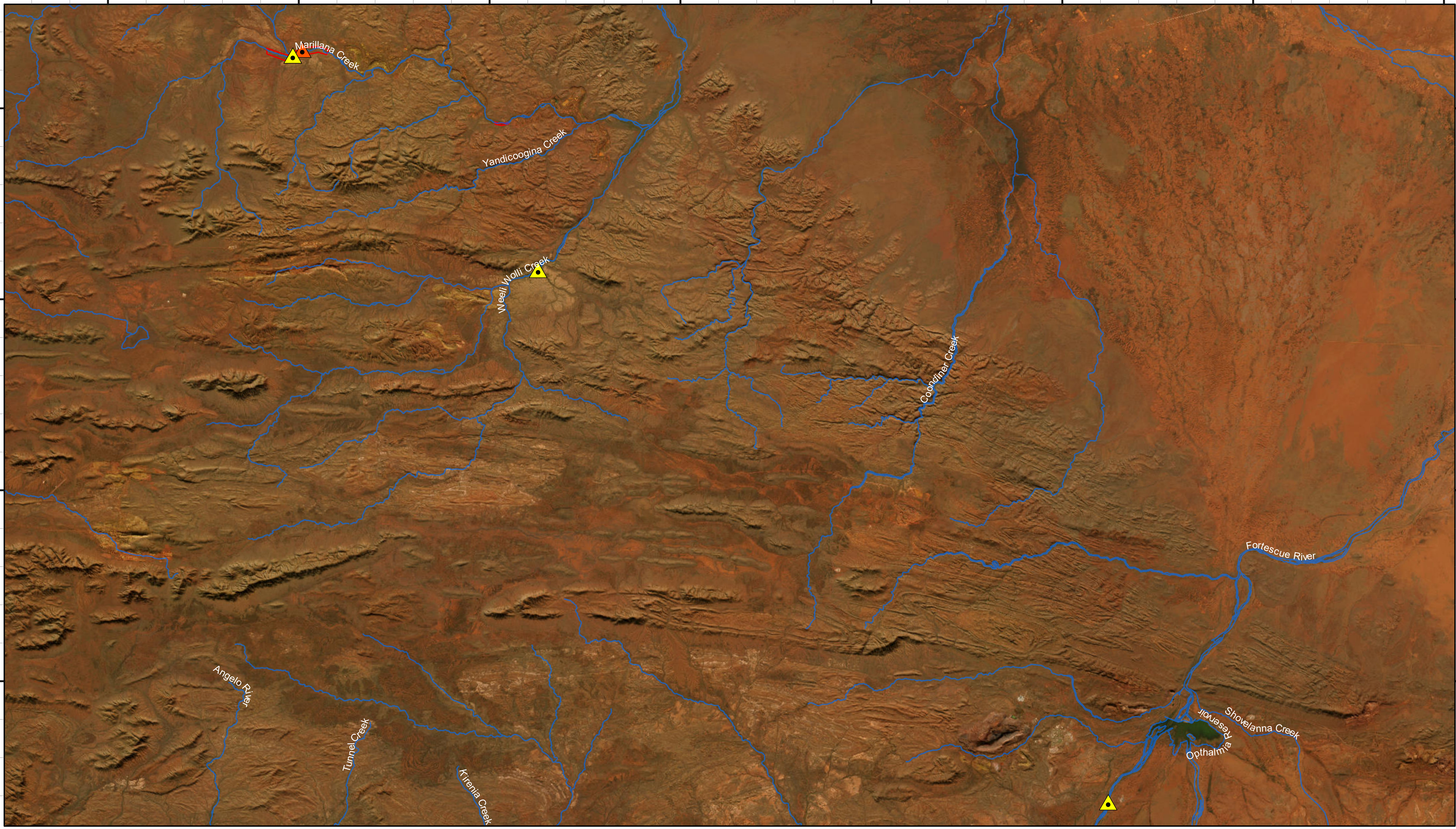
Water mites morphologically identified as belonging to the *Rutacarus* genus were also submitted for molecular analysis. Some specimens failed to deliver an appropriate sequence (i.e., contamination, and therefore identification remains at *Rutacarus* sp.) while others fell into a previously known OTU; *Rutacarus* `sp. Biologic-ACAR006` (Biologic, 2022c). This taxon is previously known from the nearby

Weeli Wolli Creek (Biologic, 2022i), and during the current study was recorded from the hyporheic zone of MC4H on Marillana Creek (Figure 4.17). The *Rutacarus* genus is poorly known within Western Australia, with only two described species from river interstices in eastern Australia. *Rutacarus* sp. was previously recorded during the PBS from a single sampling occasion at Bamboo Spring, approximately 98 km northeast of the Study Area. Two other *Rutacarus* taxa have recently been delineated through molecular analysis, *Rutacarus* \`sp. Biologic-ACAR005\` (Biologic, 2022i) and *Rutacarus* \`sp. Biologic-ACAR007\` (Biologic, unpub. data) The former is currently known from Weeli Wolli Creek (Biologic, 2022i), while the latter was recorded from the Study Area previously (Wet 2021) and is also known from reference site BENS, on Weeli Wolli Creek (Biologic, unpub. data) (Figure 4.17). *Rutacarus* \`sp. Biologic-ACAR006\` recorded during the current study was more than 20% divergent from *Rutacarus* \`sp. Biologic-ACAR007\` recorded from Marillana Creek previously.

Hesperomomonia humphreysi is a hyporheic mite species known to be restricted to the Fortescue River. Few records of the species exist, but it was first recorded in 1997 via Bou-Rouch pump from a pool beneath the Fortescue Road Bridge on the lower Fortescue River (Harvey, 1998). Since then, it has been recorded from the hyporheos of Weeli Wolli Spring via Bou-Rouch pump (ALA, 2022), as well as its surface waters (Biologic, 2023a; WRM, 2013) (Figure 4.18). During the current study, specimens belonging to the *Hesperomomonia* genus were recorded from the hyporheos of MC10H on Marillana Creek (Figure 4.18). While the current specimens were submitted for molecular analysis, no sequence data exists for *Hesperomomonia humphreysi*. The OTU *Hesperomomonia* \`sp. Biologic-ACAR014\` was therefore assigned (Biologic, 2022c). The description for *H. humphreysi* was based on specimens collected from the Lower Fortescue River, some 350 km from the other, more recent records. It is possible that the records from Weeli Wolli Creek and Marillana Creek represent a different species to *H. humphreysi*, but it is likely the records in close proximity (Weeli Wolli Creek and Marillana Creek) all represent the same taxon.

<u>Ostracoda</u>

Stygal ostracods of the genus *Meridiescandona* were collected in the current study and submitted for molecular analysis. The specimens matched a known OTU within the genetic database; *Meridiescandona* \`sp. Biologic-OSTR074\`, previously known from Yandicoogina Creek (Biologic, 2022h) (Figure 4.19). During the current study, this taxon was recorded from the hyporheic zone of MC4H and MC10H. It is considered likely that this OTU represents the described species *Meridiescandona marillanae* given its distribution (Figure 4.19), however, further morphological and molecular work is required to confirm this.



Legend

Study Area

Major Creeks

Species

Guineaxonopsis `sp. Biologic-ACAR011`

Guineaxonopsis `sp. Biologic-ACAR013`

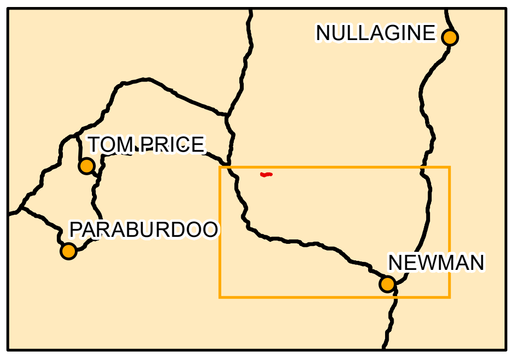
N

biologic Environmental Survey

Scale: 1:380,000

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 16/05/2023



BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 4.16: Records of *Guineaxonopsis* water mites

Legend

Study Area

Major Creeks

Species

Rutacarus `sp. Biologic-ACAR006`

Rutacarus `sp. Biologic-ACAR007`

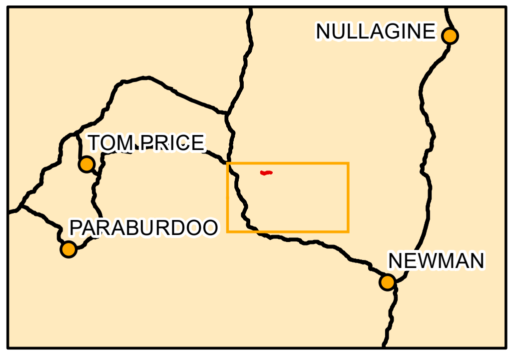
N

biologic Environmental Survey

Scale: 1:200,000

0 10 Km

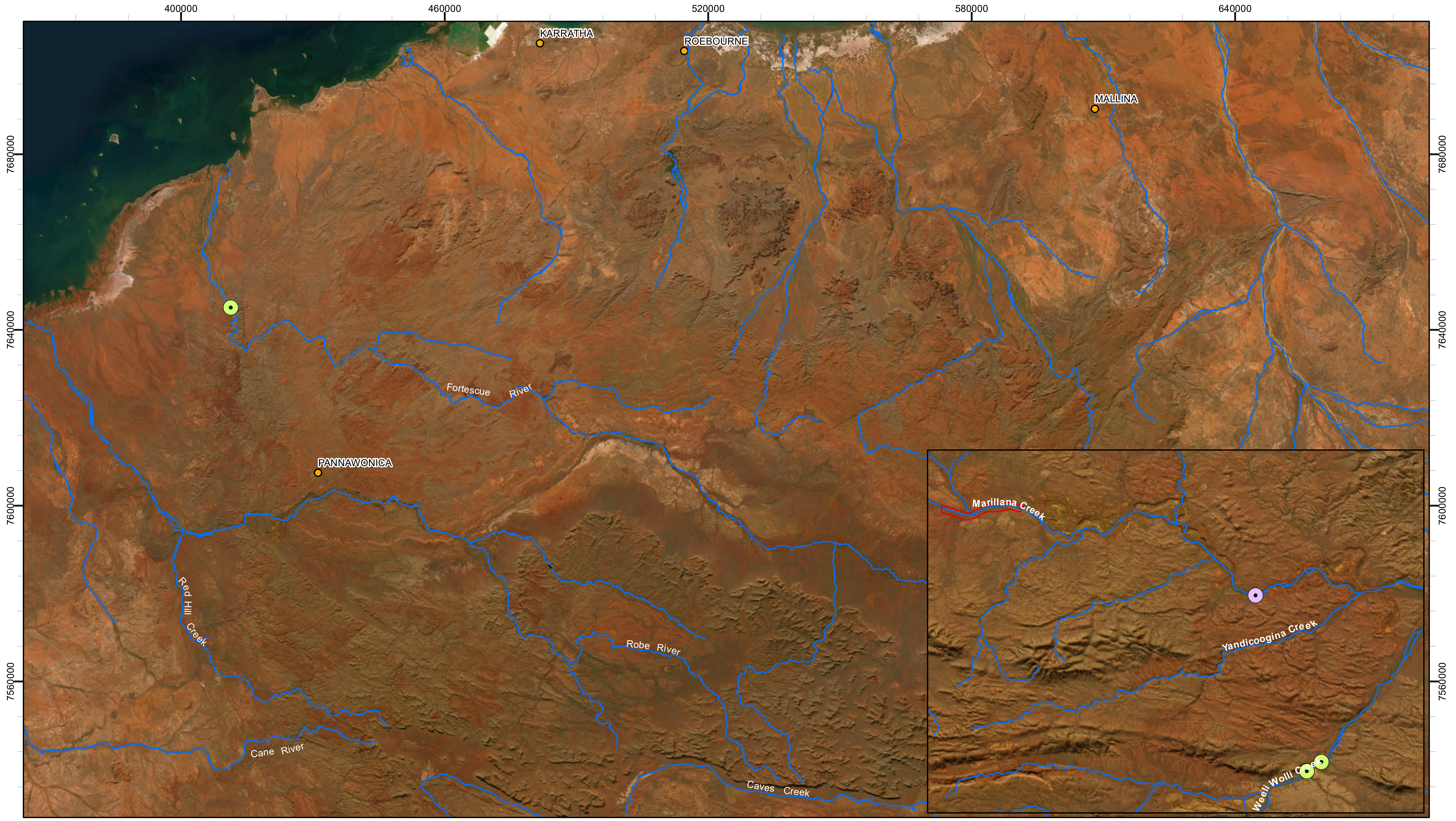
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 16/05/2023



BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 4.17: Records of *Rutacarus* water mites



Legend

Study Area

Major Creeks

Species

Hesperomomonia humphreysi

Hesperomomonia `sp. Biologic-ACAR014`

biologic Environmental Survey

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 16/05/2023

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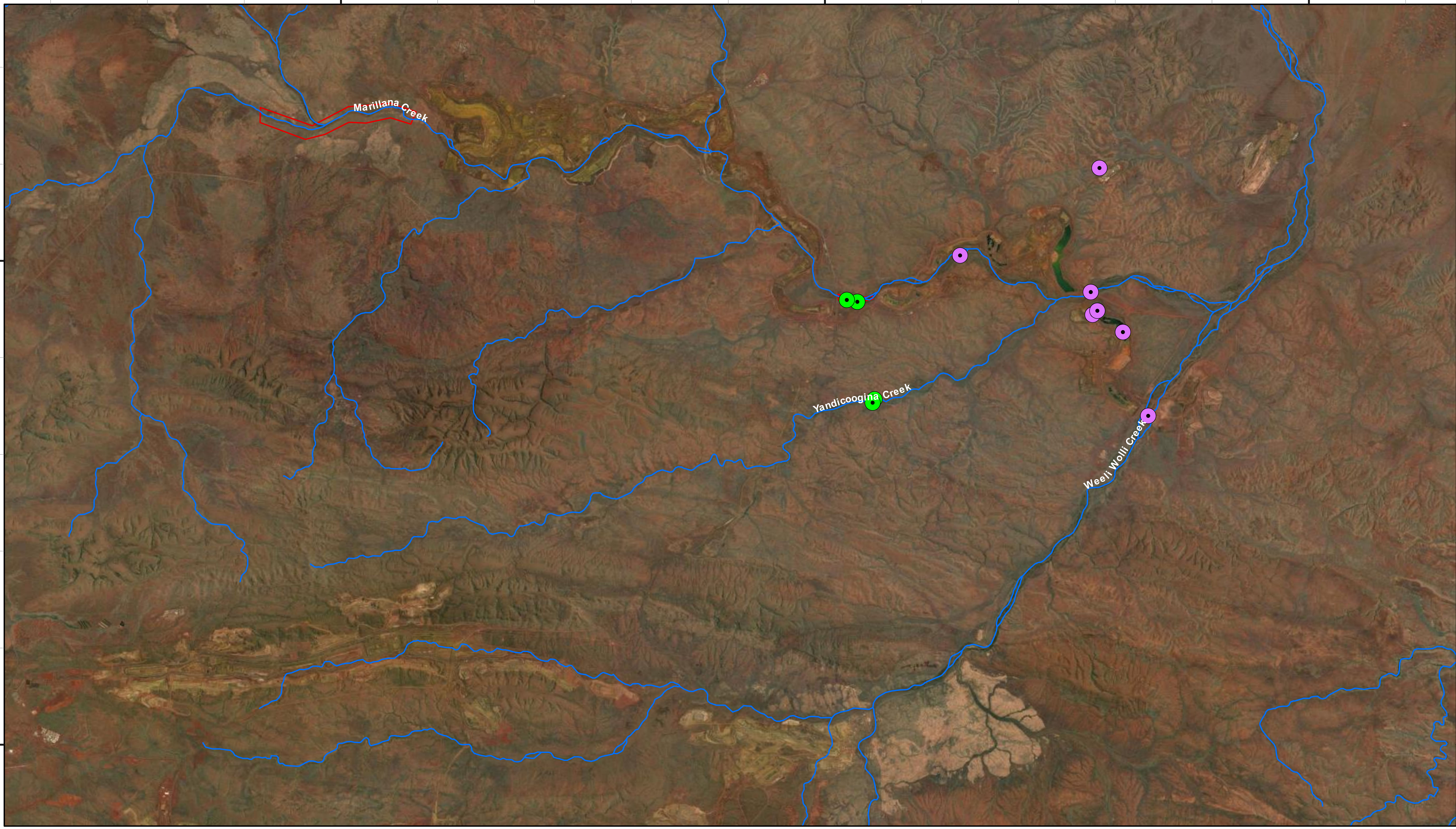
MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 4.18: Records of *Hesperomomonia* water mites



Legend

Study Area

Major Creeks

Species

Meridiescandona `sp. Biologic-OSTR074`

Meridiescandona marillanae

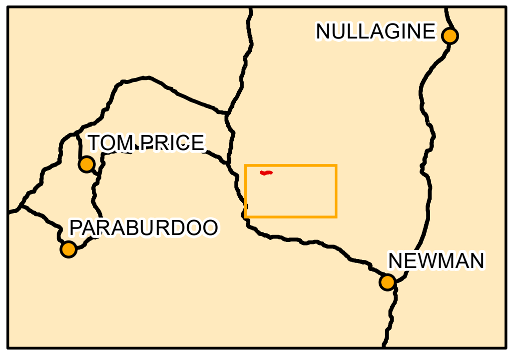
N

biologic Environmental Survey

Scale: 1:150,000

0 4 8 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 16/05/2023



BHP WAIO

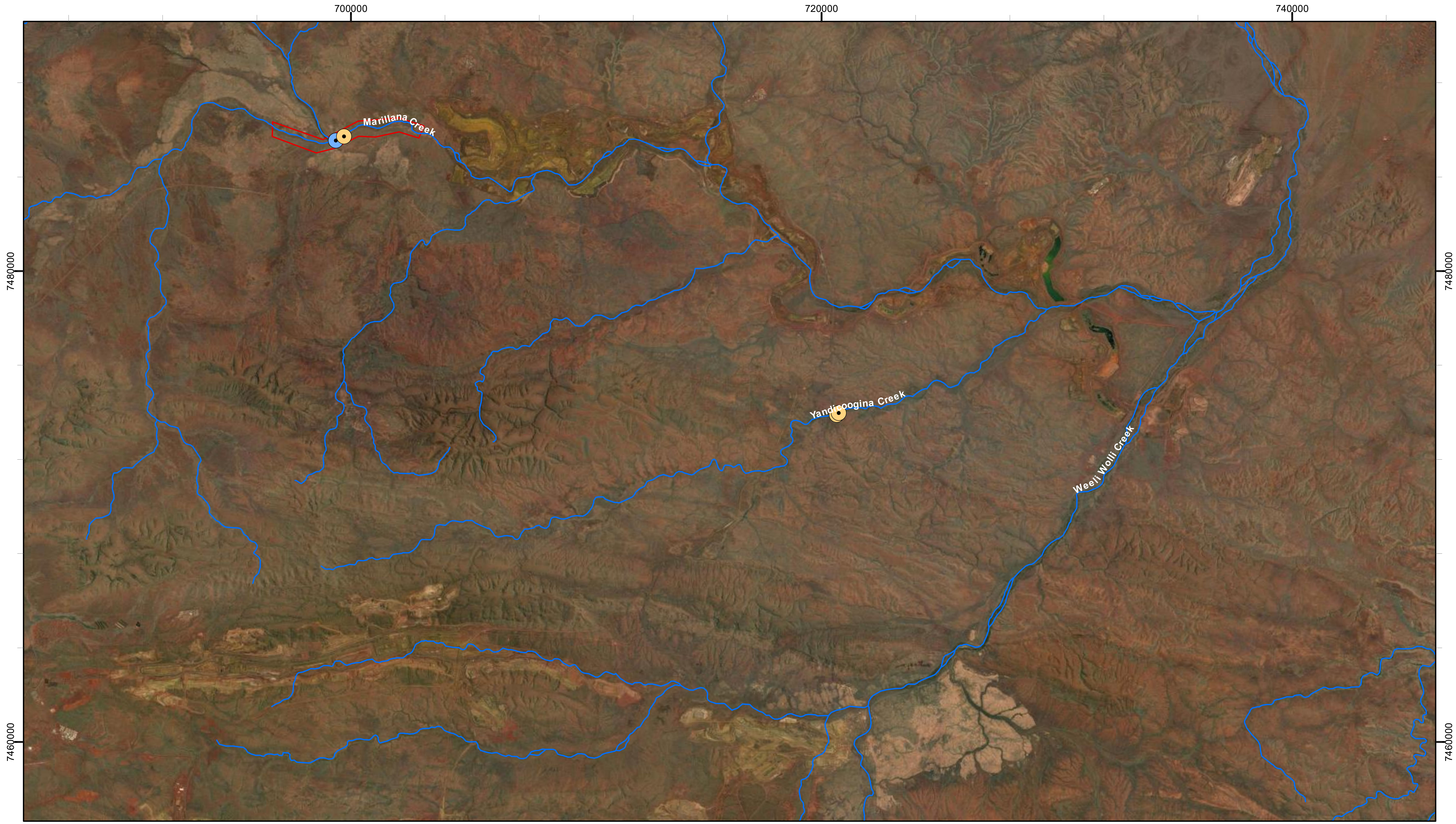
MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 4.19: Records of *Meridiescandona* ostracods

Gomphodella ostracods were recorded from the additional hyporheic sampling reach on Marillana Creek, downstream of the Study Area (sites MC4H and MC5H) as well as reference site WWS. Although the DNA analysis failed for these specimens, they are considered likely to be *Gomphodella alexanderi* based on broad morphology and distribution. *Gomphodella alexanderi* was recorded from the Study Area (MarC2) in the Dry 2020 (Biologic, 2022b). The species was previously known only from interstices of Marillana Creek and groundwater bores at Rio Tinto's Yandi Mine (Karanovic & Humphreys, 2014). However, it has more recently been recorded from the hyporheos of lower Weeli Wolli Creek (Jess Delaney, unpub. data), and nearby Yandicoogina Creek (Biologic, 2020). It is a Potential SRE (Data Deficient). All known records of this species are in areas either currently impacted by mining activities or those proposed for future mining.

<u>Copepoda</u>

Harpacticoid specimens from the *Parastenocaris* genus were collected from the hyporheic zone of MarC2 and MarC3 in the Wet 2022 (Figure 4.20). These specimens were submitted for molecular analysis and found to align with other sequences in the genus (Biologic, 2022c). Two distinct OTUs were detected, including one which did not match any previously known species or OTUs within the genetic database. A unique OTU was assigned to this taxon; *Parastenocaris* `sp. Biologic-HARP037`. This taxon was recorded from MarC2. Specimens from MarC3 matched a previously known OTU, *Parastenocaris* `sp. Biologic-HARP022`, which was found to be more than 22% divergent to *Parastenocaris* `sp. Biologic-HARP037` (Biologic, 2022c). *Parastenocaris* `sp. Biologic-HARP022` is previously known from the nearby Yandicoogina Creek (Biologic, 2022e)(Figure 4.20), but also from a bore in the Robe Valley over 300 km from the Study Area (Biologic, unpub. data). Another species of *Parastenocaris* also exhibits a relatively large range, *Parastenocaris jane*, which is known to occur over a linear distance of approximately 600 km (Huon *et al.*, 2021). In contrast, there are several *Parastenocaris* taxa which are currently known from few records and appear to have restricted distributions. Such taxa include *Parastenocaris* sp. B25 (known only from nearby Lamb Creek) (Bennelongia, 2021), *Parastenocaris* sp. B31 and *Parastenocaris* sp. B32 both known from Ophthalmia Dam (MWH, 2016), *P. eberhardi* currently known only from two caves in Margaret River in the south west of WA (Karanovic, 2005), and *P. kimberleyensis* which is known from a single water monitoring bore at the Argyle Diamond Mine in the Kimberley region (Karanovic, 2005). Therefore, current information is too limited to assess the distribution status of *Parastenocaris* `sp. Biologic-HARP037` but it is possible that additional morphological and molecular work will increase the known records of this taxon.



Legend

- Study Area
- Major Creeks

Species

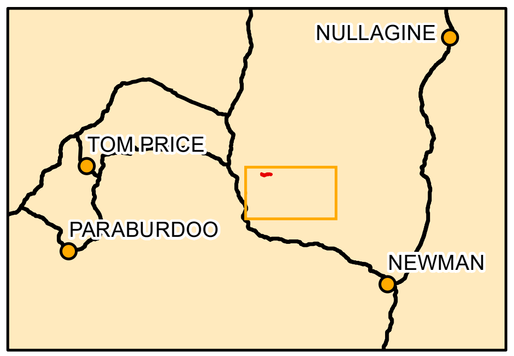
- *Parastenocaris* `sp. Biologic-HARP022`
- *Parastenocaris* `sp. Biologic-HARP037`

biologic Environmental Survey

Scale: 1:150,000

0 4 8 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 16/05/2023



BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 4.20: Records of *Parastenocaris*

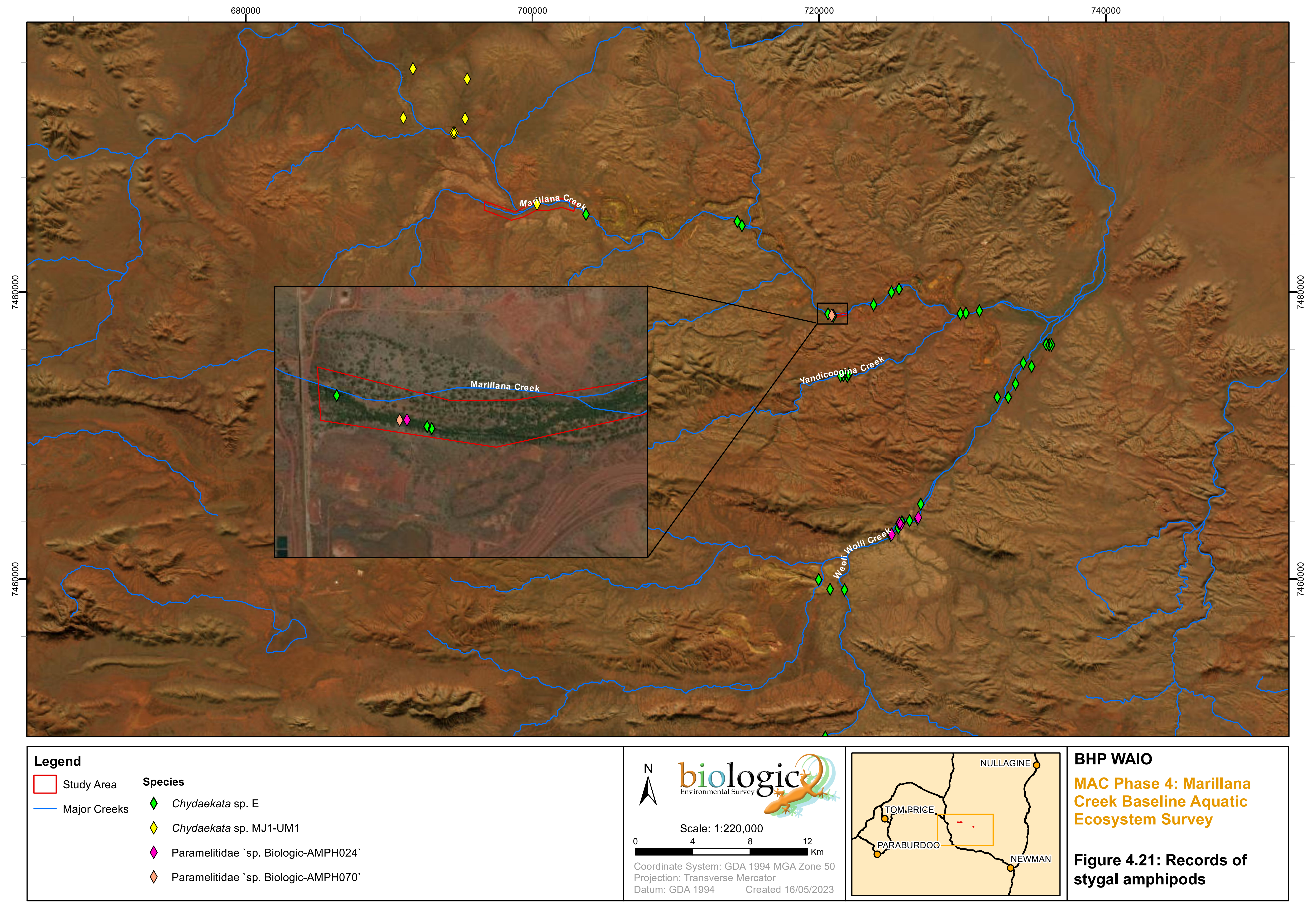
Amphipoda

Sampling of the hyporheic zone during the current study yielded a total of four stygal amphipod taxa, as well as specimens for which their further identity could not be resolved, either due to damage and/or immaturity, and failed genetic analysis (Paramelitidae sp.). The four taxa were determined using a combination of morphological and molecular techniques and included *Chydaekata* sp. E, *Chydaekata* sp. MJ1-UM1, Paramelitidae `sp. Biologic-AMPH024`, and Paramelitidae `sp. Biologic-AMPH070` (Biologic, 2022c).

Chydaekata `sp. E` is an undescribed morphotype that belongs to a previously published OTU (Finston *et al.*, 2007). While previously known only from Marillana and Weeli Wolli Creeks (Bennelongia, 2015b; Finston *et al.*, 2007), additional, more recent records of *Chydaekata* `sp. E` indicate this species is restricted to Marillana, Weeli Wolli and Yandicoogina Creeks (Figure 4.21). In the current study, *Chydaekata* `sp. E` was recorded from the hyporheos of MC5H and MC9H on Marillana Creek in the Wet 2022, and reference sites BENS and WWS in the Dry 2021. Other *Chydaekata* specimens matched a separate, distinct, previously published OTU, *Chydaekata* sp. MJ1-UM1 (Biologic, 2022c). This OTU is known from upper Marillana Creek (Figure 4.21). During the current study *Chydaekata* sp. MJ1-UM1 was recorded from MarC4 (Figure 4.21). *Chydaekata* sp. MJ1-UM1 was more than 20% divergent from *Chydaekata* `sp. E` sequences in the available genetic database.

Of the remaining specimens identified as belonging to the Paramelitidae family, two distinct OTUs were represented; Paramelitidae `sp. Biologic-AMPH024` and Paramelitidae `sp. Biologic-AMPH070`. The former is a previous OTU originally identified by Biologic using morphological and molecular analysis on specimens collected from WWS (Biologic, 2022h, 2022i). Paramelitidae `sp. Biologic-AMPH024` is on average 10% divergent from Paramelitidae `sp. Biologic-AMPH023` recorded from Marillana Creek and nearby Yandicoogina Creek. Prior to the current study, Paramelitidae `sp. Biologic-AMPH024` was known only from Weeli Wolli Creek, and the current record from Marillana Creek (MC4H) increases its known distribution (Figure 4.21). This taxon was also recorded from the reference site on Weeli Wolli Creek (WWS) during the current study. The second Paramelitidae OTU represented the first record of Paramelitidae `sp. Biologic-AMPH070` (Biologic, 2022c). This OTU was more than 16% divergent from all available sequences in the genetic database (Biologic, 2022c). It was recorded from the hyporheic zone of MC3H during the current study (Figure 4.21).

All four stygobitic amphipod taxa would be considered Potential SREs based on the WAM's three-tier classification system. Genetic analysis undertaken by others have indicated that most paramelitid species have ranges in the tributary-scale (Finston *et al.*, 2008; Finston *et al.*, 2011; Finston *et al.*, 2007), and that multiple highly divergent lineages are present within *Chydaekata*, associated with distinct tributaries (Finston *et al.*, 2007). A high level of morphological variation amongst Paramelitidae species, including within the *Chydaekata* genus, has been documented (Bradbury, 2000), but the morphological diversity does not align with molecular diversity (Finston & Johnson, 2004; Finston *et al.*, 2007). This highlights the importance of undertaking molecular analysis to complement morphological identification of species within this family.



BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 4.21: Records of stygal amphipods

Syncarida

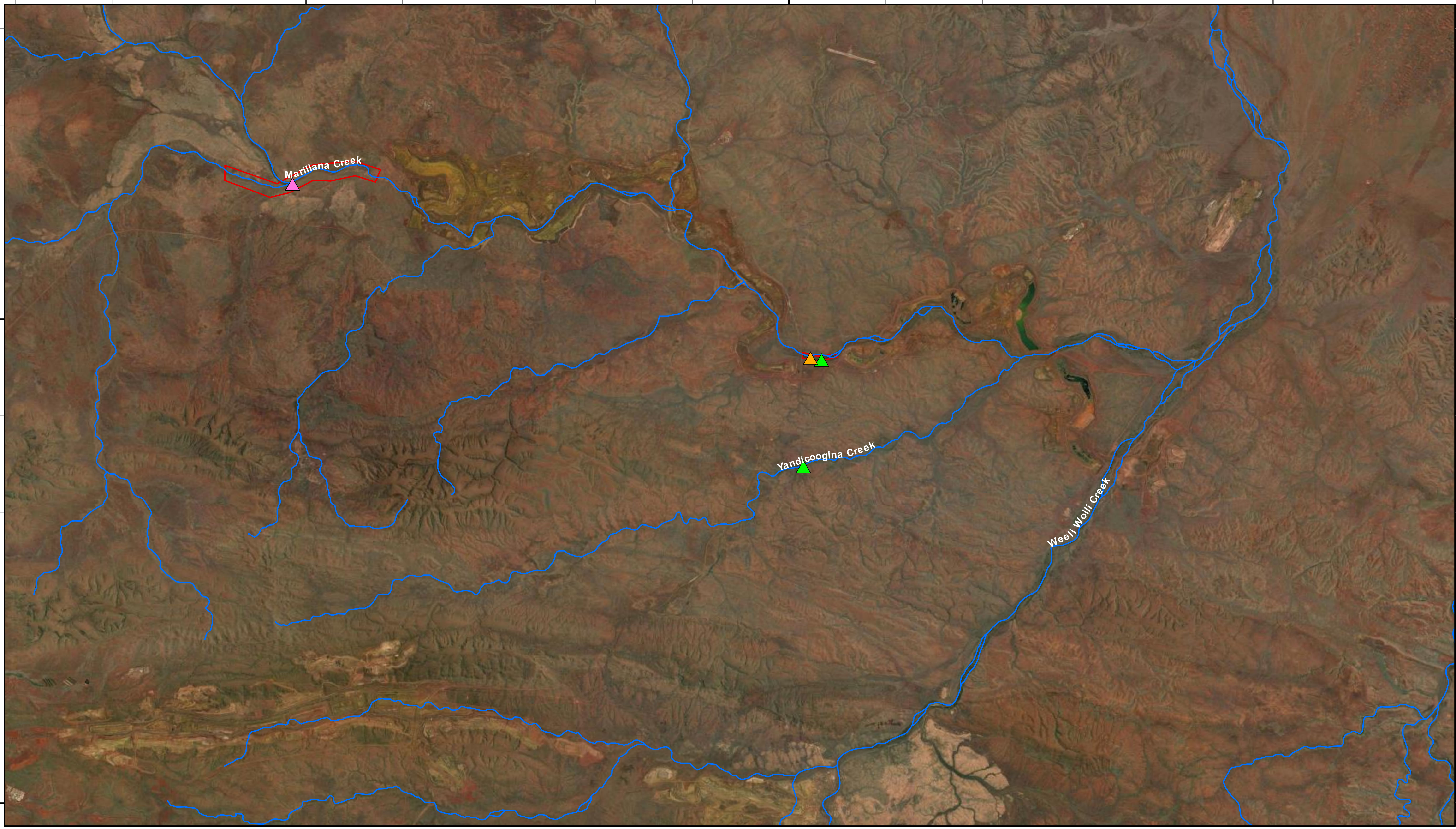
Three stygobitic syncarid taxa were recorded, including two Parabathynellidae and one Bathynellidae. The two Parabathynellids were morphologically identified as belonging to the genus *Atopobathynella*. Molecular analysis confirmed this genus level identification, with specimens from the current study grouping with other *Atopobathynella* sequences in the available GenBank database (Biologic, 2022c). Two distinct OTUs were detected, including one which matched a previously known OTU, *Atopobathynella* \`sp. Biologic-PBAT042\` (Biologic, 2022c).This taxon is known from the nearby Yandicoogina Creek (Biologic, 2022e), across a linear distance of 4.5 km. During the current study, *Atopobathynella* \`sp. Biologic-PBAT042\` was recorded from the hyporheic zone of MC10H (Figure 4.22). The second OTU did not match any previously known species or OTUs within the available genetic database, and therefore was assigned a unique OTU; *Atopobathynella* \`sp. Biologic-PBAT044\` (Biologic, 2022c). This taxon was recorded from the hyporheos of MC3H in the Wet 2022 (Figure 4.22). *Atopobathynella* \`sp. Biologic-PBAT042\` and *Atopobathynella* \`sp. Biologic-PBAT044\` were more than 19% divergent from one another (Biologic, 2022c), and 19% divergent to a previously known OTU, *Atopobathynella* \`sp. Biologic-PBAT041\`, recorded from the Fortescue River (Biologic, 2022h).

An individual specimen morphologically identified as belonging to the Bathynellidae family was collected from the hyporheic zone of MarC2 in the Wet 2022 (Figure 4.22). It was morphologically distinct from all previously known bathynellid species and was considered likely to be represent a new, undescribed species (Giulia Perina, Biologic, pers. comm.). Unfortunately, molecular analysis failed to yield an appropriate genetic sequence, and the identification remained at the family-level (Bathynellidae sp.).

Many Bathynellacea species are known to be restricted to small areas (Abrams, 2012; Coineau & Camacho, 2013), with several known only from a single calcrete (Guzik *et al.*, 2008), and more than two-thirds of species having a known range less than 10 km (Bennelongia, 2008). Recent research also suggests that *Atopobathynella* occurs within deeper aquifers as well as interstices within the hyporheic zone, and that separate species occupy different ecological niches in the same locality (i.e., shallow alluvials within the hyporheic zone vs deeper groundwater) (Giulia Perina, Biologic, pers. comm.). All three Syncarida taxa recorded would be considered Potential SREs (Data Deficient).

4.5.3 Troglofauna

One troglofauna specimen was collected from the hyporheic zone of MarC4 in the Dry 2021. It was morphologically identified as a Symphyla (pseudo-centipede). To provide further clarity on its identity and information on troglofauna species residing in hyporheic zones of Marillana Creek, the specimen was submitted for molecular analysis. It grouped with the genus *Hanseniella* but did not align with any described species or OTUs in the genetic database (Biologic, 2022c). The specimen was more than 10% divergent from its closest relative in the analysis, *Hanseniella* \`sp. Biologic-SYMP054\`, from the hyporheos of nearby Yandicoogina Creek (Biologic, 2022c). As such, it was assigned a unique OTU; *Hanseniella* \`sp. Biologic-SYMP055\`. All taxa within the *Hanseniella* genus are considered troglobites and have small ranges less than 50 km (Bennelongia, 2013, 2015a, 2016). As such, *Hanseniella* \`sp. Biologic-SYMP055\` likely represents a Potential SRE (Data Deficient).



Legend

- Study Area
- Major Creeks

Species

- *Atopobathynella* `sp. Biologic-PBAT042`
- *Atopobathynella* `sp. Biologic-PBAT044`
- Bathynellidae sp.

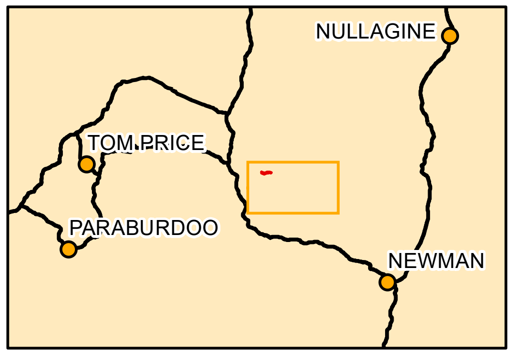
N

biologic Environmental Survey

Scale: 1:150,000

0 4 8 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 16/05/2023



BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 4.22: Records of potential SRE syncarida

4.5.4 Hyporheos fauna comparison with previous studies

Patterns of change over time for average hyporheos fauna taxa richness (stygobites, permanent hyporheos stygophiles, occasional hyporheos stygophiles, and potential hyporheic taxa) were different between the Study Area and reference sites (Figure 4.23). Within the Study Area, average hyporheos taxa richness was generally higher in the wet season, and lower in the dry, while at reference sites richness was greatest in the Dry 2020 but then relatively stable since the Wet 2021 (Figure 4.23). Overall, there was no significant difference in average hyporheos fauna taxa richness between sampling events, nor between site type (Table 4.7). There was, however, a significant interaction between sampling event and site type (Table 4.7).

The additional Marillana Creek sites were only sampled in the Wet 2022. Average hyporheos fauna richness recorded from this reach was greater than all other site types sampled in the Wet 2022, but did not represent the highest average hyporheos fauna taxa richness recorded over all sampling occasions and site types (Figure 4.23). That was recorded from the Study Area in the Wet 2021.

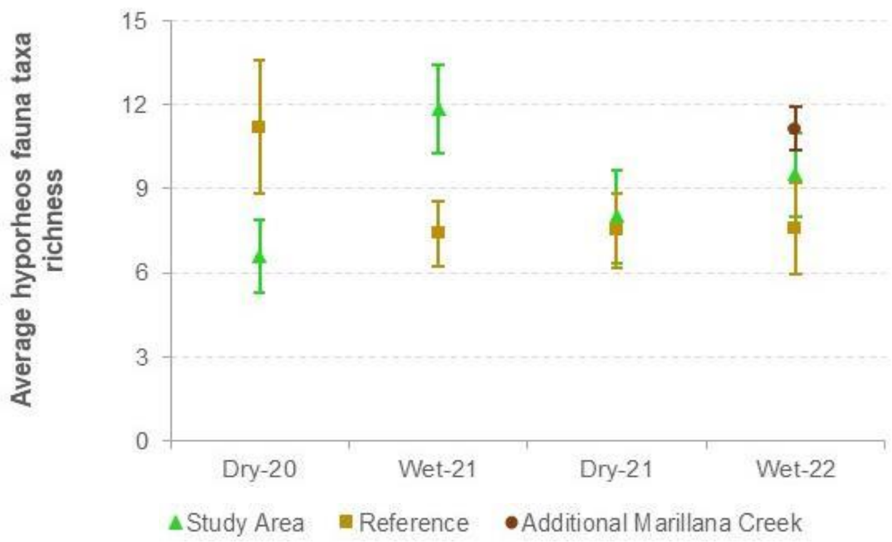


Figure 4.23: Average hyporheos fauna taxa richness (± standard error) in the Study Area and Reference sites recorded during each sampling event since the Dry 2020.

The average richness of groundwater dependent taxa (stygobites and permanent hyporheos stygophiles) was variable, but generally showed similar seasonal patterns of change between reference and Study Area sites, with higher richness recorded in the wet season (Figure 4.24). The average groundwater dependent taxa richness recorded from the additional Marillana Creek sites in the Wet 2022, represented the greatest richness recorded across all sampling events and site types (Figure 4.24). Overall, there was no significant difference in groundwater dependent taxa richness between site types or sampling events (Table 4.7).

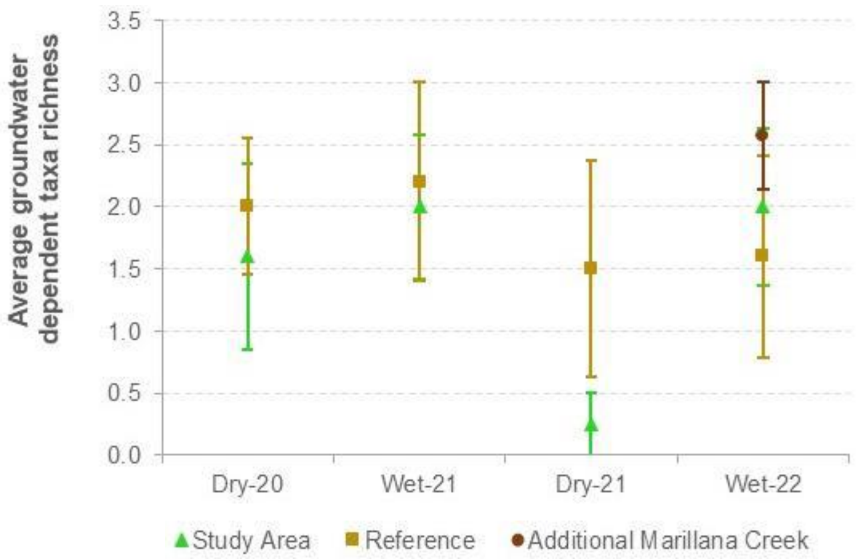


Figure 4.24: Average groundwater dependent taxa richness (stygobites + permanent hyporheos stygophiles) (± standard error) from the Study Area and Reference sites recorded during each sampling event since the Dry 2020.

Table 4.7: Two-way ANOVA results, comparing hyporheos fauna richness and groundwater dependent taxa richness between sampling events and site type (Study Area vs reference). Significant *p*-values are shown in red.

Analyte	Source	df	F	*p*-value
Hyporheos fauna taxa richness	Sampling event	3	0.47	0.703
	Type	2	1.32	0.280
	Sampling event*type	3	3.15	0.036
	Corrected total	46		
Groundwater dependent taxa richness	Sampling event	3	1.13	0.348
	Type	2	0.90	0.414
	Sampling event*type	3	0.49	0.692
	Corrected total	46		

4.6 Macroinvertebrates

4.6.1 Taxa composition and richness

A total of 208 macroinvertebrate taxa was recorded from surface waters within the Study Area, with 105 taxa being recorded from the two sites successfully sampled in the Dry 2021, and 179 taxa recorded from six sites in the Wet 2022 (see Appendix G for full taxa list). Macroinvertebrate taxa from the Study Area included specimens from 14 higher taxonomic orders, including:

- Cnidaria (freshwater polyp; one taxon),

- Platyhelminthes (flatworm; one taxon),
- Nematoda (roundworm; one taxon),
- Mollusca (freshwater snails; six taxa),
- Oligochaeta (aquatic segmented worm; 10 taxa),
- Acarina (water mites; 27 taxa),
- Collembola (springtails; two taxa),
- Coleoptera (beetles; 63 taxa),
- Diptera (two-winged flies; 42 taxa),
- Ephemeroptera (mayflies; seven taxa),
- Hemiptera (aquatic true bugs; 22 taxon),
- Lepidoptera (moth larva; two taxa),
- Odonata (dragonflies and damselflies; 15 taxa), and
- Trichoptera (caddisflies; nine taxa).

Most sites were dominated by slow flow and relatively tolerant taxa, i.e., Coleoptera and Diptera (Figure 4.25). Dominance of Diptera within aquatic macroinvertebrate assemblages of the Pilbara is common (Pinder *et al.*, 2010). Taxa which require faster flows, such as Lepidoptera, leptophlebiid mayflies, Simulidae (Diptera), *Cheumatopysche* and *Chimarra* caddisflies (Trichoptera) were generally restricted to the flowing reference sites (Figure 4.25). However, within the Study Area, flow taxa (Simulidae and *Cheumatopsyche*) were recorded from MarC2 and MarC3 in the Wet 2022. As has been reported previously (Biologic, 2022b), notably high odonate richness was recorded within the Study Area. In the current study, this high diversity was recorded from MarC4 (in the Wet 2022; 12 taxa), as well as reference site MACREF1 (in the Dry 2021; 13 taxa) (Figure 4.25). In the previous study, high odonate diversity was recorded from MarC5 and MarC6 (Biologic, 2022b).

Within-site macroinvertebrate richness varied between sites and seasons, but was generally high at most sites, with the notable exception of reference site WWS (Figure 4.25). In the Dry 2021, taxa richness ranged from 38 (at reference site WWS) to 86 (at reference site MACREF1 on the tributary of Yandicoogina Creek). Within the Study Area, the two sites successfully sampled yielded high richness (65 at MarC3 and 71 at MarC6a) (Figure 4.25). In the Wet 2022, macroinvertebrate taxa richness ranged from 35 (at reference sites MACREF1 and WWS) to 88 at Study Area site MarC2 (Figure 4.25).

Seasonal variation was greater at some sites than others. Reference site MACREF1 on Yandicoogina Creek recorded both the greatest (Dry 2021) and lowest (Wet 2022) richness of all sites sampled, while reference site WWS underwent minimal change in richness between seasons. Within the Study Area, only two sites were successfully sampled in both seasons, making seasonal change difficult to quantify. However, at MarC3, greater richness was recorded in the wet season (78 taxa compared to 65 in the dry; Figure 4.25).

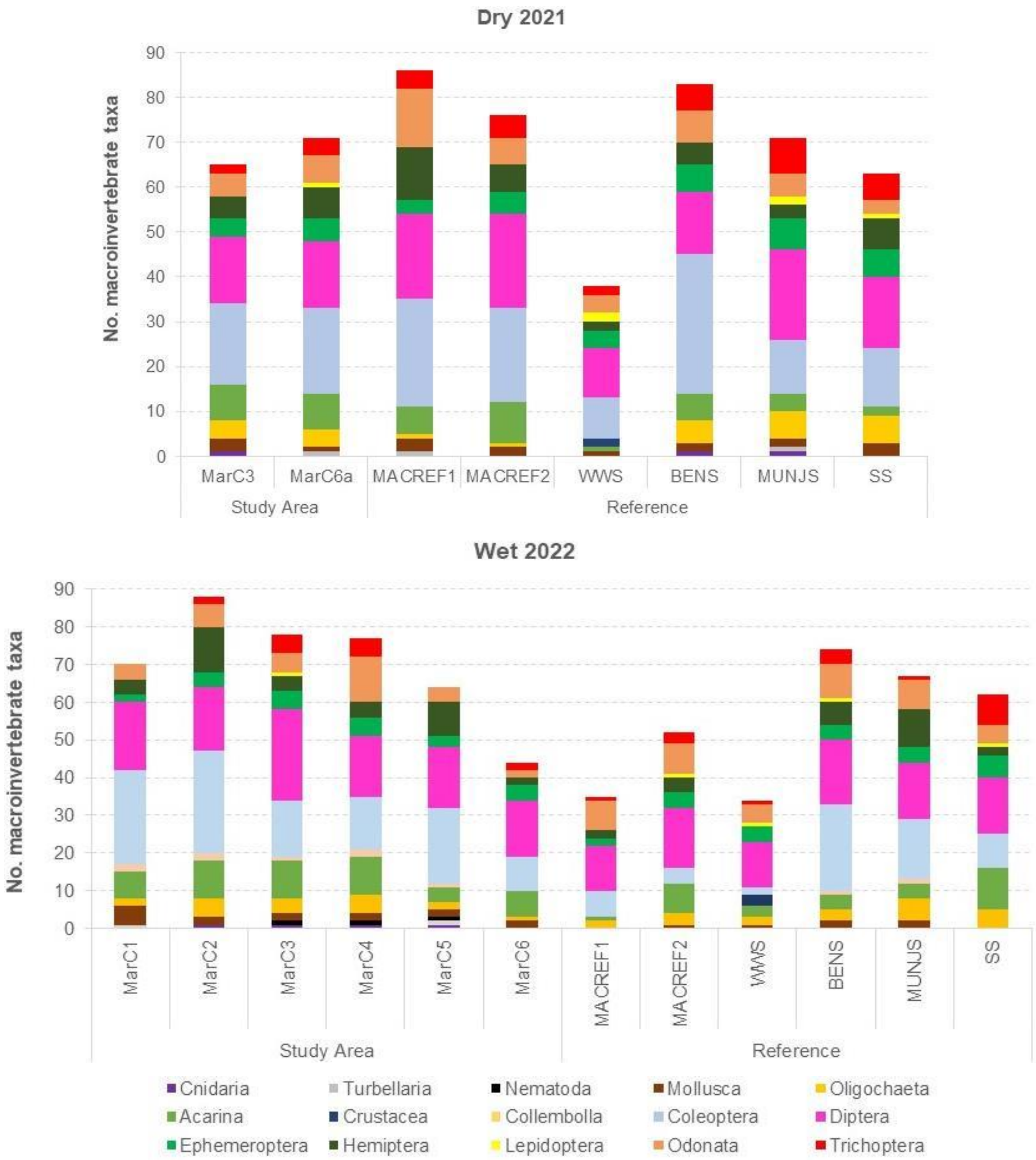


Figure 4.25: Macroinvertebrate taxa richness recorded from each site in the Dry 2021 (top) and Wet 2022 (bottom).

4.6.2 Conservation significant macroinvertebrate taxa

The majority of aquatic macroinvertebrates recorded from the Study Area were common, ubiquitous species. Excluding taxa which could not be assigned a distribution status due to insufficient information or taxonomy (juveniles/damaged specimens), most remaining taxa had distributions extending across Australia (39%), the world (cosmopolitan species; 18%), Northern Australia (15%), or the Australasian region (9%). A total of 6% were endemic to Western Australia, and 2% were found across northern WA.

Taxa restricted to the Pilbara region accounted for 12% of the taxa from the Study Area (of those with known distributions). No introduced invertebrate taxa were recorded from the Study Area.

Pilbara endemic taxa were recorded from all sites sampled, in at least one season (Figure 4.26). The greatest number of Pilbara endemic taxa was recorded from reference site BENS in the wet season (seven taxa). Study Area site MarC4 (Wet 2022) and reference site BENS (Dry 2021) recorded the next greatest richness, each with five endemic taxa (Figure 4.26).

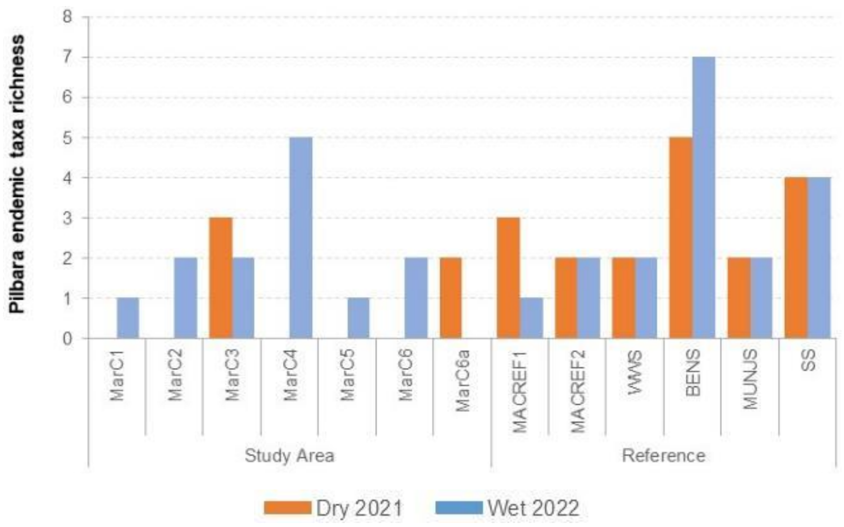


Figure 4.26: Number of Pilbara endemic taxa recorded from each site, in each season.

Within the Pilbara endemic fauna were three taxa of further interest which represented either conservation significant species currently listed on the IUCN Red List of Threatened Species (*Eurysticta coolawanyah*), or potentially uncommon and/or restricted taxa (*Wandesia* sp. and *Guineaxonopsis* sp.). Further detail on these taxa is provided below.

<u>Acarina</u>

The water mite *Wandesia* sp. was recorded from surface waters of MarC2 in the Wet 2022. The taxonomy of this genus in Western Australia is poorly known, the geographic ranges of the various species have not been determined, and all described species are known from river interstices in eastern Australia. One known, but undescribed species, *Wandesia* sp. P1 (nr *glareosa*), was recorded during the PBS from river pools and springs (Pinder *et al.*, 2010). It is not known whether *Wandesia* sp. recorded from the current study is the same as the known morphotype from the PBS, as specimens from the PBS are not available for comparison. *Wandesia* specimens have previously been recorded from Marillana Creek, within the hyporheos of MarC1 and MarC5 (Biologic, 2022b), and Weeli Wolli Creek (*Wandesia* `sp. Biologic-ACAR009`) (Biologic, 2022i). *Wandesia* taxa are considered permanent hyporheos stygophiles, with specimens most commonly being collected from the hyporheic zone. The identity of the *Wandesia* from MarC2 remains unknown as genetic analysis failed to produce a successful sequence.

A *Guineaxonopsis* water mite was recorded from surface waters of MarC4 in the Wet 2022. The identification of this specimen has not been resolved further as genetic analysis failed. However, the specimen may represent one of the known OTUs from Marillana Creek; *Guineaxonopsis* \`sp. Biologic-ACAR011\` or *Guineaxonopsis* \`sp. Biologic-ACAR013\`. The latter was recorded from the hyporheos of MarC4 in the current study (see section 4.5.2).

Odonata

The Pilbara pin damselfly, *Eurysticta coolawanyah* is currently listed as Vulnerable (IUCN, 2022). This listing was based on its collection from less than five locations. Although the listing for *E. coolawanyah* was revised in 2016, the revision did not take into account grey literature records. Its extent of occurrence, based on a polygon around the known occupied areas (four locations listed in the IUCN listing), is 7,937 km² (Dow, 2019); however, Bush *et al.* (2014) provide an estimate of the current extent of suitable habitat as 298,177 km². Including the PBS and grey literature records (sampling programs undertaken by Biologic and others), the species has now been recorded from numerous locations in the Pilbara, albeit in low numbers and with a disjunct distribution (Pinder *et al.,* 2010, Jess Delaney, unpub. data). During the current study, *E. coolawanyah* was recorded from MarC4 (Wet 2022), as well as reference sites MACREF2 (on Marillana Creek upstream of the tributary) and BENS (both seasons). Within the Study Area, the Pilbara pin has previously been recorded from MarC5 (Biologic, 2022b).

4.6.3 Macroinvertebrate comparison with previous MAC survey

Average macroinvertebrate taxa richness within the Study Area increased between the Dry 2020 and Dry 2021 (Figure 4.27). Although there was a slight decrease in the Wet 2022, macroinvertebrate richness recorded from the Study Area was still considerably greater than that recorded in the previous Dry 2020 and Wet 2021 sampling events. It was also greater than the average richness recorded from reference sites at this time (Figure 4.27). Within reference sites, average macroinvertebrate richness was relatively consistent between the Dry 2020 and Dry 2021, with a slight decrease also recorded in the Wet 2022 (Figure 4.27). Overall, there was no significant difference in average macroinvertebrate taxa richness between sampling events, nor between site type (Table 4.8).

With respect to Pilbara endemic taxa, average richness decreased slightly over time, in both the Study Area and reference sites (Figure 4.28). This equated to an average reduction of 1.17 endemic taxa from the Dry 2020 to Wet 2022, in both the Study Area and within reference sites. Overall, there was no significant difference in average Pilbara endemic taxa richness between sampling events or site type (Table 4.8).

Table 4.8: Two-way ANOVA results, comparing macroinvertebrate richness between sampling events and site type (Study Area vs reference). Significant *p*-values are shown in red.

Analyte	Source	df	F	*p*-value
Macroinvertebrate taxa richness	Sampling event	3	1.49	0.233
	Type	1	2.09	0.157
	Sampling event*type	3	1.30	0.290
	Corrected total	43		
Pilbara endemic taxa richness	Sampling event	3	1.34	0.277
	Type	1	3.55	0.068
	Sampling event*type	3	0.04	0.989
	Corrected total	43		

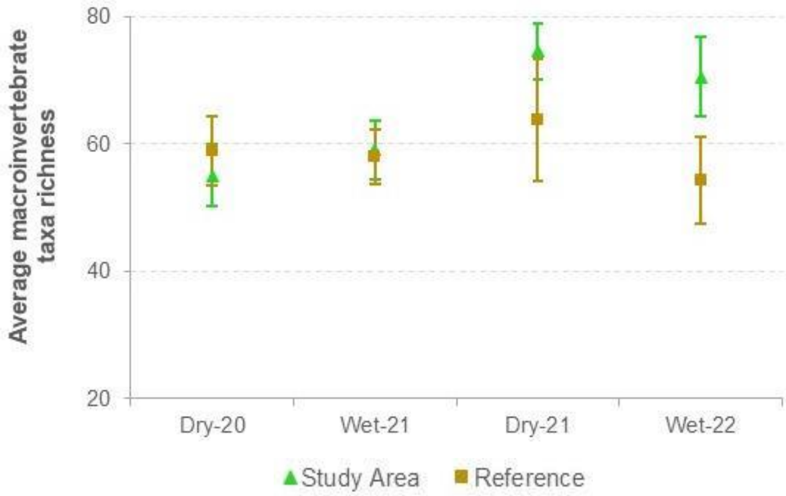


Figure 4.27: Average macroinvertebrate taxa richness (± standard error) in the Study Area and Reference sites recorded during each sampling event since the Dry 2020.

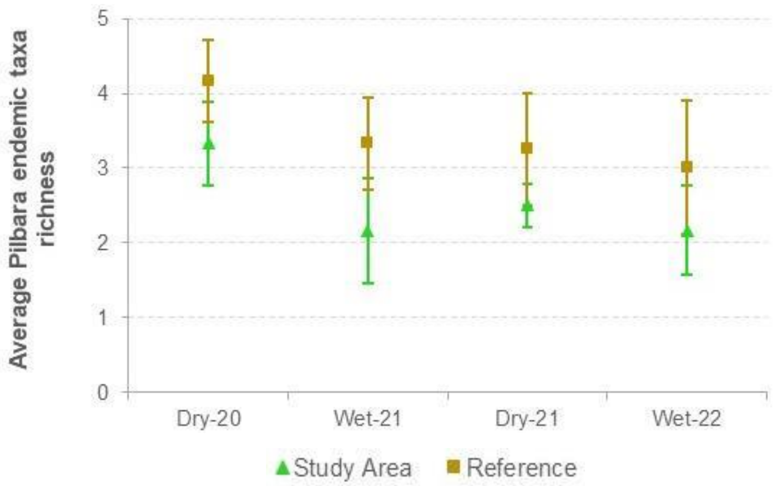


Figure 4.28: Average Pilbara endemic taxa richness (± standard error) in the Study Area and Reference sites recorded during each sampling event since the Dry 2020.

4.6.4 Macroinvertebrate assemblage correlations with environmental characteristics

Macroinvertebrate assemblages within the Study Area only (not reference sites) were significantly different between sampling events (ANOSIM; R = 0.46, p < 0.0001). Correlations between macroinvertebrate assemblages and environmental characteristics (water quality and habitat data) were investigated using DistLM. A model with a strong correlation (r = 0.88) between macroinvertebrate assemblages and seven predictor variables was produced (Table 4.9). The environmental variables were EC, pH, turbidity, calcium concentration, concentration of dissolved copper, total phosphorus, and percent cover by submerged macrophytes. Together, these environmental variables explained close to 40% of the variation amongst the Marillana Creek Study Area macroinvertebrate assemblages. The correlation between each individual environmental variable and the assemblages of Marillana Creek were all significant (Table 4.9).

Table 4.9: DistLM results examining correlations between Yandicoogina Creek macroinvertebrate assemblages and environmental data (water quality and habitat).

Variable	r	Pseudo-F	*p*-value	% variance explained
EC	0.23	1.26	<0.0001	5.40
pH	0.35	1.71	0.0230	7.13
Turbidity	0.53	2.61	0.0003	9.87
Calcium	0.56	0.76	<0.0001	2.92
Dissolved copper	0.65	1.85	0.0122	6.66
Total phosphorus	0.76	1.00	<0.0001	3.57
Submerged macrophyte cover	0.78	1.18	<0.0001	4.14
		Total % variation explained		**39.69%**

4.6.5 Macroinvertebrate comparison with other studies

Macroinvertebrate richness from the Study Area was compared with previous studies detailed in section 3.6.3 above, for those studies which sampled more than one replicate site within a creek system. As with the zooplankton data (see section 4.4.4), taxonomy was aligned and amalgamated, where necessary, prior to analysis. Again, Weeli Wolli Creek sites were split into Weeli Wolli Spring (recorded from the historic spring area) and Weeli Wolli Creek (upper Weeli Wolli Creek river pools). Due to a lack of replication, reference site BENS and MUNJS were not included in this analysis.

Average macroinvertebrate richness within the Study Area was relatively high in comparison to other nearby creeklines and the downstream reach of Marillana Creek included in the analysis (Figure 4.29). In fact, average richness in the Study Area was just slightly lower than that recorded from the Davis River, where reference sites SS and RW are both known for their particularly high richness of aquatic invertebrate fauna (Kendrick & McKenzie, 2001) (Figure 4.29). Statistically, average richness from the Study Area was comparable to the Davis River, as well as all creeks/reaches in the analysis except Weeli Wolli Creek (Two-way ANOVA; df = 5, p < 0.001; Figure 4.29). Average richness recorded from the Davis River was significantly greater than that recorded from Weeli Wolli Creek (Figure 4.29).

Overall, there was no significant difference in average richness between seasons (df = 1, p = 0.788), and no significant interaction between creek and season (df = 5, p = 0.441).

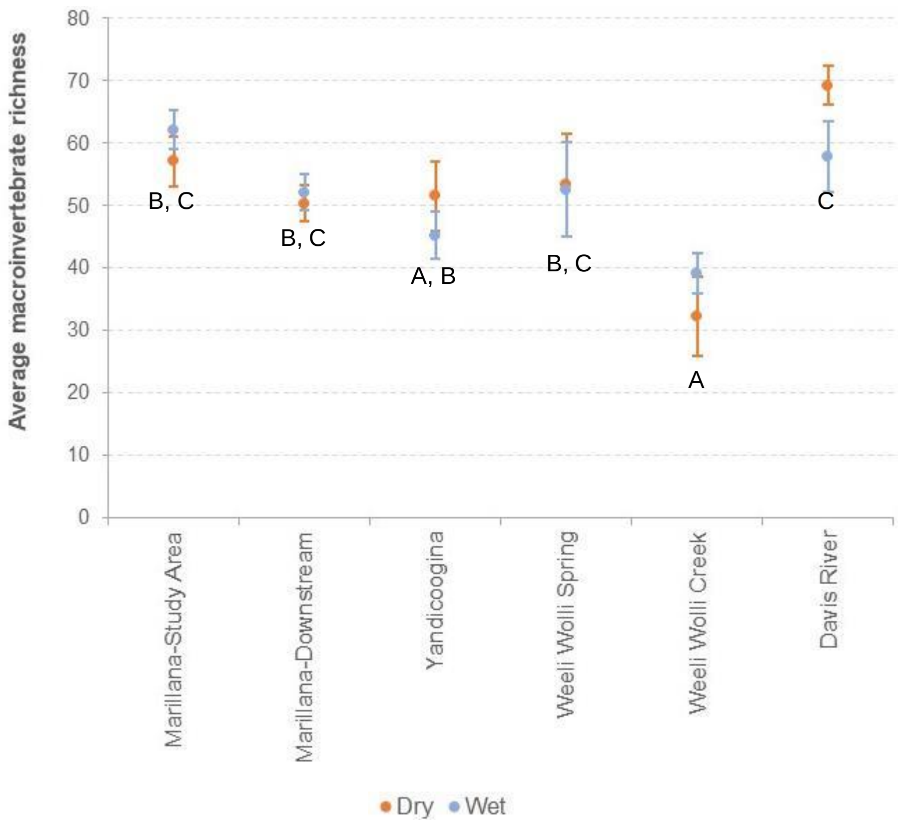


Figure 4.29: Average macroinvertebrate taxa richness (± se) recorded from the Study Area, in comparison to other studies and nearby creeks and reaches, in both seasons.

*Letters denote equal means as determined from the Tukeys post-hoc test.

For multivariate analyses, all data were included, i.e., BENS and MUNJS were also incorporated into the dataset. Data were transformed to presence/absence as this was the level of information provided in the PBS. Macroinvertebrate assemblages from the Marillana Creek Study Area were relatively variable in ordination space, but not to the extent of the Yandicoogina Creek or Weeli Wolli Creek samples (Figure 4.30). The Marillana Creek Study Area samples sat closest (were most similar) to Bens Oasis, Munjina Spring and the Davis River. The two Marillana Creek samples sitting within the Weeli Wolli Springs cluster are the MACREF2 reference site samples from the Wet 21 and Wet 22 (Figure 4.30). Overall, there was a significant difference in macroinvertebrate assemblages between creeks/reaches (Two-way ANOSIM; R = 0.43, p < 0.0001). The post-hoc test indicated that assemblages of the Marillana Creek Study Area were statically similar to assemblages from Bens Oasis, Munjina Spring and the Davis River, but were significantly different to the downstream reach of Marillana Creek, Yandicoogina Creek, Weeli Wolli Spring and Weeli Wolli Creek (Table 4.10).

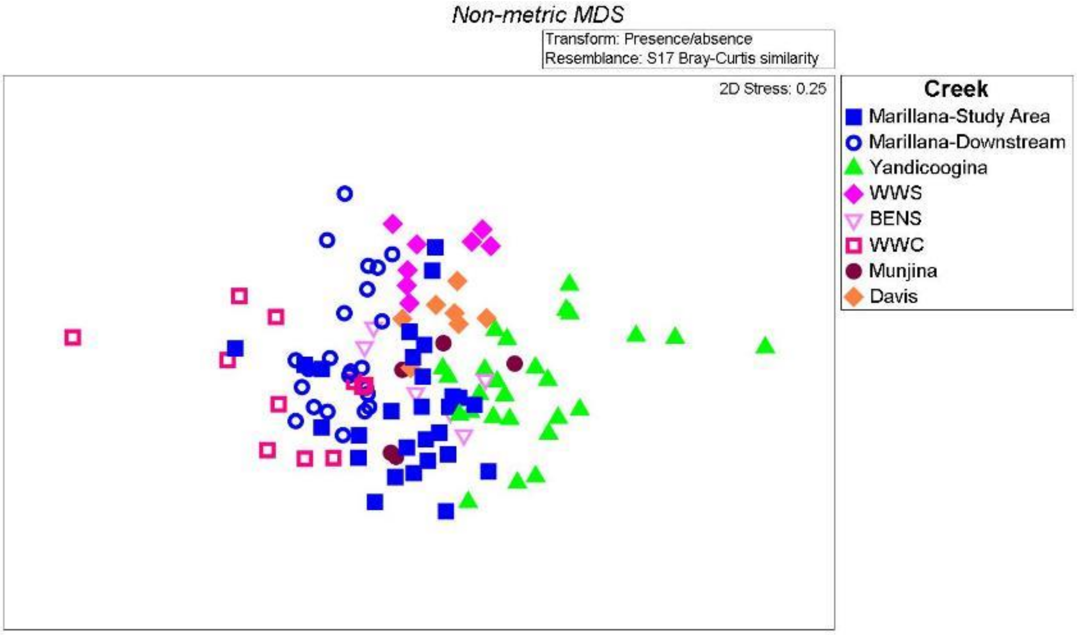


Figure 4.30: nMDS of macroinvertebrate assemblages recorded during the current study and other studies undertaken nearby. Samples are identified by creek.

Table 4.10: Post-hoc pairwise results comparing macroinvertebrate assemblages from the Marillana Creek Study Area with other creeks/reaches . NB: significant separations are indicated by red font).

Creek/reach	R	*p*-value
Marillana Creek - Downstream	0.331	<0.0001
Yandicoogina Creek	0.411	<0.0001
Weeli Wolli Spring	0.658	0.0001
Bens Oasis	0.080	0.262
Weeli Wolli Creek	0.534	<0.0001
Munjina Spring	0.310	0.027
Davis River	0.182	0.085

There was considerable overlap of samples based on season (Figure 4.31). Although ANOSIM did detect a significant difference (p = 0.008), the low R value (0.13) indicated that the two groups were barely separable.

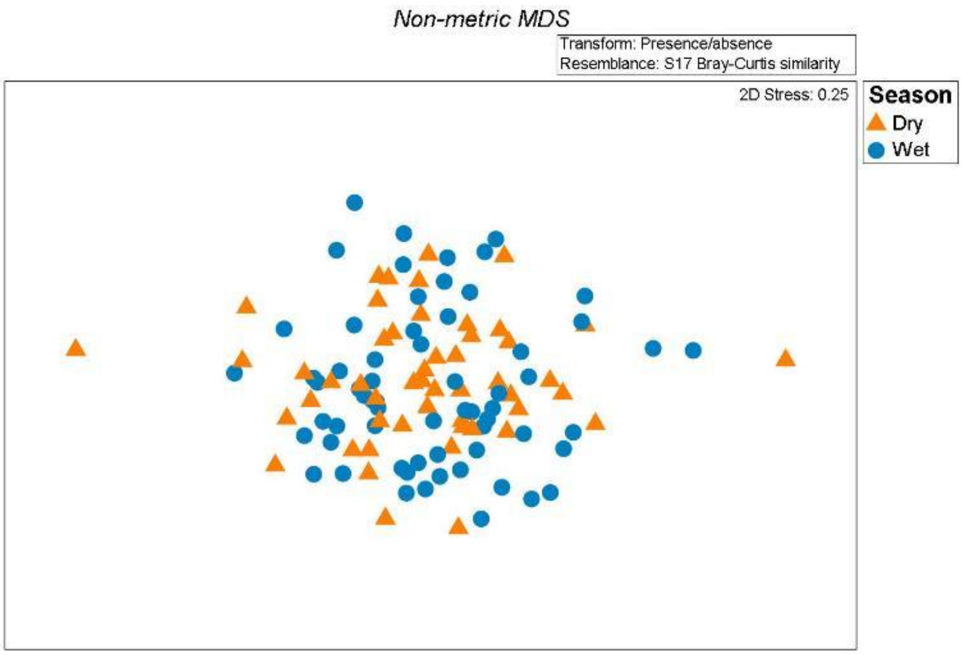


Figure 4.31: nMDS of macroinvertebrate assemblages as above, but with samples identified by season.

4.6.6 Introduced macroinvertebrate taxa

No introduced invertebrate taxa were recorded from the Study Area. However, the introduced redclaw crayfish (*Cherax quadricarinatus*) was recorded from reference site WWS. Over the course of the study, a total of 25 redclaw crayfish were removed from WWS, with four individuals removed in the Dry 2021 and 21 in the Wet 2022. The sex ratio was in favour of females in the Dry 2021 (2:1), and males in the Wet 2022 (1.2:1). Two berried females were removed from WWS in the Dry 2021 (Plate 4.1).

Plate 4.1: Two berried females collected from WWS.

4.7 Rehydration Emergence Trials

4.7.1 Water quality

Water quality recorded from rehydrate tanks was generally conducive to emergence of fauna and germination of flora, although DO and temperature did become temporarily low in some tanks on a small number of occasions. DO ranged from 40% (MarC2 tank in the Phase 2 trial) to 98.7% (MarC1 in the Phase 1 trial) (Table 4.11). Water temperatures in trial tanks ranged from 18.0 °C (MarC6 in the Phase 1 trial) to 28.3 °C (MarC2 in the Phase 2 trial). This is generally similar to the average water temperatures recorded from pools within the Survey Area during the Dry 2021 (22.7 °C), although the lowest temperature recorded from trial tanks was somewhat lower than surface water pools (20.2 °C). Overall, the temperatures in the rehydrate tanks were considered sufficient to allow emergence to occur.

Table 4.11: Summary of water quality recorded during the Dry 2021 rehydration trials.

Highlighted cells refer to values which are in excess of; > the ANZG 95% DGV, and > point of ecological stress.
P = Wetting phase (1 refers to the initial wetting phase, and 2 the re-wetting following the first harvest).

		Temp °C		pH		EC (µs/cm)		DO %	
Dry 2021		**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
ANZG DGV				6-8		250		85-120	
MarC1	**min**	18.1	21.2	8.0	8.1	989.0	477.3	60.3	54.6
	max	25.5	27.5	9.2	9.1	1927.0	852.0	93.2	98.7
	mean	22.0	23.6	8.4	8.7	1447.3	743.4	74.4	82.1
	se	0.7	0.7	0.1	0.1	114.0	35.0	5.5	4.8
MarC2	**min**	18.4	21.3	8.1	8.1	909.0	454.1	52.8	39.6
	max	25.5	28.3	9.3	9.0	1455.0	823.0	93.0	97.8
	mean	22.0	24.3	8.5	8.6	1200.3	709.6	74.2	79.2
	se	0.6	0.7	0.1	0.1	61.4	35.0	5.9	5.0
MarC4	**min**	18.2	20.9	8.1	8.1	1571.0	547.0	69.9	54.1
	max	25.6	27.2	9.3	9.1	2791.0	999.0	91.1	96.6
	mean	21.8	23.4	8.5	8.7	2140.3	868.3	78.8	82.4
	se	0.7	0.7	0.1	0.1	136.1	42.0	3.9	4.2
MarC5	**min**	18.4	20.8	7.8	8.0	899.0	466.0	57.6	56.0
	max	25.6	26.5	9.3	9.0	1459.0	825.0	90.5	88.6
	mean	22.1	23.2	8.4	8.6	1213.2	720.4	72.1	79.3
	se	0.6	0.6	0.2	0.1	62.1	37.1	6.3	3.4
MarC6	**min**	18.0	20.8	8.3	8.1	643.0	486.0	63.9	56.0
	max	25.6	26.5	9.5	9.1	1278.0	980.0	93.6	88.6
	mean	22.0	23.2	8.7	8.7	917.1	815.7	78.8	79.3
	se	0.7	0.6	0.1	0.1	62.7	45.3	4.1	3.4

pH was similar within the rehydration tanks to that recorded from inundated pools within the Survey Area in the Dry 2021. Average pH recorded from the tanks during the trials ranged from 7.8 in MarC5 during Phase 1, to 9.5 in MarC6 during Phase 2 (Table 4.11). This is comparable to the range recorded from Marillana Creek in the Dry 2021; 7.8 (MarC6a) to 9.1 (MarC3). The pH recorded within the inundated trial tanks was well within the range experienced in Pilbara pools and was considered to be conducive to successful hatching.

EC was notably lower within the rehydration tanks than that recorded from inundated Marillana Creek pools. For example, EC was 3,187 µS/cm at MarC6a and 2,517 µS/cm at MarC3 during the Dry 2021, in comparison to averages in the rehydration trials ranging from 710 µS/cm (MarC2 during Phase 2) to 2,140 µS/cm (MarC4 during Phase 1) (Table 4.11). The mean EC values recorded during the rehydration trials were indicative of fresh waters (i.e., < 1500 µS/cm) for all tanks aside from MarC4 (2,140 µS/cm during Phase 1). Overall, EC was unlikely to adversely affect emergence in the rehydration tanks. The higher EC recorded from inundated pools on Marillana Creek likely reflect the evapoconcentration of ions as the pools were highly receded at the time of sampling.

4.7.1 Taxonomic composition and species richness

The Dry 2021 rehydration trials were relatively productive, yielding a total of 19 invertebrate taxa and three submerged macrophytes (Table 4.12). Over 2,500 specimens emerged from the five trial tanks. Invertebrate taxa which emerged from the Marillana Creek sediments included Rotifera (rotifers; two taxa[8]), Turbellaria (flat worms; one taxon), Collembola (spring tail; one taxon), Cladocera (water fleas; four taxa), Copepoda (copepods; two taxa), Ostracoda (seed shrimp; seven taxa), and Diptera (two-winged flies; two taxa). Three of the rehydrate tanks (MarC1, MarC4 and MarC6) also yielded macrophytes, including *Chara fibrosa*, *Chara globularis* and *Vallisneria* sp.

Overall taxa richness across both wetting phases ranged from five (at MarC2 and MarC4) to nine (at MarC5) (Table 4.12). Crustacea was the richest group, of which Ostracoda was the most diverse and found to emerge from sediments collected from every site. As is commonly the case in emergence trials, macrophytes tended to emerge first, followed by Rotifera on Day 13 (Wetting Phase 1). On Day 25 (Wetting Phase 1), Turbellaria appeared in MarC5 and MarC6, and Ostracoda in MarC4. However, an algal bloom occurred in the MarC4 tank two days later, resulting in a die-off and few Ostracoda remained at harvest (Day 29). During Wetting Phase 2, Cladocera were the first to emerge on Day 23 in the MarC4 tank, followed by Ostracoda in MarC1 on Day 26.

The emergence trials added four taxa to the list of species known from the Study Area, including:

- Rotifera Flosculariidae spp. (MarC4)
- Cladocera *Alona excisa* (MarC4) and *Alona rigidicaudis* (MarC2, MarC5 and MarC6)
- Ostracoda *Riocypris* `sp. Biologic-OSTR019` (MarC5).

[8] Rotifers collected from rehydrate-emergence trials were not sent to the taxonomic expert and therefore were not identified past Rotifera.

Table 4.12: Taxa recorded from the Dry 2021 rehydration trials.

			Wetting Phase 1					Wetting Phase 2				
			MarC1	**MarC2**	**MarC4**	**MarC5**	**MarC6**	**MarC1**	**MarC2**	**MarC4**	**MarC5**	**MarC6**
CHLOROPHYTA												
CHAROPHYCEAE												
Charales	**Characeae**	*Chara fibrosa*	X				X	X				
		Chara globularis			X					X		
PLANTAE												
LILIOPSIDA												
Alismatales	**Hydrocharitaceae**	*Vallisneria* sp.				X					X	
ANIMALIA												
ROTIFERA		Rotifera sp.				2	2					2
Monogononta												
Flosculariaceae	**Flosculariidae**	Flosculariidae spp.			2							
PLATYHELMINTHES		Turbellaria sp.				1	1		1		1	
COLLEMBOLA												
Poduromorpha												
Poduroidea		Poduroidea sp.				1						
ARTHROPODA												
Branchiopoda												
Diplostraca	**Chydoridae**	*Alona* cf. *rigidicaudis*					2					
		Alona excisa			3					3		
		Alona rigidicaudis		1		2			4		4	3
	Ilyocryptidae	*Ilyocryptus spinifer*										1
Maxillopoda												
Calanoida		Calanoida sp.				1						
Cyclopoida		Cyclopoida sp.	1									
Ostracoda												
Podocopida	**Cyprididae**	Cyprididae sp.						3				
		Cypretta `sp. Biologic-OSTR015`		1		1						
		Ilyodromus sp.										2
		Riocypris `sp. Biologic-OSTR019`				1						
		Stenocypris major						3	3			
	Limnocytheridae	*Limnocythere dorsosicula*								1		
		Limnocythere sp.	2					1				
INSECTA												
Diptera												
	Psychodidae	Psychodidae sp.		1	2	1						
	Sciaridae	Sciaridae sp.	1									
		Taxa richness	**4**	**3**	**4**	**9**	**4**	**4**	**3**	**3**	**3**	**4**

4.7.2 Conservation significance of emergent fauna

Taxa recorded during the rehydration trials are widely distributed and none are listed as being of conservation significance.

4.8 Fish

4.8.1 Species composition and richness

Four freshwater fish species were recorded in the current study: western rainbowfish *Melanotaenia australis* (Melanotaeniidae), Pilbara tandan *Neosilurus* sp.[9] (Plotosidae), Pilbara bony bream *Nematalosa* sp.[10] (Clupeidae) and spangled perch *Leiopotherapon unicolor* (Terapontidae). Of these, two (spangled perch and Pilbara tandan) were recorded within the Study Area.

4.8.2 Abundance

A total of 1,431 individual fish was recorded in the current study, with 915 recorded in the Dry 2021 (305 from the Study Area and 610 from reference sites), and 516 in the Wet 2022 (70 individuals from the Study Area and 446 from reference sites) (Table 4.13). Within the Study Area, the greatest abundance of fish was recorded from MarC6a in the Dry 2021 (166 individuals), and MarC3 in the Wet 2022 (41 individuals). This compares to a maximum of 256 individuals recorded from a reference site in the Dry 2021 (WWS), and 211 in the Wet 2022 (SS). Of all sites successfully sampled, MarC3 recorded the lowest abundance of fish in the Dry 2021 (139 individuals), and MarC5 in the Wet 2022 (12 individuals) (Table 4.13).

Fish diversity within the Study Area was low, with only one species recorded from MarC5, MarC6 and MarC6a (spangled perch) (Table 4.13). Highest fish diversity was recorded from reference site SS, with all four fish species recorded. Spangled perch was the most widespread species overall, being recorded at all Study Area sites that held sufficient water for sampling (MarC3, MarC5, MarC6 and MarC6a), and all six reference sites, in at least one season. Although western rainbowfish was widely distributed across reference sites, it was not recorded within the Study Area (Table 4.13). Previous surveys within the Study Area also failed to record western rainbowfish (Biologic, 2022b).

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[9] The *Neosilurus* catfish known from the Pilbara is genetically distinct to the described species *Neosilurus hyrtlii* (Unmack 2013). The Pilbara species is currently known as *Neosilurus* sp. until further taxonomic work has been undertaken and descriptions have been made.

[10] Similarly, the *Nematalosa* bony bream from the Pilbara is genetically distinct to the described *Nematalosa erebi*. The Pilbara species is referred to as *Nematalosa* sp. until further taxonomic work has been undertaken.

Table 4.13: Abundance of each freshwater fish species recorded from each site.

Type	Site	*Leiopotherapon unicolor* Spangled perch		*Melanotaenia australis* Western rainbowfish		*Neosilurus* sp. Pilbara tandan		*Nematolosa* sp. Pilbara bony bream		Abundance		Diversity	
		D	W	D	W	D	W	D	W	D	W	D	W
Study Area	**MarC1**	-	0	-	0	-	0	-	0	**-**	**0**	**-**	**0**
	MarC2	-	0	-	0	-	0	-	0	**-**	**0**	**-**	**0**
	MarC3	136	41	0	0	3	0	0	0	**139**	**41**	**2**	**1**
	MarC4	-	0	-	0	-	0	-	0	**-**	**0**	**-**	**0**
	MarC5	-	12	-	0	-	0	-	0	**-**	**12**	**-**	**1**
	MarC6	-	17	-	0	-	0	-	0	**-**	**17**	**-**	**1**
	MarC6a	166	-	0	-	0	-	0	-	**166**	**-**	**1**	**-**
Reference	**MACREF1**	0	1	87	36	0	0	0	0	**87**	**37**	**1**	**2**
	MACREF2	25	19	0	0	0	0	0	0	**25**	**19**	**1**	**1**
	WWS	0	1	248	32	8	12	0	0	**256**	**45**	**2**	**3**
	BENS	32	66	11	42	3	26	0	0	**46**	**134**	**3**	**3**
	SS	133	42	41	109	19	22	3	38	**196**	**211**	**4**	**4**
	Abundance	**492**	**199**	**387**	**219**	**33**	**60**	**3**	**38**	**915**	**516**		
										1,431			

D = dry season

W = wet season

* MUNJS does not support fish

Spangled perch was the most abundant fish in the Study Area, with 302 individuals recorded during the Dry 2021 and 70 during Wet 2022. Only three individual Pilbara tandan were recorded in the Study Area (MarC3 in Dry 2021). Western rainbowfish was the most abundant fish within reference sites, with 387 individuals recorded during the Dry 2021, and 219 during Wet 2022. Pilbara tandan was relatively abundant at reference sites, with 30 individuals recorded in the Dry 2021, and 60 in the Wet 2022. The Pilbara bony bream was only recorded at reference site SS, with three individuals recorded during the Dry 2021, and 38 individuals in the Wet 2022 (Table 4.13).

4.8.3 Conservation significant fish species

Despite the low diversity known from the Pilbara, the region does support high endemicity in freshwater fishes (56%; Morgan *et al*., 2014). Two species recorded during the current study are endemic to the region: the Pilbara tandan and the Pilbara bony bream. Both are representatives of genera which are wide-ranging across northern Australia; however, the species' recorded from the Pilbara are genetically distinct to common and widespread congeners (i.e., *Neosilurus hyrtlii* or *Nematalosa erebi*) (Unmack, 2013). Both species occur widely throughout the Pilbara, and neither are currently listed as being of conservation significance. The Pilbara tandan is generally less commonly recorded, likely due to its cryptic nature, being commonly found under snags and undercuts. The Pilbara tandan was recorded from the Study Area, while the Pilbara bony bream was only recorded from one reference site.

4.8.4 Length-frequency analysis

The seasonal, yet unpredictable nature of rainfall and streamflow in the Pilbara is reflected in the opportunistic and periodic reproductive strategies of Pilbara freshwater fish (Beesley, 2006). Most species breed during the wet season, a time when new recruits and juveniles have the greatest chance of survival owing to the greater persistence of water/ habitat, increased ecosystem productivity, and availability of food resources. Larvae have only a short window, usually in the order of a few days, with which to locate food or risk starving. Analysis of population structure and age-class distribution provides a way of characterising recruitment, the health of local fish assemblages, and therefore the environmental conditions present which can support or impede recruitment. Length-frequency analysis was only undertaken for spangled perch, as this was the only species recorded from the Study Area, in sufficient abundance

Spangled perch

Spangled perch breed during the wet season, between late November and March (Beesley, 2006), with spawning generally coinciding with flooding events (Morgan *et al.*, 2002). Several spawning events will occur over the wet season (Beesley, 2006). Maturity is attained after the first year, at around 58 mm TL[11] for males and 78 mm TL for females. To allow for determination of age-classes (without knowing

[11] Measurements of TL (total length) include the tail.

sex), size at maturity was estimated at 70 mm SL for the purposes of this study. Maximum size is ~ 300 mm TL.

In the Study Area, juveniles comprised a large proportion of spangled perch during both the Dry 2021 and Wet 2022 (48% and 62%, respectively (Figure 4.32). A high proportion of sub-adults and adults were also present in the Dry 2021 (23% and 30%, respectively). In the Wet 2022 however, new recruits made up 23% of spangled perch recorded, suggesting a recent recruitment event prior to the Wet 2022 survey, likely following rainfall associated with the wet. Adults constituted the greatest proportion of spangled perch at reference sites during Dry 2021 (66%), while juveniles made up the greatest proportion in Wet 2022 (48%) (Figure 4.32).

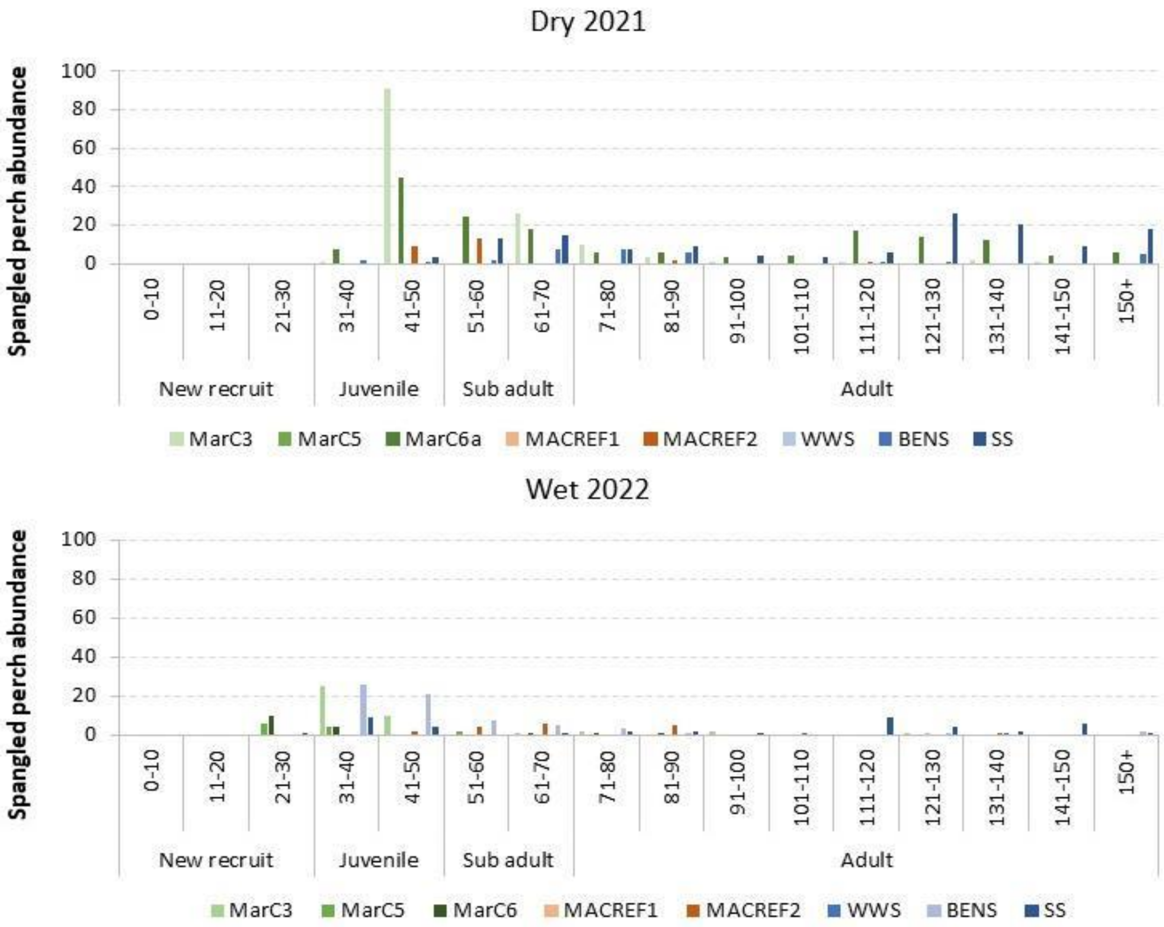

Figure 4.32: Length frequency analysis for spangled perch in the Dry 2021 (top) and the Wet 2022 (bottom).

Pilbara tandan

As it is a relatively new, undescribed species, the breeding ecology of the Pilbara tandan is unknown; however, information relating to congeneric species may provide some insight. In northern populations of the closely related *Neosilurus hyrtlii,* breeding occurs early in the wet season in shallow, sandy/gravelly areas of the upper reaches of creeks (Allen *et al.*, 2002) and fecundity ranges from 1,600 to 15,300 eggs (Orr & Milward, 1984). While other eel-tailed catfish, such as *Tandanus tandanus*, construct a unique nest into which eggs are spawned (Burndred *et al.*, 2017), the available evidence suggests that *N. hyrtlii* simply scatter fertilised eggs over the substrate (Orr & Milward, 1984). Sexual maturity in *N. hyrtlii* is attained at around 90 mm SL and they reach a maximum size of 400 mm TL (Bishop *et al.*, 2001).

Only three Pilbara tandan were recorded from the Study Area during the Dry 2021 (one sub-adult and two adults). No Pilbara tandan were recorded in the Wet 2022. At reference sites, adults comprised the greatest proportion of Pilbara tandan during both the Dry 2021 and Wet 2022 (70% and 95%, respectively). No new recruits or juveniles were recorded from the Study Area or reference sites during the current study. Interpretations regarding population structure of Pilbara tandan in the area are complicated by the low numbers of fish recorded as a result of their cryptic nature.

4.9 Other Vertebrate Fauna

4.9.1 Frogs

Two species of frog were recorded during the current study. Desert tree frog (*Litoria rubella*) adults (Plate 4.2) were observed at reference site (MACREF1), while adults (MarC3) and tadpoles (MarC1) were recorded from two sites within the Study Area. Pilbara toadlet (*Uperoleia saxatilis*) tadpoles were also recorded from MarC1 during the Wet 2022.

Plate 4.2: The desert tree frog (*Litoria rubella*) recorded from Marillana Creek.

5 DISCUSSION

5.1 Habitat Assessment

Numerous surface water pools occur along the length of the Study Area, with some riffle/run sequences present in the upper extent of Marillana Creek and its tributary during the wet season, especially at reference site MACREF2. Although the sampling site pools were previously considered permanent to semi-permanent, all previous sampling locations along the creek were dry at the time of the Dry 2021 survey, except MACREF2. A pool approximately 120 m downstream of MarC3 was present, however, and able to be sampled. The drying of the creek occurred after a relatively good wet season, with above average rainfall recorded from the Flat Rocks gauging station (near MarC6) in February and April 2021, although there was minimal rainfall between this time and the October 2021 dry-season survey. The lowering water levels in the creek may be associated with drawdown impacts from nearby mining, especially those in the more downstream extent of the Study Area. This should be investigated further. Other disturbances included the presence of weeds throughout the Study Area as well as disturbance by cattle, with banks trampled and vegetation showing signs of grazing.

Most sites were dominated by submissive substrates such as pebbles, gravel and sand. Exceptions included MarC3, MarC6a, MARCREF1, MACREF2 and MUNJS, which were comprised primarily of bedrock, and MarC6, which was dominated by clay and bedrock substrate. In-stream habitat diversity was generally high throughout the Study Area, consisting of complex, heterogenous structures that support aquatic fauna, including macrophytes, LWD, root mats, detritus and trailing vegetation. Sites along Marillana Creek had particularly high percent cover of macrophytes compared with reference sites.

5.2 Water Quality

Surface waters of the Study Area were characterised by fresh to brackish, well buffered, clear waters, with wide-ranging dissolved oxygen saturation, basic to circum-neutral pH, low concentrations of nitrogen nutrients but high total phosphorus, and generally low concentrations of dissolved metals. EC of all sites within the Study Area exceeded both the ANZG (2018) DGV, and several also exceeded the 1,500 µS/cm point of ecological stress, with the exception of MarC1, MarC5 and MarC6. EC recorded from the Study Area was significantly greater than that from the reference sites. Generally, aquatic ecosystems with EC lower than 1,500 µS/cm experience little ecological stress but a considerable shift in aquatic fauna assemblages is known to occur above this threshold. Many Pilbara waters have wide-ranging EC, with large temporal and seasonal variability. Receding waters in the drier months lead to evapoconcentration of ions, followed by wet season flushing and dilution effects. Long-term changes in EC, however, may be accompanied by impacts to invertebrates and a change in the structure of assemblages.

DO concentrations within the Study Area were highly variable, with low DO recorded at many sites and often falling below the lower ANZG (2018) DGV. DO at one Study Area site (MarC1) and one reference site (BENS in the wet) were below the point of ecological stress (~30%). Although the oxygen needs of aquatic biota differ between species and life history stage, Butler and Burrows (2007) reported that acute toxicity occurred between 25% and 30% DO saturation for six tropical freshwater fish species from northern Australia. In addition, DO saturation and water temperature in aquatic systems vary across the diel cycle (Connolly *et al.*, 2004). Typically, the lowest DO saturation and water temperatures occurs in the early morning, and the highest saturation in the early afternoon (Connolly *et al.*, 2004). The diel cycle for DO is usually driven by photosynthetic processes in aquatic plants and algae, producing high oxygen concentrations during the daytime. Conversely, overnight respiration by organisms produces carbon dioxide, lowering oxygen levels in the water column (Connolly *et al.*, 2004). Therefore, short periods of low DO would be well within the aquatic fauna's ability to persist, but sustained periods of low DO would likely adversely affect the resident biota. Conversely, two sites in the Study Area had super-saturated DO (MarC3 in the dry and MarC6 in the wet). The high DO at these sites was likely due to the relatively small pool size and relatively high abundance of algae at MarC3, and the high proportion of submerged macrophyte cover and therefore high rates of photosynthesis during the day at MarC6. These sites would likely experience oxygen stress overnight. The high DO recorded during the day could result in gas bubble disease, which can lead to emboli in the blood, heart and gill filaments of fish (Wang *et al.*, 2018). Effects can vary from mild to fatal depending on the extent of supersaturation and water temperature, and the species, life history stage and general health of the fish (Beeman *et al.*, 2003). No reference sites had DO saturation in excess of the ANZG (2018) upper DGV. Overall, DO saturation within the Study Area pools was significantly greater than the reference sites.

There was minimal change in ionic dominance of surface waters within the Study Area between site and season, or across surveys over time (see Biologic, 2022a). Generally, all sites were dominated by sodium (Na) cations and hydrogen carbonate (HCO_3) anions. The only exceptions to this were MarC1 (dominated by calcium cations) and MarC6 (dominated by chloride anions). These exceptions were consistent with the previous survey (Biologic, 2022b). Generally, ionic concentrations (Na, Ca, HCO_3 and Cl) decreased along Marillana Creek, from upstream to the downstream extent, suggesting that perhaps there is a greater contribution by rainfall in the lower reaches, as rainwater tends to have lower concentrations of ions than groundwater. Dogramaci and Skrzypek (2015) found that groundwater hydrochemistry within alluvial, fractured and CID aquifers was dominated by Ca, Mg and HCO_3, while groundwaters within saline alluvium (i.e. beneath the Fortescue Marsh) were dominated by Na and Cl. The ion concentrations that were recorded from Study Area sites such as MarC1 (Ca and HCO_3 dominant) indicate some contributions by groundwater. In contrast, those from surface water pools at the most downstream extent of Marillana Creek, such as MarC6 (Na and Cl dominant), reflect the contribution of rainwater, with persistence likely linked to the clay and bedrock substrate which has low transmissivity.

Nitrogen nutrient concentrations within the Study Area were low and below toxicity DGVs. The only exception was total N, which was recorded in excess of the eutrophication DGV at two Study Area sites in the dry season (MarC3 and MarC6a). Overall, the average total N concentrations within the Study Area were significantly greater than at reference sites. Total P concentrations were high and in excess of the eutrophication DGV across all Study Area and reference sites in both seasons. Similar results were recorded previously from the creek for total N and total P (Biologic, 2022b). The eutrophication DGV is designed to protect aquatic ecosystems from the effects of nuisance algal and macrophyte growth. Excessive plant growth can physically smother aquatic invertebrates, as well as deplete oxygen in the water, due to increased biological oxygen demand as plants decay and are decomposed by bacteria. The relationship between nitrate-enrichment and enhanced algal growth in freshwaters is well documented, often resulting in very high density/abundance but low species richness (Camargo & Alonso, 2006; Wagenhoff *et al.*, 2011). While the idea that phosphorus (as FRP or total P) is the primary factor limiting algal growth in freshwaters has been challenged as too simplistic (Beck & Hall, 2018; Elser *et al.*, 2007; Muhid & Burford, 2012), any additional nutrient inputs to the Study Area (such as from cattle or groundwater discharge) would increase the risk of eutrophication.

Dissolved metal concentrations were generally low but dB was recorded in concentrations greater than the 95% toxicity DGV within the Study Area. Dissolved boron was elevated at MarC6a (dry), MarC2 (wet), MarC4 (wet), and MarC3 (in both seasons), as well as reference site MACREF2, also located on Marillana Creek (in both seasons). The high dB concentrations recorded in the current study are not atypical for Pilbara surface waters, with many pools and springs commonly having dB values within the range recorded here. Elevated dB was recorded from the Study Area previously (Biologic, 2022b). The ANZG (2018) DGV is perhaps too conservative for freshwater ecosystems of the Pilbara region. Two other dissolved metals exceeded 99% toxicity DGVs from at least one Study Area site (dAs and dMn). Several dissolved metals were recorded in significantly greater concentrations from the Study Area compared with the reference sites, including dAs, dB, dU and dV.

The drying which occurred in the Study Area in the Dry 2021 led to greater concentrations of several analytes within the remaining pools, including EC and associated ions, total N, dAs and dB. Overall, EC and concentrations of Na, Mg and total N differed significantly between sampling events.

5.3 Macrophytes

As noted previously (Biologic, 2022b), a 2.7 km portion of the Study Area from the confluence with the tributary down to MarC4 comprises a high significance GDE (Biologic, 2022a). This GDE extends a further 1.2 km on Marillana Creek upstream of the confluence with the tributary and includes the MACREF2 reference site. This reach supports numerous species of groundwater-dependent vegetation, including *Melaleuca argentea*, a known obligate phreatophyte that is almost entirely dependent on groundwater (Graham *et al.*, 2003; McLean, 2014). *M. argentea* is considered a very high-level key mesophytic/hydrophytic indicator species (Rio Tinto, 2021), indicating the presence of groundwater close to, and expressing on, the surface. In addition to *M. argentea*, other high level mesophytic/hydrophytic indicator species such as *Eucalyptus camaldulensis*, *Acacia ampliceps* and *Melaleuca bracteata* were recorded from this area, as well as the moderate-level indicator species *Eucalyptus victrix*, *Cyperus vaginatus* (where abundant, such as at MarC2 and MACREF2), *Eleocharis geniculata* and *Schenoplectus subulatus* (Rio Tinto, 2021). This reach also supported low-level indicator species such as *Acacia coriacea* subsp. *pendens*, *Ammannia baccifera* (aquatic), *Cyperus vaginatus* (when in scattered abundance), *Melaleuca glomerata* and *Typha domingensis*. In places, the groundwater-dependent vegetation was dense. In addition to these GDVs, numerous submerged macrophytes were recorded from this reach of Marillana Creek, including *Chara* sp., *Chara fibrosa*, *Chara globularis*, *Vallisneria nana*, *Potamogeton tepperi* and *Najas tenuifolia*, all of which are considered to be moderate hydrophytic indicators.

Downstream of this significant GDE, a GDE of moderate significance (Biologic, 2022a) occurrs over an approximate distance of 1.45 km. This section of Marillana Creek contained sparser stands of *M. argentea*, but still supported other mesophytic species (*Cyperus vaginatus* and *Schoenoplectus subulatus*). Large mature *M. argentea* were present at MarC5, near the lower extent of the GDE.

Upstream, on the tributary of Marillana Creek, a small and isolated GDE of moderate significance (Biologic, 2022a) was present at MarC1, which extended for approximately 250 m. Mesophytic /hydrophytic indicator species were recorded, including *Melaleuca argentea* and *Cyperus vaginatus*, at this location.

The pools within the Study Area that were initially selected for sampling were thought to be permanent or at least highly persistent, with MarC6 acknowledged to dry from time to time. The flora and vegetation within the Study Area provides evidence that these pools, especially those in the upper extent of the Study Area and MACREF2, held permanent water, given the high richness and density of mesophytic and hydrophytic indicator flora species. Despite this, only two sites held water in the Dry 2021. The flora and vegetation showed signs of water stress, with sedges in poor condition. In addition, during tree-health monitoring, a decline in tree canopy health was observed by Biologic (2022d) in the dry season of 2021, compared with previous tree health surveys. At tree-health monitoring Site 2 (located 194 m downstream of MarC2) and Site 1 (located 132 m upstream of MarC5), reductions in average foliage cover were reported for *M. argentea* and *E. camaldulensis* at both sites. Declines in the health of *M. argentea* have been recorded with as little as an 0.5 m decrease in groundwater levels (McLean, 2014). The dry condition of Marillana Creek in the Dry 2021, and the accompanying reductions in tree health, were unexpected given the previous assessment which noted the presence of permanent surface water pools across the reach {Biologic, 2022 #5773}. Potential impacts from dewatering from the nearby BHP Yandi mine should be considered and investigated.

As has been previously reported (Biologic, 2022b), macrophyte (submerged and emergent macrophyte) richness in the Study Area is high, particularly at MarC4 and MarC6. When compared with the PBS dataset, these two Study Area sites had greater macrophyte richness than the Weeli Wolli Spring PEC, as sampled prior to any mining or impacts from invasive species. The high macrophyte richness within pools of the Study Area is notable for the region, given that the listing of the Weeli Wolli Spring Priority 1 PEC states: “Weeli Wolli Spring's riparian woodland and forest associations are unusual as a consequence of the composition of the understorey. The sedge and herbfield communities that fringe many of the pools and associated water bodies along the main channels of Weeli Wolli Creek have not been recorded from any other wetland site in the Pilbara” (DBCA, 2017).

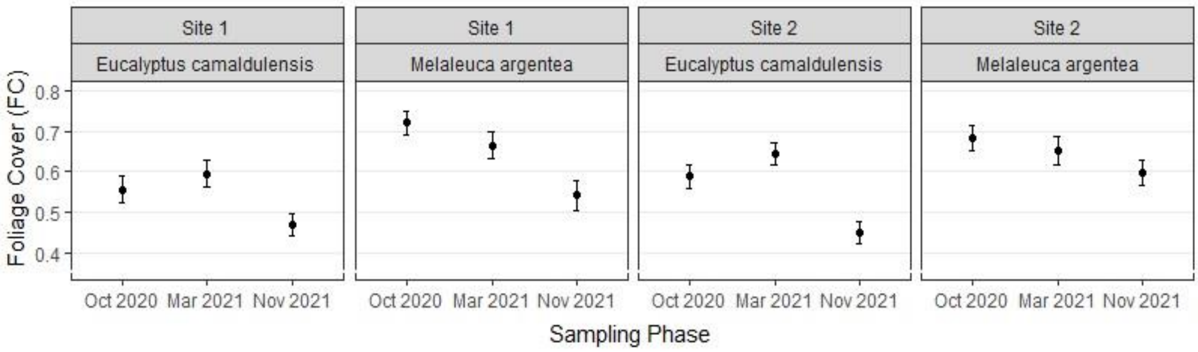

Figure 5.1: Average foliage cover (± standard error) recorded from trees on Marillana Creek at Tree Health Monitoring Site 1 (~ 132 m upstream of MarC6) and Site 2 (~ 194 m downstream of MarC2) by Biologic (2022d).

5.4 Zooplankton

Eighty-seven zooplankton taxa were recorded from the Study Area, including protists, Ciliophora, Gastrotricha, rotifers, Cladocera, Maxillopoda (copepods) and ostracods. No taxa recorded from the Study Area are currently listed or are of conservation significance. Most were widespread species, with two being Pilbara endemics (*Vestalenula marmonieri*, and *Bennelongia* `sp. Biologic-OSTR026`).

Within-site zooplankton richness was highly variable but, overall, average richness within the Study Area was significantly greater than reference sites. Seasonal variation within reference sites was high, with lower zooplankton richness generally recorded in the wet season following rainfall and flooding. Being planktonic, zooplankton are highly responsive to increases in flow and flooding events, with high flows likely flushing zooplankton taxa from these reference sites, and the population yet to fully re-establish by the time of the survey. This seasonal variation was not as apparent within the Study Area; however, change over time is, with zooplankton richness increasing significantly over time (linear regression).

Average zooplankton richness from the Study Area was compared to nearby creeklines and, overall, there was a significant difference between creeks/reaches. Although the post-hoc test failed to locate these differences due to the large variation within creeks, the average zooplankton richness recorded from the Study Area was greater than all other creeks/reaches included in the analysis (Marillana Creek Downstream of the Study Area, Munjina Creek, Yandicoogina Creek, Weeli Wolli Spring, Weeli Wolli Creek and the Davis River).

5.5 Hyporheos Fauna

A total of 151 invertebrate taxa was recorded from hyporheic zones along Marillana Creek in the current study. These included:

- 41 taxa recorded from the Study Area in the Dry 2021
- 76 taxa recorded from the Study Area in the Wet 2022

- 106 taxa recorded from the additional hyporheic sites on Marillana Creek, downstream of the Study Area in the Wet 2022.

Of these, 15% are directly dependant on groundwater for their persistence (8% stygobites and 3% permanent hyporheos stygophiles). The percentage of stygobitic taxa was greater than that reported previously for Pilbara hyporheic zones (i.e. 5% stygobitic fauna recorded in Halse *et al*. 2002), highlighting the strong groundwater connection beneath Marillana Creek.

This connection varies along the length of the creek, with the greatest richness of hyporheos fauna recorded from MarC2 and MarC9H, and the greatest richness of groundwater-dependent fauna (stygobites and permanent hyporheos stygophiles) recorded from MarC2, MC4H and MC10H. Reference sites also had a relatively high number of groundwater-dependent taxa from WWS and SS, although this was lower than the Marillana Creek sites. With the exception of the Dry 2021, the richness of groundwater-dependent taxa recorded from the Study Area was generally comparable with that recorded from the reference sites, most of which are springs known for their connection to groundwater and their rich stygofauna. Overall, there was no significant difference in the richness of hyporheos fauna or groundwater-dependent taxa between sampling events or between site type (Study Area vs reference).

While most of the taxa recorded within hyporheic zones of the Study Area and additional Marillana Creek sites were common and widespread, several were of interest due to being either locally restricted, rarely collected and/or representing potentially new species. These include:

- Water mites
    - *Guineaxonopsis* \`sp. Biologic-ACAR011\` (MarC2) – based on current records, appears to occur only within the Upper Fortescue River catchment (Western Creek, Upper Fortescue River, Weeli Wolli Spring and Marillana Creek). Further work may find this taxon to be more widespread.
    - *Guineaxonopsis* \`sp. Biologic-ACAR013\` (MarC2 and MarC4) – currently known only from Marillana Creek, but it is likely that further morphological and molecular work will increase its known distribution in the future.
    - *Rutacarus* \`sp. Biologic-ACAR006\` (MC4H) – previously known from Weeli Wolli Creek. Further work may find this taxon to be more widespread.
    - *Hesperomomonia* \`sp. Biologic-ACAR014\` (MC10H) – may represent the described species *Hesperomomonia humphreysi* but insufficient information is available to confirm this. *Hesperomomonia humphreysi* is known only from the Fortescue River system, but has a linear range of more than 350 km.
- Ostracods
    - *Meridiescandona* \`sp. Biologic-OSTR074\` (MC4H and MC10H) – known from Yandicoogina Creek and now Marillana Creek. Likely represents the described species *Meridiescandona marillanae* given its distribution. Likely to have a restricted range.
- Copepods

  - *Parastenocaris* `sp. Biologic-HARP037` (MarC2) – first record of this taxon.
- Amphipods
  - *Chydaekata* sp. E ((MC5H and MC9H) – known to have a restricted range, occurring only within Marillana, Weeli Wolli and Yandicoogina Creeks.
  - *Chydaekata* sp. MJ1-UM1 (MarC4) – a known SRE, recorded from upper Marillana Creek only.
  - Paramelitidae `sp. Biologic-AMPH024` (MC4H) - previously known from Weeli Wolli Spring. Should be considered a Potential SRE.
  - Paramelitidae `sp. Biologic-AMPH070` (MC3H) – first record of this taxon. Likely represents a Potential SRE.
- Syncarids
  - *Atopobathynella* `sp. Biologic-PBAT042` (MC10H) – currently known only from Yandicoogina Creek and Marillana Creek, across a linear distance of 4.5 km. Should be considered a Potential SRE.
  - *Atopobathynella* `sp. Biologic-PBAT044` (MC3H) – first record of this taxon. Should be considered a Potential SRE.
  - Bathynellidae sp. (MarC2) – likely represents a new, undescribed species.

In addition to the groundwater-dependent taxa recorded from hyporheic zones in Marillana Creek, one troglofauna specimen was collected from MarC4 in the Dry 2021. This was the Symphyla *Hanseniella* `sp. Biologic-SYMP055`. All taxa within the *Hanseniella* genus are considered troglobites and have small ranges less than 50 km (Bennelongia, 2013, 2015a, 2016). Therefore, *Hanseniella* `sp. Biologic-SYMP055` likely represents a Potential SRE (Data Deficient).

5.6 Macroinvertebrates

A total of 208 macroinvertebrate taxa was recorded from surface waters within the Study Area: 105 taxa from two sites in the Dry 2021 and 179 from six sites in the Wet 2022. The macroinvertebrate fauna included Cnidaria, Platyhelminthes, Nematoda, Mollusca, Oligochaeta, Acarina, Collembola, Coleoptera, Diptera, Ephemeroptera, Hemiptera, Lepidoptera, Odonata and Trichoptera. Within-site macroinvertebrate diversity was relatively high within the Study Area (≥ 44 taxa at MarC6), with greatest richness from the Study Area recorded from MarC2 (88 taxa in the wet) and MarC3 (78 taxa in the wet). In comparison, the greatest richness recorded from a reference site was 83 (BENS in the Dry 2021). Overall, there was no significant difference in average macroinvertebrate richness between sampling events or between site type (Study Area vs reference). Interestingly, the average richness recorded from the Study Area during the Dry 2021 was greater than the previous Wet 2021 or Dry 2020 sampling events. Remnant pools within ephemeral systems are known to provide important refuge habitat during drought conditions where habitat, quality and pool size remain suitable (Bogan *et al.*, 2019). It is likely that aerial and mobile aquatic invertebrates moved to the remaining pools, as others receded and dried, leading to high richness within the two remnant pools.

The composition of macroinvertebrates was generally similar to most Pilbara pools, being dominated by slow flow taxa and those known to be relatively tolerant of anthropogenic disturbance and water quality changes (Pinder *et al.,* 2010). Taxa that require faster flows, such as Lepidoptera, leptophlebiid mayflies, Simulidae (Diptera), *Cheumatopsyche* and *Chimarra* caddisflies (Trichoptera) were generally restricted to the flowing reference sites and, within the Study Area, to the upstream sites MarC2 and MarC3 in the Wet 2022. As has been reported previously (Biologic, 2022b), notably high odonate richness was recorded within the Study Area, from MarC4 (12 taxa, Wet 2022). In the previous study, high odonate diversity was recorded from MarC5 (14 taxa, Dry 2020) and MarC6 (11 taxa, Wet 2021) (Biologic, 2022b). Reference site MACREF1 on the tributary of Yandicoogina Creek also had notably high richness of odonates (13 taxa, Dry 2021). The diversity and composition of odonate assemblages is known to be related to the abundance and richness of littoral zone wetland flora, extent of riparian disturbance, benthic substrate granularity and in-stream productivity (Butler & deMaynadier, 2007). Although habitat preferences may vary depending on species, most damselflies and hawker dragonflies require substantial submerged and emergent macrophytes on which to lay their eggs and ensure protection from predators (Paulson, 2019). Females have a sharp ovipositor that they use to cut into vegetation and deposit their eggs. Other species use waterside vegetation as perches (Theischinger *et al.*, 2021). The high diversity of odonate larvae within the Study Area suggests that pools have reasonably extensive riparian vegetation and a high abundance and diversity of submerged and macrophytes.

Significant differences were found in macroinvertebrate assemblages of the Study Area between sampling events. These differences in assemblages over time were found to be significantly correlated with seven environmental predictor variables, including EC, pH, turbidity, calcium concentration, concentration of dissolved copper, total phosphorus and percent cover of submerged macrophytes. This highlights the importance of water quality and macrophyte cover to the aquatic invertebrate assemblages of the Study Area pools. Variables relating to hydrology (persistence), EC, turbidity, submerged macrophytes and sediment composition are known to be important drivers of invertebrate community composition in dryland rivers (Costelloe *et al.*, 2004; Shiel *et al.*, 2006). In their study of over 100 Pilbara pools, Pinder *et al.* (2010) found that EC, turbidity and submerged macrophytes were three of the environmental variables most strongly correlated with macroinvertebrate assemblages and patterns of occurrence in Pilbara pools, along with flow, hydrological persistence and sediment.

While most aquatic macroinvertebrates recorded from the Study Area were common, widespread species, several species were of note and/or were of conservation significance, including:

- the Pilbara pin damselfly *Eurysticta coolawanyah* (MarC4) – Vulnerable on the IUCN Redlist
- the water mite *Wandesia* sp. (MarC2) – taxonomy is poorly known, but potentially represents a restricted taxon
- the water mite *Guineaxonopsis* sp. (MarC4) – taxonomy is poorly known, but potentially represents a restricted taxon.

The Pilbara emerald dragonfly, *Hemicordulia koomina* (Vulnerable; IUCN, 2022) was also previously recorded from the Study Area but was not present in the Dry 2021 or Wet 2022 sampling events. *Hemicordulia koomina* was previously recorded from all Study Area sites except MarC2.

Macroinvertebrate richness was compared statistically to other aquatic surveys undertaken in the area. Overall, macroinvertebrate richness differed significantly between creeks, but not between seasons. Average macroinvertebrate richness within the Study Area was statistically similar to all creeklines/reaches included in the analysis, including the Weeli Wolli Spring PEC (as sampled during the PBS prior to any disturbance or mining impact) and the Davis River, but statistically greater than Weeli Wolli Creek (pools upstream of the spring). This is notable given that Weeli Wolli Spring is a recognised Priority 1 PEC, while SS and RW on the Davis River are both known for their particularly high richness of aquatic invertebrate fauna (Kendrick & McKenzie, 2001).

Multivariate analyses of the same dataset (current and previous other surveys) indicated that macroinvertebrate assemblages of the Study Area were statistically similar to those from Ben's Oasis, Munjina Spring and the Davis River, all of which are groundwater-fed systems. Study Area macroinvertebrate assemblages were significantly different to the downstream reach of Marillana Creek, Yandicoogina Creek, Weeli Wolli Spring and Weeli Wolli Creek.

While no introduced macroinvertebrate taxa were recorded from the Study Area, the introduced redclaw, *Cherax quadricarinatus* (a species of freshwater crayfish) was recorded from reference site WWS in both seasons. The short-term impacts of introduced crayfish have been widely reported in the literature and include habitat modification (Gherardi *et al.*, 2011), alteration to food webs, changes in nutrient and energy flow (Nyström *et al.*, 1999), introduction of disease, increased competition for limiting resources (Lynas *et al.*, 2006; Lynas *et al.*, 2007) and increased predation.

5.7 Rehydrates

The Dry 2021 rehydration trials were relatively productive, yielding over 2,500 specimens from 19 invertebrate taxa, as well as three submerged macrophyte taxa. While few rehydration studies are publicly available, and reported results are highly variable, the current study recorded comparable invertebrate taxa richness to what has been recorded for Pilbara sediments previously (i.e., ten invertebrate taxa recorded from Coolibah wetlands, 20 taxa from Warramboo, and 36 taxa from creeks near Paraburdoo) (WRM, 2016). As is commonly reported in rehydration studies, ostracods were the richest group found to emerge from sediments. Rotifers and crustaceans typically make up a large proportion of the invertebrate assemblage in temporary waters due to their ability to produce desiccation resistant propagules (also known as resting stages) capable of withstanding long periods of drought (Rossi *et al.*, 2013; Timms, 1993). In the current study, richness within the Rotifera was not quantified.

None of the taxa which emerged from Study Area sediments are listed as being of conservation significance. Three represent additional records to the known invertebrate richness with the Marillana Creek Study Area, including flosulariid rotifers (MarC4), the Cladocera *Alona excisa* (MarC4) and *Alona rigidicaudis* (MarC2, MarC5 and MarC6), and ostracod *Riocypris* \`sp. Biologic-OSTR019\` (MarC5).

5.8 Fish

Two freshwater fish species were recorded from Marillana Creek within the Study Area, and two additional species were recorded from reference sites. Study Area species included the spangled perch (*Leiopotherapon unicolor*) and Pilbara tandan (*Neosilurus* sp.). The absence of western rainbowfish (*Melanotaenia australis*) from the Study Area is interesting, given this species is known to be present downstream, including in locations as close as 800 m from the Study Area (WRM, 2015, 2018). However, the low diversity of fish across the Pilbara generally is well known, and is considered likely due to the region's aridity (Allen *et al.*, 2002; Masini, 1988; Morgan *et al.*, 2014). The greatest diversity of freshwater fish in the region is found in relatively clear, permanent, and semi-permanent pools. Although the Pilbara tandan is endemic to the region, none of the four species recorded are listed or of conservation significance. All are common and ubiquitous across the Pilbara.

A healthy breeding population of spangled perch was recorded from the Study Area, with new recruits present in the population during the Wet 2022 sampling event. Representatives from all life-history stages were present at this time. Although no new recruits were recorded in the Dry 2021, this was expected given that they breed in the wet season. Juveniles, sub-adults and adults were all present during the dry season. Yet the distribution of spangled perch throughout the Study Area appears to have decreased over time, and this is of concern. Despite all Study Area sites holding water during the Wet 2022, no fish were recorded from MarC1, MarC2 or MarC4. In the previous study, all Study Area sites supported an abundance of spangled perch (Biologic, 2022b). It appears that the drying of the creek in the Dry 2021 resulted in a loss of fish from this reach, with re-colonisation only occurring at a small subset of pools by the Wet 2022 survey. Further surveys in the future will assess the success of recolonisation throughout this reach of Marillana Creek.

5.9 Other Vertebrate Fauna

Frogs were the only other vertebrate aquatic fauna observed in the Study Area. Two species were recorded, including the desert tree frog (*Litoria rubella*) and Pilbara toadlet (*Uperoleia saxatilis*). At least one other species, the Mains Frog (*Cyclorana maini*), is considered likely to occur, based on database searches and the authors' experience in and around the Study Area. None of these frog species are restricted or listed as having conservation significance. All are relatively widespread along creeklines in the Pilbara region.

Other aquatic vertebrates considered likely to occur within the Study Area included the flat-shelled, or dinner plate turtle (*Chelodina steindachneri*) and the Pilbara olive python (*Liasis olivaceus barroni*). The flat-shelled turtle is endemic to Western Australia, and is found between the De Grey River in the north and the Irwin River in the south. They are found in both permanent and ephemeral systems and survive drought by aestivating in the riverbed or bank, emerging in response to heavy rain (Cann, 1998). They have been recorded from systems that dry for more than two years. *Chelodina steindachneri* is not currently listed on any conservation lists.

The Pilbara olive python, listed as a Matter of National Environmental Significance (MNES), is restricted to the Pilbara region and can be found in gorges, waterholes and on escarpments. It is currently listed as Vulnerable on both Federal (EPBC Act) and State (BC Act) conservation lists. Threats to Pilbara olive python and their habitat include fire, foxes and development of mining infrastructure. The closest record of the Pilbara olive python is from approximately 8 km to the west of the Study Area, on Herbert Creek (DBCA, 2022).

6 CONCLUSION

6.1 Main findings

This study confirmed the previous findings for the Study Area (Biologic, 2022b) that GDEs of varying levels of significance are present, and that the area is notable for its high richness of aquatic macrophytes, high diversity of odonates, and high aquatic invertebrate richness. In addition, the Study Area supported a greater richness of zooplankton taxa in comparison with spring reference sites, though this difference was not significant. Zooplankton richness within the Study Area has increased significantly over time. The connection to, and dependence on, groundwater within the hyporheic zone is variable across the Study Area. One of the more upstream sites, MarC2, supported the greatest richness of hyporheos fauna and groundwater-dependent taxa, across all sites, including reference spring sites. The additional area of creekline sampled for hyporheic fauna downstream of the main Study Area also supported a relatively rich hyporheos fauna, with a high richness of groundwater-dependent taxa also recorded from this area, particularly MC4H, MC9H and MC10H. This included potentially restricted species. While most of the taxa recorded from the Study Area are generally common and ubiquitous across the Pilbara, a number are of conservation significance, and are either locally restricted or rarely collected (Table 6.1).

The reduction in surface water availability across the Study Area in the Dry 2021 is of concern, particularly given the pools sampled were initially selected for their level of persistence. Impacts to emergent macrophytes and GDVs were noted at the time of the survey, with a decline in tree health also noted by Biologic (2022d). Spangled perch also appear to have been affected by the drying event, with their abundance and distribution throughout the creek considerably reduced in the Wet 2022 in comparison with the previous wet season survey (Wet 2021). Although there was not a significant difference in invertebrate richness between sampling events, the high macroinvertebrate richness recorded from two sites in the Dry 2021 indicates that fauna are responding to the decreasing water levels and moving to remnant, refuge pools. If the creek continues to dry over time, and these pools remain dry for longer periods or the remnant pools are no longer present during the dry season, all aspects of the aquatic ecosystem are likely to be detrimentally affected. Further investigation of the effects of the declining surface water and groundwater levels is warranted.

6.2 Final remarks

This study represents the second aquatic ecosystem survey undertaken in Marillana Creek within the Study Area. Results from this survey provide an assessment of the ecological values and health of aquatic systems within the Study Area, and provide additional data towards developing a robust dataset with which to detect any potential future impacts.

The Study Area supports GDEs of varying levels of significance across the reach. Due to the aridity of the Pilbara, rivers of the region tend to be ephemeral. Streamflow is highly seasonal and variable, and generally occurs over the summer months in response to cyclonic events and thunderstorms.

Permanent water sources are relatively scarce and restricted to springs and permanent pools. Such predictable sources of water have high conservation importance as they support richer faunas than ephemeral water-bodies and provide a refuge for many species during drought (Halse *et al.*, 2002; Kay *et al.*, 1999). That surface water, and likely groundwater, in the area appears to be declining over time is a concern, and the cause for the decline should be investigated further.

Table 6.1: Conservation significant taxa or taxa of note recorded from the Study Area during this and the previous MAC Aquatic Survey.

Type	Species	Sites Recorded			Previous MAC aquatic survey (Biologic, 2022b)	Conservation significance/ Distribution
		Within Study Area	Additional Marillana Hyporheic Study Area	Reference Sites		
Water mites (some are permanent hyporheos stygophiles)	*Aspidiobates pilbara*				MarC2, MarC3 (surface waters)	Pilbara endemic known only from springs and permanent pools in good ecological condition
	Guineaxonopsis `sp. Biologic-ACAR011`	MarC2 (hyporheos)				Appears to be restricted to the Upper Fortescue River catchment based on current records
	Guineaxonopsis `sp. Biologic-ACAR013`	MarC2 and MarC4 (hyporheos)				Currently known only from Marillana Creek. Further work may find it to be more widespread.
	Guineaxonopsis sp.	MarC1 (hyporheos) MarC4 (surface waters)			MarC1, MarC2, MarC4 (hyporheos)	Species identification unknown, may be uncommon, with a disjunct or restricted distribution in the Pilbara. May be one of the two *Guineaxonopsis* taxa known from Marillana Creek (see above)
	Rutacarus `sp. Biologic-ACAR006`		MC4H (hyporheos)			Previously known from Weeli Wolli Creek. Appears to be restricted based on current information but further work may find it to be more widespread
	Rutacarus sp.	MarC2 (hyporheos)			MarC4, MarC5 (hyporheos)	Species identification unknown, may be uncommon, with a disjunct or restricted distribution in the Pilbara
	Hesperomomonia `sp. Biologic-ACAR014`		MC10H (hyporheos)			May represent the described species *Hesperomomonia humphreysi* but insufficient information to confirm this. *H. humphreysi* is known only from the Fortescue River system, but has a linear range of more than 350 km
	Wandesia sp.	MarC2 (surface waters)			MarC1, MarC5 (hyporheos)	Species identification unknown, may be uncommon, with a disjunct or restricted distribution in the Pilbara
Ostracods	*Gomphodella alexanderi*				MarC2 (hyporheos)	SRE known only from the hyporheos of Marillana Creek, Yandicoogina Creek, lower Weeli Wolli Creek, and groundwater bores at Yandi.
	Gomphodella sp. (likely to be *G. alexanderi*)		MC4H and MC5H	WWS		Likely to represent *G. alexanderi*. SRE
	Meridiescandona `sp. Biologic-OSTR074`		MC4H and MC10H (hyporheos)			Known from Yandicoogina Creek and now Marillana Creek. Likely represents the described species *Meridiescandona marillanae* given its distribution, but further work is required to confirm this.
	Bennelongia `sp. Biologic-OSTR026`				MarC1 (surface water)	Appears to be restricted to Marillana Creek based on current knowledge
Harpacticoids	*Elaphoidella* sp.				MarC4 (hyporheos)	Undescribed and may be new to science
	Parastenocaris `sp. Biologic-HARP037`	MarC2 (hyporheos)				This is the first record of this taxon
	Parastenocaris sp.				MarC5 (hyporheos)	Represents either a specimen new to science or additional records for known fauna
Stygal amphipods	*Chydaekata* sp. E		MC5H and MC9H (hyporheos)			Known to have a restricted range, occurring only within Marillana, Weeli Wolli and Yandicoogina Creeks
	Chydaekata sp. MJ1-UM1	MarC4 (hyporheos)				Known to have a restricted range, recorded from upper Marillana Creek only
	Paramelitidae `sp. Biologic-AMPH024`		MC4H (hyporheos)			Previously known from Weeli Wolli Spring. Should be considered a Potential SRE
	Paramelitidae `sp. Biologic-AMPH070`		MC3H (hyporheos)			First record of this taxon. Should be considered a Potential SRE
Syncarids	*Atopobathynella* `sp. Biologic-PBAT042`		MC10H (hyporheos)			Currently known only from Yandicoogina Creek and Marillana Creek, across a linear distance of 4.5 km. Should be considered a Potential SRE
	Atopobathynella `sp. Biologic-PBAT044`		MC3H (hyporheos)			First record of this taxon. Should be considered a Potential SRE
	Bathynellidae sp.	MarC2 (hyporheos)				Likely represents a new, undescribed species based on morphology

Type	Species	Sites Recorded			Previous MAC aquatic survey (Biologic, 2022b)	Conservation significance/ Distribution
		Within Study Area	Additional Marillana Hyporheic Study Area	Reference Sites		
Damselfly	*Eurysticta coolawanyah*	MarC4 (surface waters)			MarC5 (surface waters)	Vulnerable IUCN Redlist
Dragonfly	*Hemicordulia koomina*				MarC1, MarC4, MarC5, MarC6 (surface waters)	Vulnerable IUCN Redlist
Beetle	*Haliplus fortescueensis*				MarC4 (surface waters)	Pilbara endemic with a restricted distribution

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Appendix A: Conservation status codes

International Union for Conservation of Nature

Category	Definition
Extinct (EX)	A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Extinct in the Wild (EW)	A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Critically Endangered (CR)	A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see Section V), and it is therefore considered to be facing an extremely high risk of extinction in the wild.
Endangered (EN)	A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (see Section V), and it is therefore considered to be facing a very high risk of extinction in the wild.
Vulnerable (VU)	A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see Section V), and it is therefore considered to be facing a high risk of extinction in the wild.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases, great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.

Environment Protection and Biodiversity Conservation Act 1999

Category	Definition
Extinct (EX)	Taxa not definitely located in the wild during the past 50 years.
Extinct in the Wild (EW)	Taxa known to survive only in captivity.
Critically Endangered (CE)	Taxa facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	Taxa facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	Taxa facing a high risk of extinction in the wild in the medium-term future.
Migratory (MG)	Consists of species listed under the following International Conventions: Japan-Australia Migratory Bird Agreement (JAMBA) China-Australia Migratory Bird Agreement (CAMBA) Convention on the Conservation of Migratory Species of Wild animals (Bonn Convention)

Biodiversity Conservation Act 2016

Category	Definition
CR	Rare or likely to become extinct, as *critically endangered* fauna.
EN	Rare or likely to become extinct, as *endangered* fauna.
VU	Rare or likely to become extinct, as *vulnerable* fauna.
EX	Being fauna that is presumed to be extinct.
MI	Birds that are subject to international agreements relating to the protection of migratory birds.
CD	Special conservation need being species dependent on ongoing conservation intervention. (Conservation Dependant)
OS	In need of special protection, otherwise than for the reasons pertaining to Schedule 1 through to Schedule 6 Fauna. (Other specially protected species

Department of Biodiversity, Conservation and Attractions Priority codes

Category	Definition
Priority 1 (P1)	Taxa with few, poorly known populations on threatened lands.
Priority 2 (P2)	Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
Priority 3 (P3)	Taxa with several, poorly known populations, some on conservation lands.
Priority 4 (P4)	Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection but could be if present circumstances change.

Appendix B: Default ANZECC & ARMCANZ (2000) water quality guidelines

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

Aquatic Ecosystem	**Analyte**						
	TP mg/L	**FRP** mg/L	**TN** mg/L	**NOx** mg/L	**NH_4^+** mg/L	**DO** % saturation[f]	**pH**
Upland River[e]	0.01	0.005	0.15	0.03	0.006	90-120	6.0-7.5
Lowland River[e]	0.01	0.004	0.2-0.3[h]	0.01[b]	0.01	85-120	6.0-8.0
Lakes	0.01	0.005	0.35[c]	0.01[b]	0.01	90-120	6.0-8.0
Wetlands[3]	0.01-0.05[g]	0.05-0.025[g]	0.35-1.2[g]	0.01	0.01	90[b]-120 [b]	6.0-8.0

b = Northern Territory values are 0.005mg/L for NO_x, and < 80 (lower limit) and >110% saturation (upper limit) for DO;

c = this value represents turbid lakes only. Clear lakes have much lower values;

e = no data available for tropical WA estuaries or rivers. A precautionary approach should be adopted when applying default trigger values to these systems;

f = dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability;

g = higher values are indicative of tropical WA river pools;

h = lower values from rivers draining rainforest catchments.

Default trigger values for salinity and turbidity for the protection of aquatic ecosystems, applicable to tropical systems in Australia (ANZECC & ARMCANZ, 2000).

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

Guideline values for toxicants at alternative levels of protection (in mg/L). Values in grey shading are applicable to typical *slightly-moderately disturbed systems* (ANZG, 2018).

Chemical			**Guideline values for freshwater mg/L Level of protection (% species)**			
			99%	**95%**	**90%**	**80%**
Metals and metalloids						
Aluminium	pH > 6.5		0.027	0.055	0.08	0.15
Aluminium	pH < 6.5		ID	ID	ID	ID
Arsenic (As III)			0.001	0.024	0.094[C]	0.36[C]
Arsenic (AsV)			0.0008	0.013	0.042	0.14[C]
Boron			0.09	0.37[C]	0.68[C]	1.3[C]
Cadmium		H	0.00006	0.0002	0.0004	0.0008[C]
Chromium (Cr III)		H	ID	ID	ID	ID
Chromium (Cr IV)			0.00001	0.001[C]	0.006[A]	0.04[A]
Cobalt			ID	ID	ID	ID
Copper		H	0.001	0.0014	0.0018[C]	0.0025[C]
Iron		G	ID	ID	ID	ID
Lead		H	0.001	0.0034	0.0056	0.0094[C]
Manganese			1.2	1.9[C]	2.5[C]	3.6[C]
Mercury (inorganic)		B	0.00006	0.0006	0.0019[C]	0.0054[A]
Mercury (methyl)			ID	ID	ID	ID
Molybdenum			ID	ID	ID	ID
Nickel		H	0.008	0.011	0.013	0.017[C]
Selenium (Total)		B	0.005	0.011	0.018	0.034
Selenium (SeIV)		B	ID	ID	ID	ID
Uranium			ID	ID	ID	ID
Vanadium			ID	ID	ID	ID
Zinc		H	0.0024	0.008[C]	0.015[C]	0.031[C]
Non-metallic inorganics						
Ammonia		D	0.32	0.9[C]	1.43[A]	2.3[A]
Chlorine		E	0.0004	0.003	0.006[A]	0.013[A]
Nitrate		J	1.0	2.4	3.4[C]	17[A]

Notes:

Most guideline values listed here for metals and metalloids are *High Reliability* figures, derived from field or chronic NOEC data (see 3.4.2.3). The exceptions are *Moderate Reliability* for freshwater aluminium (ph>6.5) and manganese.

Most non-metallic inorganics are *Moderate Reliability* figures, derived from acute LC50 data (see section 3.4.2.3). The exception is *High Reliability* for freshwater ammonia.

A = Figure may not protect key test species from acute toxicity (and chronic) (Section 8.3.4.4).

B = Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered (Section 8.3.3.4)

C = Figure may not protect key test species from chronic toxicity (this refers to experimental chronic figures or geometric mean for species) - check Section 8.3.7 for spread of data and its significance.

D = Ammonia as TOTAL ammonia as [NH_3_N] at pH 8. For changes in trigger value with pH refer to Section 8.3.7.2

E = Chlorine as Total Chlorine, as [Cl]; see Section 8.3.7.2

F = Figures protect against toxicity and do not relate to eutrophication issues. Refer to Section 3.3 if eutrophication is a concern.

G = There were insufficient data to derive a reliable guideline value for iron. The current Canadian guideline level is 0.3 mg/L which could be used as an interim working level. However, further data are required to establish a figure appropriate for Australian waters.

H = Chemicals for which algorithms have been provided in table 3.4.3 to account for the effects of hardness. The values have been calculated using a hardness of 30 mg/L $CaCO_3$. These should be adjusted to the site-specific hardness (see Section 3.4.3).

J = Figures relate to toxicity (not eutrophication). The ANZECC & ARMCANZ (2000) DGVs for nitrate have been found to be erroneous (ANZG, 2018). In the absence of updated values, ANZG (2018) suggest reference is made to current New Zealand nitrate toxicity guidelines, specifically the 'Grading' GVs published in the '*Updating Nitrate Toxicity Effects on Freshwater Aquatic Species*' report (NIWA, 2013). These New Zealand Grading DGVs for N_NO_3 are provided above.

Appendix C: Habitat results

Percentage cover by each of the in-stream substrate types.

Dry season 2021

Type	Site	Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt	Clay
Marillana Creek	MarC3	3	0	4	30	43	14	5	1
	MarC6a	85	0	0	5	5	2	3	0
Reference Sites	MACREF1	87	0	0	3	3	0	5	2
	MACREF2	51	0	2	12	11	6	8	10
	WWS	2	1	12	32	42	8	3	0
	BENS	2	4	2	21	36	32	2	1
	MUNJS	85	1	0	4	5	2	3	0
	SS	3	0	9	27	39	18	3	1

Wet season 2022

Type	Site	Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt	Clay
Marillana Creek	MarC1	4	1	4	37	40	8	6	0
	MarC2	0	0	4	34	48	12	2	0
	MarC3	64	8	4	6	11	2	3	2
	MarC4	5	0	7	15	50	3	8	12
	MarC5	0	0	2	40	49	6	1	2
	MarC6	0	2	12	4	18	12	10	42
Reference Sites	MACREF1	75	2	0	0	8	6	4	5
	MACREF2	48	3	5	6	9	13	4	12
	WWS	6	1	9	30	28	18	8	0
	BENS	2	4	2	21	31	27	12	1
	MUNJS	89	1	0	3	2	1	4	0
	SS	1	0	9	25	36	18	10	1

Percentage cover by each of the in-stream habitat types. NB: Inorganic sed. = inorganic sediment, Sub. Mac = submerged macrophyte, Emerg. Mac. = emergent macrophyte, LWD = large woody debris, and Trailing Veg. = trailing vegetation.

Dry season 2021

Type	Site	Inorganic seds	Sub. mac.	Emerg. mac.	Algae	LWD	Detritus	Roots	Trailing veg.	Habitat types
Marillana Creek	MarC3	22	9	4	55	1	7	1	1	8
	MarC6a	27	7	2	55	0	9	0	0	5
Reference Sites	MACREF1	18	8	10	40	4	15	2	3	8
	MACREF2	5	11	22	52	3	5	1	1	8
	WWS	54	0	1	32	4	2	6	1	7
	BENS	47	1	1	1	12	22	11	5	8
	MUNJS	51	12	10	10	8	3	3	3	8
	SS	7	2	2	48	4	24	12	1	8

Wet season 2022

Type	Site	Inorganic seds	Sub. mac.	Emerg. mac.	Algae	LWD	Detritus	Roots	Trailing veg.	Habitat types
Marillana Creek	MarC1	29	4	30	22	3	2	2	8	8
	MarC2	50	0	22	8	2	3	11	4	7
	MarC3	30	4	11	49	2	1	2	1	8
	MarC4	64	5	8	12	2	6	2	1	8
	MarC5	30	9	18	20	5	6	9	3	8
	MarC6	38	39	2	8	3	4	4	2	8
Reference Sites	MACREF1	39	11	20	12	4	10	2	2	8
	MACREF2	6	2	9	67	3	1	8	4	8
	WWS	86	0	2	2	2	4	12	2	7
	BENS	38	0	1	11	12	22	11	5	7
	MUNJS	51	10	9	9	8	6	3	4	8
	SS	36	3	2	10	6	25	15	3	8

Appendix D: Water quality results

Dry season 2021

		ANZG DGV		Study Area		Reference Sites					
Analyte	**Units**	**99% DGV**	**95% DGV**	**MarC3**	**MarC6a**	**MACREF1**	**MACREF2**	**MUNJS**	**BENS**	**WWS**	**SS**
Temperature	ºC			27.5	20.2	24.1	19	22.8	24.2	26	22.5
Conductivity (EC)	µS/cm		250	3187	2517	969	1517	902	954	984	639
pH	pH units		6-8	7.77	9.05	7.47	7.26	8.07	7.76	6.2	8.33
Redox	mV			123.5	75.8	101.4	232	75.2	36.5	108.5	72
DO	%		85-120	147.9	65.3	76	67.8	88.2	50.1	44.5	35.2
Turbidity	NTU		15	4.3	4.6	4.6	0.6	2.7	2.1	0.5	0.6
TSS	mg/L			9	7	9	4	1	2	<1	2
Alkalinity	mg/L			670	558	338	487	232	428	355	257
Hardness	mg/L			923	670	330	570	275	419	402	248
Na	mg/L			261.0	291.0	82.6	129.0	72.2	25.4	43.2	37.8
Ca	mg/L			62.8	11.2	45.2	76.9	38.2	61.9	69.9	48.2
Mg	mg/L			186.0	156.0	52.7	91.8	43.6	64.2	55.2	30.9
K	mg/L			26.3	40.4	6.7	19.2	9.5	4.9	9	4.6
HCO_3	mg/L			660	360	338	487	232	428	355	257
Cl	mg/L			550	572	129	273	173	58	80	45
S_SO_4	mg/L			62.3	37.7	6.87	34	1.50	10.00	20.60	7.10
CO_3	mg/L			10	198	<1	<1	<1	<1	<1	<1
dAl	mg/L	0.027	0.055	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
dAs	mg/L	0.001	0.024	0.0008	0.0022	0.0005	0.0004	0.0002	0.0004	0.0003	<0.0002
dB	mg/L	0.09	0.37	0.498	0.943	0.304	0.446	0.133	0.128	0.325	0.072
dBa	mg/L			0.0789	0.0238	0.0384	0.1320	0.0609	0.0515	0.0089	0.2080
dCd	mg/L	0.00006	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
dCo	mg/L			0.0002	0.0002	0.0001	<0.0001	<0.0001	0.0003	<0.0001	<0.0001
dCr	mg/L	0.00001	0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
dCu	mg/L	0.001	0.0014	0.00008	0.00047	0.00008	0.00006	<0.00005	0.00028	<0.00005	0.00008
dFe	mg/L	0.300*		0.216	0.088	0.092	0.036	0.084	0.018	0.006	0.038
dMn	mg/L	1.2	1.9	0.0730	0.0288	0.2080	0.0196	0.0130	0.0802	<0.0005	0.1310
dMo	mg/L			0.0002	0.0006	0.0002	0.0002	<0.0001	0.0002	0.0002	0.0002
dNi	mg/L	0.008	0.011	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
dPb	mg/L	0.001	0.0034	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
dS	mg/L			62.30	37.70	6.87	34.00	1.39	10.90	20.40	7.13
dSe	mg/L	0.005	0.011	<0.0002	0.0003	<0.0002	0.0011	<0.0002	<0.0002	<0.0002	0.0003
dU	mg/L			0.00294	0.00172	0.00021	0.00230	<0.00005	0.00051	0.00069	0.00065
dV	mg/L			0.0009	0.0029	0.0012	0.0031	0.0002	0.0010	0.0023	0.0014
dZn	mg/L	0.0024	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N_NH_3	mg/L	0.32	0.90	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
N_NO_3	mg/L	1.00	2.40	<0.01	<0.01	<0.01	0.22	0.02	<0.01	0.05	0.22
N_NOx	mg/L		0.01	<0.01	<0.01	<0.01	0.22	0.02	<0.01	0.05	0.22
Total N	mg/L		0.30	0.60	2.43	0.29	0.49	0.17	0.15	0.05	0.30
Total P	mg/L		0.01	0.044	0.049	0.050	0.044	0.034	0.018	0.022	0.017

Wet season 2022

		ANZG DGV		Study Area						Reference Sites					
Analyte	**Units**	**99% DGV**	**95% DGV**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF1**	**MACREF2**	**MUNJS**	**BENS**	**WWS**	**SS**
Temperature	ºC			24.7	25.6	30.8	23.8	25.5	29.0	21.4	21.0	24.3	26.7	25.7	28.1
Conductivity (EC)	µS/cm		250	1502	2172	2109	1607	1143	1088	829	1466	452	514	975	492
pH	pH units		6-8	7.60	7.43	7.84	7.98	7.78	8.51	7.98	7.88	8.04	7.40	7.42	7.84
Redox	mV			-39.1	4.5	21.6	1.5	1.9	19.4	-61.3	19.9	-21.4	0.9	124.7	-23.1
DO	%		85-120	19.2	38.9	109.5	61.2	46.6	128.2	57.8	74.3	88.8	26.2	71.7	55.8
Turbidity	NTU		15	0.4	1.2	2.2	0.3	0.6	1.3	1.9	0.4	1.1	2.5	<0.1	5.8
TSS	mg/L			<1	<1	<1	<1	<1	<1	<1	<1	<1	2	<1	8
Alkalinity	mg/L			277	439	397	332	235	204	152	365	93	213	303	199
Hardness	mg/L			458	789	662	576	400	341	308	368	132	224	382	186
Na	mg/L			67.2	175.0	159.0	138.0	94.9	93.0	80.1	119.0	7.6	3.4	41.4	4.7
Ca	mg/L			78.1	105.0	90.4	71.5	56.4	43.4	45.6	31.9	18.6	40.2	68.4	37.4
Mg	mg/L			63.9	128.0	106.0	96.6	62.9	56.6	47.2	69.9	20.7	30.0	51.2	22.4
K	mg/L			12.0	26.3	23.7	22.0	15.2	15.3	9.4	19.1	36.1	10.4	8.9	29.6
HCO_3	mg/L			277	439	397	332	235	180	152	365	93	213	303	199
Cl	mg/L			170	428	373	330	218	192	159	311	79	16	83	30
S_SO_4	mg/L			22.2	63.7	49.7	44	29.1	26.8	32.3	26.9	9.4	3.8	20.00	5.2
CO_3	mg/L			<1	<1	<1	<1	<1	24	<1	<1	<1	<1	<1	<1
dAl	mg/L	0.027	0.055	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	0.006	0.016	<0.005	0.017
dAs	mg/L	0.001	0.024	0.0004	0.0006	0.0007	0.0009	0.0004	0.0006	0.0003	0.0004	<0.0002	0.0005	0.0003	<0.0002
dB	mg/L	0.09	0.37	0.193	0.532	0.482	0.433	0.295	0.307	0.235	0.498	0.116	0.037	0.210	0.061
dBa	mg/L			0.0821	0.1370	0.1160	0.0914	0.0759	0.0591	0.0498	0.1210	0.0388	0.0335	0.0106	0.1440
dCd	mg/L	0.00006	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
dCo	mg/L			0.0002	0.0002	0.0004	0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.0004	<0.0001	<0.0001
dCr	mg/L	0.00001	0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
dCu	mg/L	0.001	0.0014	0.00023	0.00046	0.00144	0.00038	0.00026	0.00081	0.00032	0.00021	0.00012	0.00055	0.00017	0.00038
dFe	mg/L	0.300*		0.111	0.019	0.010	0.022	0.032	0.011	0.091	0.032	0.246	0.099	<0.002	0.034
dMn	mg/L	1.2	1.9	0.0404	0.0297	0.0798	0.0215	0.0177	0.0013	0.0234	0.0059	0.0244	0.5060	<0.0005	0.0558
dMo	mg/L			0.0002	0.0002	0.0003	0.0003	0.0002	0.0003	0.0002	0.0002	<0.0001	0.0002	0.0002	0.0002
dNi	mg/L	0.008	0.011	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
dPb	mg/L	0.001	0.0034	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
dS	mg/L			22.20	63.70	48.70	44.00	29.10	26.80	32.30	26.90	9.27	3.87	19.60	5.27
dSe	mg/L	0.005	0.011	<0.0002	0.0002	0.0002	0.0002	<0.0002	0.0004	<0.0002	0.0002	<0.0002	<0.0002	0.0002	0.0003
dU	mg/L			0.00088	0.00344	0.00234	0.00144	0.00095	0.00118	0.00010	0.00076	<0.00005	0.00020	0.00076	0.00040
dV	mg/L			0.0027	0.0048	0.0001	0.0057	0.0029	0.0071	0.0007	0.0010	0.0003	0.0009	0.0018	0.0020
dZn	mg/L	0.0024	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N_NH_3	mg/L	0.32	0.90	0.04	0.05	0.04	0.02	0.03	0.03	0.02	0.07	<0.01	<0.01	<0.01	<0.01
N_NO_3	mg/L	1.00	2.40	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.29
N_NOx	mg/L		0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.29
Total N	mg/L		0.30	0.07	0.12	0.14	0.15	0.10	0.28	0.23	0.07	0.15	0.16	0.03	0.34
Total P	mg/L		0.01	0.027	0.027	0.022	0.021	0.014	0.016	0.028	0.026	0.018	0.017	0.014	0.016

Appendix E: Zooplankton taxonomic list

Dry season 2021

Phylum/Class/Order	Family	Lowest taxon	Study Area MarC3	MarC6a	Reference Sites MACREF1	MACREF2	WWS	BENS	MUNJS	SS
PROTISTA										
SARCOMASTIGOPHORA		Sarcomastigophora sp.	1	3	0	1	0	1	1	2
CILIOPHORA										
Prostomatea		Ciliophora sp.	2	0	2	1	0	2	1	2
Prorodontida	**Colepidae**	*Coleps* sp.	0	0	0	0	0	2	0	0
ROTIFERA										
		Rotifera sp.	0	0	0	0	0	2	2	1
Bdelloidea		Bdelloidea sp.	2	2	0	2	1	2	2	1
Philodinida	**Habrotrochidae**	*Habrotrocha* sp.	0	0	0	0	0	0	1	0
Monogononta										
Flosculariaceae	**Hexarthridae**	*Hexarthra* cf. *intermedia*	0	3	0	0	0	0	0	0
		Hexarthra sp.	1	0	0	0	0	1	0	0
	Testudinellidae	*Testudinella* sp.	0	0	0	0	0	2	0	2
Ploima	**Brachionidae**	*Anuraeopsis* cf. *navicula*	2	4	2	0	0	0	0	0
		Brachionus budapestinensis	1	0	2	0	0	0	0	0
		Brachionus leydigii	2	4	2	0	0	0	0	0
		cf. *Platyias* sp.	1	0	0	0	0	0	0	0
		Keratella procurva	1	0	0	0	0	1	0	0
		Keratella sp.	0	0	0	0	0	0	0	0
		Notholca squamula	0	0	1	0	0	0	0	0
	Euchlanidae	*Euchlanis* sp.	0	0	0	0	0	0	2	0
	Lecanidae	*Lecane* cf. *batillifer*	0	0	0	0	0	0	0	1
		Lecane cf. *bulla*	1	2	2	1	0	1	2	0
		Lecane cf. *decipiens*	1	0	0	0	0	0	0	0
		Lecane cf. *opias*	0	0	1	0	0	0	0	2
		Lecane hastata	1	0	0	0	0	0	0	0
		Lecane sp.	0	1	2	0	0	0	1	1
	Lepadellidae	*Colurella* cf. *uncinata*	3	3	0	0	0	0	0	2
		Lepadella (*Lepadella*) cf. *benjamini*	0	0	0	0	0	0	3	0
		Lepadella (*Lepadella*) cf. *patella*	0	2	1	0	0	0	4	2
		Lepadella (*Lepadella*) sp.	1	1	0	1	0	0	2	1

Phylum/Class/Order	Family	Lowest taxon	Study Area		Reference Sites					
			MarC3	MarC6a	MACREF1	MACREF2	WWS	BENS	MUNJS	SS
	Mytilinidae	*Mytilina* cf. *ventralis*	0	0	0	0	0	0	2	0
	Notommatidae	*Cephalodella* sp.	0	0	0	0	0	3	0	0
		Polyarthra sp.	0	2	0	0	0	1	0	0
	Synchaetidae	*Polyarthra vulgaris*	0	0	0	0	0	0	0	2
	Tetrasiphonidae	*Tetrasiphon* sp.	0	0	0	0	0	1	0	0
	Trichocercidae	*Trichocerca* cf. *similis*	0	0	0	0	0	4	0	0
		Trichocerca similis	0	0	0	0	0	0	2	2
		Trichocerca sp.	0	0	0	0	0	3	1	1
	Trichotriidae	*Macrochaetus* cf. *danneeli*	2	0	0	0	0	0	0	0
		Macrochaetus cf. *subquadratus*	0	0	0	0	0	0	0	1
ARTHROPODA										
Branchiopoda										
Diplostraca	**Chydoridae**	*Alona* cf. *rigidicaudis*	0	0	0	0	0	0	0	3
		Alona sp.	0	0	0	0	0	0	1	2
		Ephemeroporus cf. *barroisi*	0	0	0	0	0	0	1	0
	Daphniidae	*Ceriodaphnia* sp.	0	3	0	0	0	0	0	2
	Macrotrichidae	*Macrothrix* cf. *hirsuticornis*	0	2	0	0	0	0	0	0
	Moinidae	*Moina* cf. *micrura*	0	4	0	1	0	0	0	0
Maxillopoda										
		Copepoda nauplii	2	5	0	2	2	0	0	0
Calanoida		Calanoida copepodite	0	2	0	0	2	0	0	2
	Diaptomidae	*Eodiaptomus lumholtzi*	0	0	0	0	0	0	0	0
Cyclopoida		Cyclopoid copepodite	5	0	3	3	0	0	3	3
	Cyclopidae	Cyclopidae sp.	0	0	0	0	1	0	0	0
		Eucyclops australiensis	1	0	0	1	1	0	0	3
		Mesocyclops brooksi	0	3	0	0	0	5	2	0
		Mesocyclops darwini	1	0	2	1	0	6	2	3
		Mesocyclops notius	2	2	2	2	0	0	0	0
		Mesocyclops sp.	2	0	0	1	0	0	0	0
		Microcyclops varicans	0	2	0	0	0	0	0	3
		Paracyclops cf. *affinis*	1	0	0	0	0	0	0	0
		Paracyclops cf. *fimbriatus*	0	0	0	2	0	0	1	0
		Thermocyclops cf. *decipiens*	0	0	0	0	0	4	0	2
		Thermocyclops sp.	0	0	1	0	0	0	0	0
		Tropocyclops cf. *confinus*	3	5	3	3	0	0	5	2

Phylum/Class/Order	Family	Lowest taxon	Study Area MarC3	MarC6a	Reference Sites MACREF1	MACREF2	WWS	BENS	MUNJS	SS
		Tropocyclops cf. *prasinus*	0	0	0	1	0	7	0	0
Poecilostomatoida	**Ergasilidae**	cf. *Ergasilus* sp.	0	0	0	0	0	0	0	2
Ostracoda		Ostracoda sp. (imm./dam.)	0	0	1	1	0	0	1	0
Podocopida	**Candonidae**	*Candonopsis* cf. *tenuis*	0	0	0	1	0	0	0	0
	Cyprididae	Cyprididae sp.	0	0	0	1	0	0	0	0
		Cypridopsis \`sp. Biologic-OSTR011\`	0	0	2	0	0	0	0	0
		Bennelongia tirigie	0	0	0	0	0	0	4	0
		Ilyodromus sp.	0	0	0	0	0	0	2	1
		Ilyodromus \`sp. Biologic-OSTR014\`	0	2	0	3	0	0	0	0
		Stenocypris major	0	0	2	0	0	0	0	0
	Darwinulidae	*Vestalenula marmonieri*	0	2	2	0	0	0	0	0
	Limnocytheridae	*Limnocythere dorsosicula*	0	0	0	0	0	0	0	0
	Notodromadidae	*Newnhamia fenestrata*	0	0	0	0	0	0	3	0
		Taxa richness	**23**	**22**	**18**	**19**	**5**	**18**	**25**	**27**

Wet season 2022

			Study Area						Reference Sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF1**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**
PROTISTA														
AMOEBOZOA														
		Testate Amoeba	2	3	3	2	1	2	0	2	2	1	0	0
		Testate Amoeba cf. Hyalospheniformis sp.	0	0	0	0	0	0	0	0	0	1	0	0
Tubulinea		cf. Arcellinida sp.	0	0	0	0	0	0	0	0	0	0	0	2
CILIOPHORA														
Prostomatea		Ciliate indet.	1	3	0	2	1	0	0	2	1	0	0	1
Prorodontida	**Colepidae**	*Coleps* sp.	0	2	0	2	3	2	0	0	0	0	0	2
GASTROTRICHA		Gastrotricha sp.	0	0	0	0	0	0	0	0	0	2	0	0
ROTIFERA														
		Rotifera sp.	1	1	2	0	0	2	0	2	0	1	0	0
Bdelloidea		Bdelloidea sp. indet.	1	0	1	0	0	2	0	2	0	0	1	1
Philodinida	**Philodinidae**	cf. *Rotaria* sp.	0	0	0	0	0	0	0	1	0	0	0	0
Monogononta														
Ploima	**Brachionidae**	*Keratella procurva*	2	0	1	1	0	0	0	0	0	0	0	0
		Keratella sp.	1	0	0	0	0	0	0	0	0	0	2	0
		Keratella valga	0	0	0	0	1	4	0	0	0	0	0	0
	Dicranophoridae	cf. *Dicranophorus epicharis*	0	1	0	0	0	2	0	0	0	0	0	0
	Euchlanidae	*Euchlanis* cf. *dilatata*	0	0	0	0	0	1	0	0	0	0	0	0
		Euchlanis sp.	0	0	1	0	0	0	0	2	0	0	0	0
	Lecanidae	*Lecane aculeata*	0	0	1	0	0	0	0	0	0	0	0	0
		Lecane cf. *batillifer*	0	0	0	0	0	1	0	0	0	0	0	0
		Lecane cf. *bulla*	2	3	2	2	2	2	0	0	0	0	0	1
		Lecane cf. *opias*	0	0	0	0	0	1	2	0	0	0	0	0
		Lecane cf. *pyriformes*	2	0	0	0	0	0	0	0	0	0	0	0
		Lecane hamata	0	1	0	0	0	0	0	2	0	0	0	0
		Lecane hastata	0	0	0	0	0	0	0	1	0	0	1	0
		Lecane quadrata	0	1	0	0	0	0	0	0	0	0	0	0
		Lecane quadridentata	0	0	1	0	0	0	0	0	0	0	0	0
		Lecane rhenana	0	0	0	0	0	1	0	0	0	0	0	0
		Lecane sp.	0	1	1	0	0	0	0	0	0	0	0	1
		Lecane unguitata	0	0	2	0	0	0	0	0	0	0	0	0
	Lepadellidae	*Colurella* sp.	0	0	0	0	0	0	0	1	0	0	0	0
		Colurella cf. *obtusa*	0	0	0	0	0	0	0	0	0	0	1	0
		Colurella uncinata	0	0	0	2	0	0	0	0	1	0	0	0
		Lepadella (*Lepadella*) cf. *patella*	1	0	0	0	2	0	0	0	2	0	0	1
		Lepadella (*Lepadella*) sp.	0	0	1	0	0	0	0	1	1	0	0	0
	Lindiidae	cf. *Lindia truncata*	1	0	0	0	0	0	0	0	0	0	0	0
	Notommatidae	*Cephalodella gibba*	0	0	0	0	0	0	0	1	0	0	0	0
		Monommata sp.	0	2	2	0	0	0	0	0	0	0	0	0
	Synchaetidae	*Polyarthra* cf. *dolichoptera*	0	0	0	0	0	3	0	0	0	0	0	0
		Polyarthra sp.	0	0	0	0	0	2	0	0	0	0	0	0
	Trichocercidae	*Trichocerca* cf. *flagellata*	0	0	0	0	0	3	0	0	0	0	0	0
		Trichocerca inermis	1	0	0	0	0	0	0	0	0	0	0	0
		Trichocerca similis	0	0	0	1	0	4	0	0	0	0	0	0
		Trichocerca sp.	0	0	1	0	0	1	0	1	1	0	0	0
	Trichotriidae	*Macrochaetus* cf. *altamirai*	0	0	0	0	0	0	0	2	0	0	0	0
		Macrochaetus sp.	0	0	0	0	0	1	0	0	0	0	0	0
ARTHROPODA														
Branchiopoda														
Diplostraca	**Chydoridae**	*Alona* cf. *rigidicaudis*	0	0	0	0	0	3	0	0	0	0	0	0

Phylum/Class/Order	Family	Lowest taxon	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF1	MACREF2	WWS	BENS	MUNJS	SS
			Study Area						Reference Sites					
		Alona sp.	0	0	1	2	0	2	0	0	0	0	0	0
		Chydorus sp.	0	0	1	1	0	3	0	0	0	0	0	0
		Dunhevedia crassa	0	4	2	2	4	0	0	0	0	0	0	0
	Daphniidae	*Simocephalus* sp.	0	0	0	3	4	2	3	0	0	0	0	0
	Ilyocryptidae	*Ilyocryptus spinifer*	0	0	0	0	0	1	0	0	0	0	0	0
	Macrotrichidae	*Macrothrix spinosa*	0	0	0	0	0	3	0	0	0	0	0	0
		Macrothrix sp.	0	0	0	0	0	2	0	0	0	0	0	0
	Sididae	*Diaphanosoma excisum*	0	0	0	0	0	2	0	0	0	0	0	0
Maxillopoda														
Cyclopoida		Cyclopoid copepodite	0	3	3	4	5	3	0	3	0	0	0	0
		Cyclopoid nauplii	2	2	2	5	4	4	2	2	1	0	0	0
		Cyclopoida sp. (indet.)	0	0	0	0	0	0	0	0	2	3	3	3
	Cyclopidae	*Ectocyclops phaleratus*	0	0	0	0	0	0	0	0	0	1	0	0
		Mesocyclops brooksi	0	0	0	3	4	0	0	0	0	0	0	3
		Mesocyclops darwini	0	2	2	2	2	0	0	0	0	0	2	2
		Mesocyclops notius	0	1	2	2	2	2	2	0	0	2	2	2
		Mesocyclops sp.	0	0	0	2	0	1	0	1	0	0	0	0
		Microcyclops varicans	3	2	2	1	0	2	2	3	0	1	0	2
		Microcyclops sp.	1	0	0	0	0	0	0	0	0	0	0	0
		Tropocyclops cf. *confinus*	1	2	2	0	0	2	0	3	0	0	0	0
		Tropocyclops cf. *prasinus*	0	1	0	0	2	0	0	0	0	0	0	0
		Tropocyclops sp.	0	0	0	0	0	0	0	1	0	0	0	0
Ostracoda														
Podocopida		Ostracoda sp. (imm./dam.)	1	0	1	0	0	0	0	0	0	0	0	0
	Candonidae	*Candonopsis* cf. *tenuis*	0	4	4	2	2	2	3	0	0	0	0	0
	Cyprididae	*Bennelongia* sp.	0	0	2	0	0	0	0	0	0	0	0	0
		Bennelongia strellyensis	0	0	0	0	0	0	0	0	0	0	4	0
		Bennelongia \`sp. Biologic-OSTR026\`	4	0	0	0	0	0	0	0	0	0	0	0
		Cypretta sp.	4	0	3	0	3	2	3	0	0	0	0	0
		Cypretta \`sp. Biologic-OSTR015\`	0	4	0	0	0	0	0	0	0	0	0	0
		Cypretta \`sp. Biologic-OSTR076\`	0	0	0	0	0	0	0	0	0	0	2	0
		Cyprididae \`sp. Biologic-OSTR049\`	0	0	0	0	0	0	0	0	0	1	0	0
		Cyprididae \`sp. Biologic-OSTR075\`	0	0	0	0	0	0	0	0	0	0	2	0
		Cyprididae \`sp. Biologic-OSTR021\`	3	0	0	0	0	0	0	0	0	0	0	0
		Cyprididae sp.	0	0	3	0	0	0	0	0	0	0	0	0
		Cypridopsis sp.	2	0	0	0	0	0	0	0	0	0	0	0
		Cypridopsis \`sp. Biologic-OSTR011\`	0	0	0	0	0	0	0	0	2	0	0	0
		Ilyodromus sp.	0	0	0	0	0	1	0	0	0	0	0	0
		Ilyodromus \`sp. Biologic-OSTR014\`	0	0	0	2	0	0	0	0	0	0	2	0
		Riocypris fitzroyi	0	0	0	1	2	1	2	0	0	0	0	0
		Stenocypris major	4	3	3	3	1	1	3	0	0	0	2	1
	Darwinulidae	*Vestalenula* sp.	1	0	0	0	0	0	0	2	0	0	0	0
		Vestalenula marmonieri	0	0	0	0	0	0	0	3	0	0	0	0
	Ilyocypridae	*Ilyocypris* cf. *australiensis*	1	0	2	0	0	1	0	0	0	0	0	0
	Limnocytheridae	*Limnocythere* sp.	0	0	0	0	0	0	0	2	0	0	0	0
	Notodromadidae	*Newnhamia fenestrata*	0	0	0	0	0	0	0	0	0	0	4	0
		Taxa richness	**23**	**21**	**29**	**22**	**18**	**37**	**9**	**22**	**9**	**9**	**13**	**13**

Appendix F: Hyporheic fauna taxonomic list

Dry season 2021

				Study Area				Reference Sites			
Phylum/Class/Order	**Family**	**Lowest taxon**	**Hypo Cat.**	**MarC1**	**MarC3**	**MarC4**	**MarC6a**	**BENS**	**WWS**	**MUNJS**	**SS**
NEMATODA		Nematoda sp.	P	0	0	0	0	0	1	0	0
MOLLUSCA											
Gastropoda											
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	X	0	0	1	0	0	0	0	1
	Planorbidae	*Gyraulus hesperus*	X	0	1	2	1	0	0	0	0
ANNELIDA											
Oligochaeta		Oligochaeta sp.	P	0	0	2	0	0	0	0	0
Tubificida	**Enchytraeidae**	Enchytraeidae sp.	P	0	0	0	0	0	0	0	1
	Naididae	*Dero furcata*	O	0	0	0	0	2	0	0	0
		Dero sp.	P	0	0	0	0	0	0	0	1
		Naidinae sp.	P	0	0	0	3	2	1	0	0
		Pristina aequiseta	O	4	3	0	4	0	0	3	0
		Pristina leidyi	X	0	0	0	0	0	0	0	2
		Pristina longiseta	O	2	4	0	4	0	1	0	0
		Pristina sima	O	0	0	0	0	0	0	0	1
		Pristina sp.	P	0	0	0	3	0	0	0	0
	Phreodrilidae	Phreodrilidae sp.	P	0	0	0	0	0	0	3	1
ARTHROPODA											
Arachnida		Acari sp.	P	0	0	0	2	0	0	0	0
Mesostigmata		Mesostigmata sp.	X	0	2	1	1	3	0	0	1
Sarcoptiformes		Oribatida sp.	X	0	1	0	0	0	0	0	0
Trombidiformes	**Halacaridae**	Halacaridae sp.	X	0	0	0	0	2	0	0	0
	Pezidae	Pezidae sp.	X	0	0	0	0	1	0	0	0
		Trombidioidea sp.	X	0	0	2	0	0	0	0	2
CRUSTACEA											
Maxillopoda											
Cyclopoida		Cyclopoida sp.	P	0	0	0	2	0	0	0	0
	Cyclopidae	*Ectocyclops phaleratus*	X	0	0	0	0	0	1	3	1
		Mesocyclops darwini	X	0	0	0	0	0	0	0	0

Phylum/Class/Order	Family	Lowest taxon	Hypo Cat.	Study Area MarC1	MarC3	MarC4	MarC6a	Reference Sites BENS	WWS	MUNJS	SS
		Microcyclops varicans	O	3	1	0	2	2	3	0	1
		Paracyclops cf. *affinis*	X	0	1	2	1	0	0	0	0
		Paracyclops cf. *fimbriatus*	O	0	0	0	0	0	0	3	0
		Thermocyclops sp.	P	0	0	2	0	0	0	0	0
Ostracoda											
Podocopida	**Candonidae**	Candonidae `sp. Biologic-OSTR057`	P	0	0	0	0	3	0	0	0
		Candonopsis cf. *tenuis*	O	2	2	2	4	0	0	0	0
		Notacandona boultoni	S	0	0	0	0	0	3	0	0
	Darwinulidae	*Vestalenula marmonieri*	S	0	0	0	0	0	0	0	0
Malacostraca											
Amphipoda	**Paramelitidae**	*Chydaekata* sp. E	S	0	0	0	0	1	2	0	0
		Chydaekata sp. MJ1-UM1	S	0	0	2	0	0	0	0	0
		Maarrka weeliwolli	S	0	0	0	0	0	1	0	0
		Paramelitidae `sp. Biologic-AMPH024`	S	0	0	0	0	0	3	0	0
		Paramelitidae `sp. Biologic-AMPH049`	S	0	0	0	0	0	0	0	1
COLLEMBOLLA											
Entomobryomorpha											
Entomobryoidea		Entomobryoidea sp.	X	0	0	0	2	3	1	1	2
INSECTA											
Coleoptera	**Carabidae**	Carabidae sp.	X	0	0	0	1	0	0	0	0
		Carabidae sp. (L)	X	0	0	0	0	1	1	0	0
	Dytiscidae	Dytiscidae sp. (L)	X	0	0	0	0	1	0	0	0
		Copelatus irregularis	X	0	0	0	0	0	0	2	0
		Copelatus nigrolineatus	X	0	0	0	0	0	0	2	0
		Limbodessus compactus	X	0	0	0	0	0	0	2	0
		Tribe Bidessini sp. (L)	X	0	0	0	0	0	0	1	0
	Georissidae	*Georissus* sp.	O	0	0	0	0	0	0	0	2
	Hydraenidae	*Hydraena* sp.	O	0	3	2	2	0	0	2	0
		Hydraenidae sp. (L)	O	0	0	0	3	0	0	0	2
		Limnebius sp.	O	0	0	0	1	0	0	0	0
		Ochthebius sp.	O	1	3	0	2	0	0	0	0
	Hydrochidae	*Hydrochus obscuroaeneus*	X	0	0	0	0	0	0	1	0
		Hydrochidae sp. (L)	X	0	0	0	2	0	0	0	0
	Hydrophilidae	*Anacaena horni*	X	1	1	1	0	0	0	0	0

Phylum/Class/Order	Family	Lowest taxon	Hypo Cat.	Study Area MarC1	MarC3	MarC4	MarC6a	Reference Sites BENS	WWS	MUNJS	SS
		Chaetarthria nigerrima	X	0	0	0	0	0	0	0	1
		Chaetarthria nigerrima (L)	X	0	0	0	0	0	2	0	2
		Coelostoma fabricii	X	0	0	0	0	0	0	0	0
		Enochrus sp. (L)	X	0	0	0	0	0	1	0	3
		Helochares sp. (L)	X	0	0	0	0	0	0	0	0
		Helochares tatei	X	0	0	0	0	0	0	0	0
		Hydrophilidae sp. (L)	P	0	0	0	0	0	0	0	2
		nr. *Anacaena* sp.	X	0	2	2	0	0	0	0	0
		Paracymus spenceri	X	0	0	0	0	0	0	0	0
		Sternolophus sp. (L)	X	0	0	0	0	0	0	1	0
	Limnichidae	Limnichidae sp. B	P	0	0	0	2	0	0	0	0
	Noteridae	*Neohydrocoptus subfasciatus*	X	0	0	0	1	0	0	0	0
	Ptiliidae	Ptiliidae sp.	X	0	0	0	2	3	0	0	0
	Scirtidae	Scirtidae sp. (L)	O	4	3	4	0	2	0	3	0
	Staphylinidae	Staphylinidae sp.	X	1	2	2	2	2	0	0	0
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	X	0	0	0	0	2	0	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	X	1	2	1	3	0	0	0	1
		Ceratopogoninae sp.	X	4	3	3	3	2	2	3	3
		Dasyhelea sp.	X	0	3	0	2	1	3	1	2
	Chironomidae	*?Australopelopia* sp.	P	0	0	0	0	0	0	0	2
		Ablabesmyia hilli	X	0	0	0	0	0	1	0	0
		Chironominae sp.	X	0	0	0	0	0	0	0	2
		Cladotanytarsus sp.	X	0	0	0	0	0	0	0	2
		nr. *Gymnometriocnemus* sp.	X	0	0	0	0	0	0	2	0
		Paramerina sp. 1	X	0	1	0	0	0	3	0	0
		Paramerina sp. 2	X	0	0	0	0	2	0	0	2
		Parametriocnemus sp.	X	0	0	0	0	0	0	1	0
		Polypedilum sp. K1	X	0	0	0	0	0	0	2	0
		Procladius sp.	X	0	0	0	3	0	0	0	0
		Rheotanytarsus sp.	X	0	0	0	0	0	0	0	0
		Tanytarsus sp.	X	0	3	0	0	0	0	0	0
	Culicidae	*Aedes* sp.	X	0	0	0	0	0	0	1	0
		Culex sp.	X	0	0	0	0	0	0	0	1
	Dolichopodidae	Dolichopodidae sp.	X	0	2	0	2	0	0	0	0
	Ephydridae	Ephydridae sp.	X	0	0	0	0	0	0	0	0
	Muscidae	Muscidae sp.	X	0	1	0	0	0	0	0	1

Phylum/Class/Order	Family	Lowest taxon	Hypo Cat.	Study Area MarC1	Study Area MarC3	Study Area MarC4	Study Area MarC6a	Reference Sites BENS	Reference Sites WWS	Reference Sites MUNJS	Reference Sites SS
	Stratiomyidae	Stratiomyidae sp.	X	0	0	0	0	1	0	0	0
	Thaumaleidae	Thaumaleidae sp.	X	0	0	0	0	0	1	0	0
	Tipulidae	Tipulidae sp.	X	1	0	0	2	0	0	2	0
Ephemeroptera	**Baetidae**	Baetidae sp.	P	0	0	0	0	0	0	0	2
Lepidoptera	**Crambidae**	Acentropinae sp.	X	0	0	0	0	2	0	0	0
MYRIAPODA											
Symphyla											
Cephalostigmata		Symphyla `sp. Biologic-SYMP055`	T	0	0	3	0	0	0	0	0
		Taxa richness		**11**	**21**	**18**	**28**	**20**	**18**	**20**	**28**

Wet season 2022

				Study Area						Additional Marillana Creek Hyporheic Sites							Reference Sites				
Phylum/Class/Order	**Family**	**Lowest taxon**	**Hypo cat**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MC1H**	**MC2H**	**MC3H**	**MC4H**	**MC5H**	**MC9H**	**MC10H**	**MACREF2**	**BENS**	**WWS**	**MUNJS**	**SS**
CNIDARIA																					
Hydrozoa																					
Anthoathecata	**Hydridae**	*Hydra* sp.	X	0	0	2	2	2	0	0	0	0	0	0	0	0	0	1	0	0	1
PLATYHELMINTHES		Platyhelminthes sp.	X	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
NEMATODA		Nematoda sp.	P	2	0	2	0	0	0	2	2	2	2	0	2	0	0	0	0	2	0
MOLLUSCA																					
Gastropoda																					
Hygrophila	**Planorbidae**	*Gyraulus hesperus*	X	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
ANNELIDA																					
Oligochaeta		Oligochaeta sp.	P	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Tubificida		Tubificinae sp.	P	0	0	0	0	0	0	3	4	0	0	3	2	3	0	0	0	0	0
	Enchytraeidae	Enchytraeidae sp.	P	0	0	0	0	0	0	3	0	2	0	0	3	2	0	0	0	0	0
	Naididae	*Allonais inaequalis*	O	0	0	0	0	0	0	0	4	2	3	3	0	0	0	0	0	0	0
		Allonais paraguayensis	O	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
		Allonais ranauana	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Dero furcata	O	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	0
		Dero nivea	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
		Naidinae sp.	P	2	0	1	0	2	0	0	0	3	0	0	0	3	2	3	0	2	2
		Pristina aequiseta	O	0	0	2	0	0	0	3	4	3	4	4	2	2	0	3	0	0	2
		Pristina jenkinae	O	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
		Pristina leidyi	X	0	0	0	0	0	0	0	0	3	4	0	0	0	0	0	0	0	0
		Pristina longiseta	O	3	3	3	4	2	2	0	4	3	0	0	1	0	0	0	0	0	3
		Pristina nr. *osborni*	P	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Phreodrilidae	Phreodrilidae sp.	P	0	0	0	0	0	0	0	3	2	0	3	0	4	2	0	0	0	1
ARTHROPODA																					
Arachnida		Acari sp.	P	1	1	2	0	0	1	0	6	0	3	0	1	0	0	1	2	4	0
Mesostigmata		Mesostigmata sp.	X	0	0	0	1	1	2	2	0	0	0	0	2	0	0	0	0	2	2
Sarcoptiformes		Oribatida sp.	X	2	0	2	0	0	1	1	3	0	4	3	2	0	0	0	0	0	1
Trombidiformes		Trombidioidea sp.	X	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	Anisitsiellidae	*Rutacarus* sp.	PS	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rutacarus `sp. Biologic-ACAR006`	PS	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
	Halacaridae	Halacaridae sp.	X	0	0	0	0	1	0	0	0	0	4	0	0	1	0	0	0	0	0
	Mideopsidae	*Guineaxonopsis* sp.	PS	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Guineaxonopsis `sp. Biologic-ACAR011`	PS	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Guineaxonopsis `sp. Biologic-ACAR013`	PS	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Mideopsidae sp.	P	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Momoniidae	*Hesperomomonia* `sp. Biologic-ACAR014`	PS	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Pezidae	Pezidae sp.	X	0	2	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0
	Unionicolidae	*Neumania* sp.	X	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Recifella sp.	X	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Unionicolidae sp.	X	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA																					
Branchiopoda																					
Diplostraca	**Chydoridae**	*Alona* sp.	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Maxillopoda																					
Cyclopoida	**Cyclopidae**	*Mesocyclops darwini*	X	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
		Mesocyclops sp.	P	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0	0	0

				Study Area						Additional Marillana Creek Hyporheic Sites							Reference Sites				
Phylum/Class/Order	**Family**	**Lowest taxon**	**Hypo cat**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MC1H**	**MC2H**	**MC3H**	**MC4H**	**MC5H**	**MC9H**	**MC10H**	**MACREF2**	**BENS**	**WWS**	**MUNJS**	**SS**
		Microcyclops varicans	O	3	3	2	2	2	2	2	1	0	0	2	1	2	0	0	0	2	2
		Paracyclops cf. *affinis*	X	0	0	0	0	0	0	0	0	0	0	2	2	1	0	0	0	0	0
		Paracyclops cf. *fimbriatus*	O	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Pescecyclops sp.	S	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
		Thermocyclops sp.	P	0	0	0	2	0	0	0	0	0	0	0	0	0	0	4	0	0	0
		Cyclopoida sp.	P	0	0	1	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0
Harpacticoida		Harpacticoida `sp. Biologic-HARP038`	P	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Canthocamptidae	*Elaphoidella* sp.	S	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0
	Parastenocarididae	*Parastenocaris* sp.	S	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Parastenocaris `sp. Biologic-HARP022`	S	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parastenocaris `sp. Biologic-HARP037`	S	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda		Ostracoda sp. (imm.)	P	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Podocopida	**Candonidae**	*Candonopsis* cf. *tenuis*	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Meridiescandona `sp. Biologic-OSTR074`	S	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0
		Notocandona boultoni	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Cyprididae	Cyprididae sp.	P	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Cypretta `sp. Biologic-OSTR015`	X	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ilyodromus `sp. Biologic-OSTR014`	X	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stenocypris major	X	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Darwinulidae	*Vestalenula marmonieri*	S	0	0	0	0	0	0	4	2	0	0	0	2	0	0	0	0	0	0
		Vestalenula sp.	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Limnocytheridae	*Gomphodella* sp.	S	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0
		Limnocythere sp.	P	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malacostraca																					
Amphipoda	**Paramelitidae**	*Chydaekata* sp. E	S	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0
		Paramelitidae sp.	S	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	1
		Paramelitidae `sp. Biologic-AMPH024`	S	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
		Paramelitidae `sp. Biologic-AMPH070`	S	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Bathynellacea	**Bathynellidae**	Bathynellidae sp.	S	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Atopobathynella sp.	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		Atopobathynella `sp. Biologic-PBAT042`	S	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Atopobathynella `sp. Biologic-PBAT044`	S	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Isopoda	**Tainisopidae**	*Pygolabis* `sp. Biologic-ISOP079`	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
COLLEMBOLLA																					
Poduromorpha																					
Poduroidea		Poduroidea sp.	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	1
Symphypleona		Symphypleona sp.	X	1	2	2	0	0	0	0	0	0	0	0	0	0	0	1	0	3	1
Entomobryomorpha																					
Entomobryoidea		Entomobryoidea sp.	X	3	2	2	1	0	0	2	0	0	0	2	2	0	0	0	0	0	0
INSECTA																					
Coleoptera	**Carabidae**	Carabidae sp. (L)	X	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
	Dytiscidae	Tribe Bidessini sp. (L)	X	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Dytiscidae sp. (L)	X	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Laccophilus sp. (L)	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	Elmidae	*Austrolimnius* sp.	O	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Austrolimnius sp. (L)	O	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Hydraenidae	Hydraenidae sp. (L)	O	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	2
		Limnebius sp.	O	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		Ochthebius sp.	O	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydrochidae	Hydrochidae sp. (L)	X	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydrophilidae	*Berosus* sp. (L)	X	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetarthria sp. (L)	X	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
		Coelostoma fabricii	X	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Helochares sp.	X	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
		Helochares sp. (L)	X	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0

				Study Area						Additional Marillana Creek Hyporheic Sites							Reference Sites				
Phylum/Class/Order	**Family**	**Lowest taxon**	**Hypo cat**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MC1H**	**MC2H**	**MC3H**	**MC4H**	**MC5H**	**MC9H**	**MC10H**	**MACREF2**	**BENS**	**WWS**	**MUNJS**	**SS**
		Hydrophilidae sp. (L)	P	0	2	2	2	3	0	1	0	0	0	0	0	0	0	0	2	0	2
		Laccobius sp. (L)	X	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
		nr. *Anacaena* sp.	X	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Limnichidae	Limnichidae sp. B	P	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Ptiliidae	Ptiliidae sp.	X	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Scirtidae	Scirtidae sp. (L)	O	2	2	2	2	0	0	0	0	0	0	0	3	0	2	3	0	0	0
	Staphylinidae	Staphylinidae sp.	X	1	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0
		Staphylinidae sp. (L)	X	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Coleoptera sp. (L)	X	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	X	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	X	0	0	1	1	1	0	2	2	2	0	0	2	0	0	0	0	0	3
		Ceratopogoninae sp.	X	3	3	3	3	1	3	3	3	3	3	3	3	2	2	2	0	2	2
		Dasyhelea sp.	X	0	0	2	0	0	1	3	3	3	3	2	3	0	0	0	0	0	1
		Forcipomyiinae sp.	X	0	0	0	0	0	0	2	2	2	1	0	2	0	0	0	1	0	0
	Chironomidae	?*Australopelopia* sp.	P	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
		Ablabesmyia hilli	X	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Chironomidae sp. (P)	X	0	0	0	0	0	1	0	2	0	2	2	2	0	0	0	0	0	0
		Cladotanytarsus sp.	X	1	0	0	0	0	0	2	3	1	3	0	0	0	0	0	0	0	0
		Corynoneura sp.	X	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0
		Cricotopus sp. 2	X	0	0	0	0	0	0	0	3	0	4	1	0	0	0	0	0	0	0
		Cryptochironomus griseidorsum	X	0	0	0	1	0	0	2	2	0	3	0	2	0	0	0	0	0	0
		Dicrotendipes sp. \`CA1\`	X	2	2	0	2	0	1	1	3	0	3	3	2	0	0	0	0	0	0
		Larsia ?albiceps	X	2	0	2	1	0	0	2	3	0	0	1	0	0	0	0	0	0	0
		Nanocladius sp.	X	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0
		nr. *Gymnometriocnemus* sp.	X	0	0	0	0	0	0	1	0	2	0	1	3	0	1	3	0	0	0
		Orthocladiinae sp. BES12662	X	1	2	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
		Parakiefferiella sp.	X	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0	0	0
		Paramerina sp. 1	X	2	2	3	0	3	0	0	4	2	2	1	2	0	0	2	2	0	0
		Paramerina sp. 2	X	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0	0	0
		Paratanytarsus sp.	X	0	0	0	0	0	0	3	3	1	3	0	0	0	0	0	0	0	0
		Polypedilum (Pentapedilum) leei	X	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Polypedilum nubifer	X	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
		Polypedilum sp.	X	1	0	2	1	0	0	2	0	1	0	0	0	0	0	0	0	1	0
		Polypedilum sp. K1	X	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0
		Polypedilum watsoni	X	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Procladius sp.	X	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rheocricotopus sp.	X	0	0	0	0	0	0	0	4	0	4	0	0	0	0	0	0	0	0
		Tanypodinae sp. BES10593	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		Tanytarsus sp.	X	3	2	1	3	0	2	3	3	3	4	3	3	1	1	0	2	0	0
		Thienemanniella sp.	X	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0
	Dolichopodidae	Dolichopodidae sp.	X	0	0	0	0	0	0	3	3	0	2	2	3	0	1	0	0	0	0
	Ephydridae	Ephydridae sp.	X	0	2	0	0	2	0	3	0	1	0	0	0	0	0	0	0	0	0
	Muscidae	Muscidae sp.	X	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Psychodidae	Psychodidae sp.	X	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Scatopsidae	Scatopsidae sp.	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
	Simuliidae	Simuliidae sp.	X	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Stratiomyidae	Stratiomyidae sp.	X	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
	Tabanidae	Tabanidae sp.	X	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Tipulidae	Tipulidae sp.	X	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	**Baetidae**	Baetidae sp.	P	0	0	0	0	0	1	0	3	0	2	2	2	0	0	0	0	0	0
		Cloeon sp.	X	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
		Cloeon sp. Red Stripe	X	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
		Pseudocloeon hypodelum	X	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
	Caenidae	Caenidae sp.	X	1	0	0	0	0	0	0	3	2	3	2	2	0	0	0	0	0	0
		Tasmanocoenis sp. *P/arcuata*	X	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Hemiptera	**Gelastocoridae**	*Nerthra* sp.	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Hebridae	Hebridae sp.	X	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Phylum/Class/Order	Family	Lowest taxon	Hypo cat	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MC1H	MC2H	MC3H	MC4H	MC5H	MC9H	MC10H	MACREF2	BENS	WWS	MUNJS	SS
				Study Area						Additional Marillana Creek Hyporheic Sites							Reference Sites				
Lepidoptera	**Crambidae**	*Margarosticha* sp. 3	X	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Odonata																					
Anisoptera	**Libellulidae**	*Orthetrum caledonicum*	X	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Anisoptera sp.	X	1	0	0	2	0	1	1	2	1	2	2	0	0	2	0	0	0	0
Zygoptera		Zygoptera sp.	X	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0
Thysanoptera		Thysanoptera sp.	X	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Trichoptera		Trichoptera sp.	X	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
	Ecnomidae	*Ecnomus pilbarensis*	X	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Ecnomus sp.	X	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Hydropsychidae	*Cheumatopsyche wellsae*	X	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
	Philopotamidae	*Chimarra* sp. AV18	X	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
		Philopotamidae sp.	X	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0
MYRIAPODA																					
Pauropoda		Pauropoda sp.	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Taxa richness		**30**	**29**	**28**	**22**	**16**	**19**	**35**	**44**	**26**	**36**	**31**	**45**	**14**	**9**	**17**	**10**	**15**	**27**

Appendix G: Macroinvertebrate fauna taxonomic list

Dry season 2021

Phylum/Class/Order	Family	Lowest taxon	Study Area		Reference Sites					
			MarC3	MarC6a	MACREF1	MACREF2	WWS	BENS	MUNJS	SS
CNIDARIA										
Hydrozoa										
Anthoathecata	**Hydridae**	*Hydra* sp.	1	0	0	0	0	3	1	0
PLATYHELMINTHES										
Turbellaria		Turbellaria sp.	0	2	2	0	0	0	2	0
MOLLUSCA										
Gastropoda										
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	3	0	2	3	0	0	1	2
		Lymnaeidae sp.	0	0	0	0	0	0	0	2
	Planorbidae	*Ferrissia petterdi*	1	0	2	0	2	2	0	2
		Gyraulus hesperus	4	4	4	2	0	3	2	0
ANNELIDA										
Oligochaeta			0	0	0	0	0	0	0	0
Tubificida	**Naididae**	*Allonais pectinata*	0	0	0	0	0	0	2	0
		Allonais ranauana	2	3	0	0	0	0	0	0
		Dero digitata	0	3	0	0	0	0	0	0
		Dero furcata	0	0	0	0	0	2	0	0
		Dero nivea	0	4	0	0	0	3	0	0
		Dero sp.	0	0	0	0	0	1	0	0
		Naidinae sp.	0	0	0	0	0	2	2	3
		Nais communis	0	0	0	0	0	0	0	2
		Pristina aequiseta	1	0	0	0	0	0	2	3
		Pristina jenkinae	1	0	0	0	0	0	0	0
		Pristina leidyi	0	0	4	3	0	0	2	4
		Pristina longiseta	2	4	0	0	0	2	2	3
		Pristina sp.	0	0	0	0	0	0	2	0
	Phreodrilidae	Phreodrilidae sp.	0	0	0	0	0	0	0	3
ARTHROPODA										
CHELICERATA										

Phylum/Class/Order	Family	Lowest taxon	Study Area MarC3	MarC6a	Reference Sites MACREF1	MACREF2	WWS	BENS	MUNJS	SS
Arachnida		Acari sp.	0	0	3	0	0	0	1	1
Sarcoptiformes		Oribatida sp.	0	0	0	0	0	0	1	0
Trombidiformes	**Arrenuridae**	*Arrenurus (Megaluracarus)* sp.	0	3	0	0	0	0	0	0
		Arrenurus (Truncaturus) sp.	0	3	0	0	0	0	0	0
		Arrenurus sp.	1	0	3	1	0	0	0	0
	Aturidae	*Albia* sp.	0	0	0	1	0	0	0	0
		Austraturus sp.	0	0	0	2	0	2	0	0
	Eylaidae	*Eylais* sp.	0	4	0	0	0	2	0	0
	Hydrachnidae	*Hydrachna* sp.	1	0	0	0	0	0	0	0
	Hydrodromidae	*Hydrodroma* sp.	2	3	0	0	0	0	0	0
	Hygrobatidae	*Australiobates* sp.	0	3	0	0	1	0	0	0
		Coaustraliobates minor	2	3	0	1	0	2	1	0
		Procorticacarus sp.	0	0	0	0	0	0	0	0
	Limnesiidae	*Limnesia parasolida*	0	0	3	1	0	2	0	0
		Limnesia sp. \`solida group\`	2	4	4	2	0	3	3	1
	Limnocharidae	*Limnochares australica*	0	0	0	2	0	0	0	0
	Mideopsidae	*Gretacarus* sp.	0	0	0	1	0	0	0	0
	Oxidae	*Oxus* sp.	0	0	3	0	0	0	0	0
	Unionicolidae	*Koenikea* sp.	2	0	0	0	0	0	0	0
		Neumania sp.	2	0	3	0	0	2	0	0
		Recifella sp.	0	3	0	2	0	0	0	0
		Unionicolidae sp.	1	0	0	0	0	0	0	0
CRUSTACEA										
Malacostraca										
Amphipoda	**Paramelitidae**	*Chydaekata* sp. E	0	0	0	0	2	0	0	0
Decapoda	**Parastacidae**	*Cherax quadricarinatus*	0	0	0	0	2	0	0	0
HEXAPODA										
Insecta										
Coleoptera	**Carabidae**	Carabidae sp.	0	0	0	0	0	1	0	0
	Curculionidae	Curculionidae sp. (L)	0	0	0	0	2	0	0	0
	Dytiscidae	*Allodessus bistrigatus*	0	0	3	2	1	2	0	0
		Austrodytes plateni	2	0	0	0	0	2	0	0
		Austrodytes sp. (L)	0	0	1	0	0	0	0	0
		Bidessini sp. (L)	0	1	2	0	0	0	0	0

Phylum/Class/Order	Family	Lowest taxon	Study Area MarC3	Study Area MarC6a	Reference Sites MACREF1	Reference Sites MACREF2	Reference Sites WWS	Reference Sites BENS	Reference Sites MUNJS	Reference Sites SS
		Cybister sp.	3	2	0	0	0	1	0	0
		Cybister sp. (L)	0	0	0	0	0	0	2	0
		Cybister tripunctatus	3	0	0	0	0	0	0	0
		Eretes australis	0	0	0	0	0	0	0	0
		Hydaticus consanguineus	0	0	3	0	0	0	0	0
		Hydaticus daemeli	3	0	0	0	0	2	0	0
		Hydroglyphus grammopterus	0	3	0	3	0	3	0	3
		Hydroglyphus leai	0	3	0	0	0	0	0	0
		Hydroglyphus orthogrammus	3	4	4	3	0	3	0	3
		Hydrovatus opacus	3	0	0	0	0	0	0	1
		Hydrovatus sp. (L)	2	0	0	0	0	2	0	1
		Hyphydrus elegans	0	0	3	0	0	2	2	0
		Hyphydrus lyratus	0	3	3	2	1	2	2	2
		Hyphydrus sp. (L)	0	0	2	0	0	0	0	0
		Laccophilus sharpi	0	3	4	2	1	2	1	0
		Limbodessus compactus	0	3	3	2	0	2	0	0
		Necterosoma regulare	2	0	0	2	0	1	0	0
		Necterosoma sp. (L)	0	0	0	2	0	0	0	0
		Neobidessodes denticulatus	3	3	3	2	0	0	0	0
		Platynectes decempunctatus var. *decempunctatus*	0	0	0	0	0	2	0	0
		Rhantus suturalis	0	0	3	0	0	0	0	0
		Sternopriscus multimaculatus	2	0	0	0	0	0	0	0
		Tiporus tambreyi	3	0	0	0	0	0	0	0
	Elmidae	*Austrolimnius* sp. (L)	0	0	0	2	0	0	0	3
	Gyrinidae	*Dineutus australis*	0	0	3	0	2	0	3	0
		Gyrinidae sp.	0	0	0	1	0	0	3	0
		Macrogyrus paradoxus	0	0	0	0	1	0	0	0
	Haliplidae	*Haliplus pilbaraensis*	1	0	0	0	0	0	0	0
	Hydraenidae	*Hydraena* sp.	3	0	3	2	0	3	1	0
		Limnebius sp.	2	3	0	0	0	1	0	1
		Ochthebius sp.	0	0	0	1	0	1	0	0
	Hydrochidae	*Hydrochus burdekinensis*	0	0	0	0	0	2	0	0
		Hydrochus eurypleuron	3	0	1	2	0	2	0	0
		Hydrochus interioris	0	3	0	0	0	2	0	0
		Hydrochus obscuroaeneus	0	0	1	2	0	2	1	0
		Hydrochus sp. P1	0	2	0	0	0	2	0	1

			Study Area		Reference Sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC3**	**MarC6a**	**MACREF1**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**
	Hydrophilidae	*Anacaena horni*	1	0	3	1	1	2	0	0
		Berosus dallasi	2	4	0	3	0	0	1	3
		Berosus pulchellus	0	0	0	2	0	0	0	0
		Berosus sp. (L)	0	0	1	0	0	0	0	3
		Chaetarthria nigerrima	0	0	0	0	0	0	0	1
		Coelostoma fabricii	0	0	0	0	0	1	0	1
		Enochrus deserticola	0	0	0	0	0	3	1	0
		Helochares sp. (L)	1	2	0	2	0	2	0	3
		Helochares tatei	0	3	0	0	0	0	0	0
		Hyphydrus elegans	0	0	0	2	0	0	0	0
		Paracymus spenceri	0	4	3	0	0	2	1	0
		Regimbartia attenuata	0	3	3	0	1	3	1	0
		Sternolophus australis	0	0	3	0	0	0	0	0
		Sternolophus marginicollis	0	0	4	0	0	2	0	0
		Sternolophus sp. (L)	0	0	2	0	0	2	0	0
	Limnichidae	Limnichidae sp. B	0	1	0	0	0	0	0	0
	Scirtidae	Scirtidae sp. (L)	0	0	3	2	2	3	0	0
	Staphylinidae	Staphylinidae sp.	0	1	0	0	0	0	0	0
Diptera	**Ceratopogonidae**	Ceratopogonidae sp. (P)	2	2	2	2	0	0	2	2
		Ceratopogoninae sp.	3	3	2	3	2	1	4	4
		Dasyhelea sp.	3	3	4	3	2	0	4	4
		Forcipomyiinae sp.	0	0	2	0	0	0	0	0
	Chironomidae	*Ablabesmyia hilli*	0	3	3	3	1	1	4	0
		Chironomidae sp. (P)	2	3	3	3	2	0	2	3
		Chironomini sp.	1	0	0	0	0	0	0	0
		Chironomus aff. *alternans*	0	0	0	0	0	2	0	0
		Cladopelma curtivalva	0	3	0	0	0	0	0	0
		Cladotanytarsus sp.	0	0	0	4	0	0	4	4
		Corynoneura sp.	0	0	0	2	0	0	0	0
		Cricotopus sp. 2	0	0	0	0	1	0	3	0
		Dicrotendipes jobetus	0	0	0	0	0	2	0	0
		Dicrotendipes sp.	2	0	0	0	0	0	0	0
		Dicrotendipes sp. `CA1`	1	3	4	4	1	0	4	4
		Dicrotendipes sp. P4	0	0	0	0	0	0	4	0
		Kiefferulus intertinctus	1	0	0	0	0	1	0	0
		Larsia ?albiceps	2	4	3	4	0	2	4	4

Phylum/Class/Order	Family	Lowest taxon	Study Area MarC3	MarC6a	Reference Sites MACREF1	MACREF2	WWS	BENS	MUNJS	SS
		Nanocladius sp.	0	0	0	0	0	0	4	0
		Parachironomus sp.	0	0	0	0	0	1	0	0
		Paramerina sp. 1	2	4	4	4	3	1	4	4
		Parametriocnemus sp.	0	0	0	0	0	0	4	0
		Paratanytarsus sp.	0	0	0	0	0	0	0	0
		Polypedilum (Pentapedilum) leei	0	0	3	0	0	0	0	0
		Polypedilum nubifer	0	0	0	0	0	1	3	0
		Polypedilum sp.	0	0	0	3	0	0	0	3
		Polypedilum sp. K1	1	0	0	0	0	0	0	0
		Polypedilum watsoni	1	0	0	0	0	0	0	0
		Procladius sp.	3	4	4	4	0	3	3	0
		Rheocricotopus sp.	0	0	0	0	0	0	0	5
		Stenochironomus watsoni	0	0	3	0	0	0	0	0
		Tanytarsus sp.	3	4	4	4	3	3	4	4
		Thienemanniella sp.	0	0	0	2	2	0	0	0
	Culicidae	*Aedes* sp.	0	0	0	0	0	0	2	0
		Anopheles sp.	0	0	3	3	0	0	0	2
		Culex sp.	0	3	3	0	0	0	0	3
		Culicidae sp. (P)	0	2	2	0	0	1	0	1
	Dolichopodidae	Dolichopodidae sp.	0	0	0	1	0	0	0	4
	Ephydridae	Ephydridae sp.	0	0	0	2	0	0	0	0
	Sciomyzidae	Sciomyzidae sp.	0	0	2	0	0	0	0	0
	Simuliidae	Simuliidae sp.	0	0	0	1	1	0	4	0
		Simuliidae sp. (P)	0	0	0	2	0	0	0	0
	Stratiomyidae	Stratiomyidae sp.	2	3	3	3	1	3	2	1
	Tabanidae	Tabanidae sp.	0	2	2	1	0	3	2	0
Ephemeroptera	**Baetidae**	Baetidae sp.	3	2	0	3	3	2	3	4
		Cloeon fluviatile	2	0	0	2	0	2	0	0
		Cloeon sp. Red Stripe	0	5	4	2	3	2	3	4
		Offadens G1 sp. WA2	0	0	0	2	3	0	1	4
	Caenidae	Caenidae sp.	2	2	2	0	0	0	0	0
		Tasmanocoenis sp.	0	0	0	0	2	3	2	4
		Tasmanocoenis sp. M	0	1	0	0	0	1	0	4
		Tasmanocoenis sp. P/arcuata	2	2	2	3	0	2	2	4
	Leptophlebiidae	*Atalophlebia* sp. AV17	0	0	0	0	0	0	4	0
		Leptophlebiidae sp.	0	0	0	0	0	0	4	0

			Study Area		Reference Sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC3**	**MarC6a**	**MACREF1**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**
Hemiptera	**Belostomatidae**	*Diplonychus eques*	0	1	3	0	0	0	2	1
		Diplonychus sp.	0	0	0	0	0	0	0	2
Corixoidea		Corixoidea sp.	1	0	1	0	0	0	0	0
	Gelastocoridae	*Nerthra* sp.	0	0	0	0	0	0	0	1
	Gerridae	Gerridae sp.	0	2	1	2	0	1	0	3
		Limnogonus fossarum gilguy	0	0	1	0	0	0	0	0
		Limnogonus luctuosus	0	0	0	0	0	0	0	0
		Limnogonus sp.	0	0	0	0	2	0	0	3
	Hebridae	*Hebrus axillaris*	0	0	0	0	0	2	0	0
	Hydrometridae	*Hydrometra* sp.	0	0	1	0	0	0	0	0
	Mesoveliidae	*Mesovelia hungerfordi*	0	1	0	0	0	0	0	0
		Mesoveliidae sp.	1	2	0	0	0	0	0	0
	Nepidae	*Laccotrephes tristis*	0	0	0	1	0	0	1	0
		Ranatra diminuta	1	0	0	0	0	0	0	0
		Ranatra sp.	1	0	0	0	0	0	0	0
	Notonectidae	*Anisops* sp.	0	0	2	0	0	0	0	0
		Enithares woodwardi	0	0	1	0	0	0	0	0
		Notonectidae sp.	0	0	3	0	0	0	2	0
	Pleidae	*Paraplea brunni*	2	2	2	3	0	2	0	1
		Pleidae sp.	0	4	0	1	0	0	0	0
	Veliidae	*Microvelia oceanica*	0	1	1	0	0	0	0	0
		Microvelia sp.	0	0	2	0	0	0	0	0
		Nesidovelia peramoena	0	0	0	0	0	2	0	0
		Nesidovelia sp.	0	0	0	1	1	0	0	0
		Veliidae sp.	0	0	3	2	0	3	0	1
Lepidoptera	**Crambidae**	*Margarosticha* sp. 3	0	0	0	0	2	0	2	1
		Parapoynx sp.	0	1	0	0	0	0	0	0
		Tetrernia sp.	0	0	0	0	1	0	0	0
		Acentropinae sp.	0	0	0	0	0	0	1	0
Odonata										
Anisoptera		Anisoptera sp.	1	1	4	3	2	3	4	3
	Aeshnidae	*Adversaeschna brevistyla*	0	0	3	0	0	0	0	0
		Aeshnidae sp.	0	0	4	0	0	0	0	0
		Hemianax papuensis	0	0	4	0	0	0	0	0
	Corduliidae	*Hemicordulia koomina*	0	0	3	0	0	2	0	2
	Gomphidae	*Austrogomphus gordoni*	0	1	0	4	0	0	0	0

Phylum/Class/Order	Family	Lowest taxon	Study Area MarC3	MarC6a	Reference Sites MACREF1	MACREF2	WWS	BENS	MUNJS	SS
	Libellulidae	*Crocothemis nigrifrons*	0	0	3	0	0	0	0	0
		Diplacodes haematodes	0	1	4	0	0	0	2	0
		Nannophlebia injibandi	0	0	0	0	2	0	0	0
		Orthetrum caledonicum	1	1	3	3	0	2	0	2
		Zyxomma elgneri	1	0	3	0	0	0	0	0
Zygoptera		Zygoptera sp.	3	0	4	3	2	3	3	0
	Coenagrionidae	*Argiocnemis rubescens*	2	3	4	2	0	2	2	0
		Ischnura aurora	0	5	5	0	0	0	2	0
		Pseudagrion aureofrons	0	0	3	0	3	2	0	0
	Isostictidae	*Eurysticta coolawanyah*	0	0	0	1	0	2	0	0
Trichoptera	**Ecnomidae**	*Ecnomina* sp. F group	0	0	0	0	0	0	3	0
		Ecnomus pilbarensis	0	1	2	2	0	2	2	2
	Hydropsychidae	*Cheumatopsyche wellsae*	0	0	0	3	2	0	2	2
	Hydroptilidae	*Hellyethira* sp.	1	2	0	0	0	3	2	0
		Orthotrichia sp.	0	0	0	0	2	2	0	0
	Leptoceridae	Leptoceridae sp.	0	2	2	3	0	2	2	2
		Oecetis sp.	0	2	0	3	0	0	0	0
		Oecetis sp. Pilbara 1	0	0	2	0	0	0	0	0
		Oecetis sp. Pilbara 4	0	0	0	0	0	2	0	2
		Triaenodes sp.	0	0	0	0	0	0	1	0
		Triplectides ciuskus seductus	2	0	1	4	0	3	2	2
	Philopotamidae	*Chimarra* sp. AV17	0	0	0	0	0	0	2	1
		Taxa richness	**65**	**71**	**86**	**76**	**38**	**83**	**71**	**63**

Wet season 2022

			Study Area						Reference Sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF1**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**
CNIDARIA														
Hydrozoa														
Anthoathecata	**Hydridae**	*Hydra* sp.	0	2	2	3	2	0	0	0	0	0	0	0
PLATYHELMINTHES														
Turbellaria		Turbellaria sp.	2	0	0	0	1	0	0	0	0	0	0	0
NEMATODA		Nematoda sp.	0	0	2	2	1	0	0	0	0	0	0	0
MOLLUSCA														
Gastropoda														
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	1	2	2	3	3	3	0	0	0	0	3	0
		Lymnaeidae sp.	1	0	0	0	0	0	0	0	0	0	0	0
	Planorbidae	*Ferrissia petterdi*	0	0	0	0	0	0	0	0	1	1	0	0
		Gyraulus hesperus	3	4	4	3	4	2	0	2	0	4	3	0
		Leichhardtia sp.	1	0	0	0	0	0	0	0	0	0	0	0
		Planorbidae sp.	1	0	0	0	0	0	0	0	0	0	0	0
ANNELIDA														
Oligochaeta														
Tubificida	**Naididae**	*Allonais pectinata*	0	4	4	0	0	0	0	1	0	0	2	0
		Allonais ranauana	0	0	3	0	0	0	0	0	0	0	2	2
		Dero digitata	0	0	0	0	3	0	0	0	0	0	0	0
		Dero nivea	0	0	0	0	0	0	0	0	0	0	2	0
		Naidinae sp.	0	0	0	2	0	0	0	0	0	2	0	3
		Nais communis	0	0	0	0	0	0	0	0	0	0	2	0
		Pristina aequiseta	4	3	0	1	0	0	3	2	0	0	2	2
		Pristina leidyi	0	2	4	2	0	0	0	2	1	0	0	0
		Pristina longiseta	4	4	4	1	4	0	1	0	1	2	2	3
		Pristina sp.	0	4	0	2	0	1	0	0	0	0	0	0
	Phreodrilidae	Phreodrilidae sp.	0	0	0	0	0	0	0	0	0	2	0	3
ARTHROPODA														
CHELICERATA														
Arachnida		Acari sp.	0	2	2	2	2	2	0	1	0	0	0	3
Sarcoptiformes		Oribatida sp.	2	2	0	0	0	0	0	2	3	0	0	3
Mesostigmata		Mesostigmata sp.	2	2	0	0	1	0	0	0	0	0	0	0
Trombidiformes		Trombidioidea sp.	0	1	0	0	0	0	0	0	0	0	0	0
	Anisitsiellidae	*Rutacarus* sp.	0	1	0	0	0	0	0	0	0	0	0	0
	Arrenuridae	*Arrenurus (Truncaturus)* sp.	2	0	0	0	0	0	0	0	0	0	2	0
		Arrenurus sp.	0	0	2	1	0	1	0	0	0	0	0	3
	Aturidae	*Albia* sp.	0	0	0	0	0	1	0	0	0	3	0	0
		Austraturus sp.	0	0	0	0	0	0	0	2	0	3	0	0
	Eylaidae	*Eylais* sp.	0	2	0	0	0	0	0	0	0	0	0	0
	Hydrachnidae	*Hydrachna* sp.	0	0	0	1	0	1	0	0	0	0	0	0
	Hydrodromidae	*Hydrodroma* sp.	0	0	0	1	0	0	0	0	0	0	1	3
	Hydryphantidae	*Diplodontus* sp.	0	0	0	0	0	0	0	0	0	0	2	0
		Wandesia sp.	0	2	0	0	0	0	0	0	0	0	0	0
	Hygrobatidae	*Australiobates* sp.	0	0	2	0	0	0	0	0	0	0	0	3
		Coaustraliobates minor	0	0	0	1	0	0	0	2	0	0	0	0
		Procorticacarus sp.	0	0	0	0	0	0	0	0	2	0	0	3
	Limnesiidae	*Limnesia maceripalpis*	0	0	2	0	0	0	0	0	0	0	0	0
		Limnesia parasolida	0	2	2	0	0	0	0	2	0	0	0	4
		Limnesia sp. \`solida group\`	2	2	3	3	2	2	1	2	0	4	3	3
	Limnocharidae	*Limnochares australica*	0	0	2	0	2	2	0	2	0	0	0	0
	Mideopsidae	*Gretacarus* sp.	0	0	0	0	0	0	0	0	0	0	0	3

			Study Area						Reference Sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF1**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**
		Guineaxonopsis sp.	0	0	0	1	0	0	0	0	0	0	0	0
		Mideopsidae sp.	1	0	0	0	0	0	0	0	0	0	0	0
	Oxidae	*Oxus* sp.	1	0	1	1	0	0	0	0	1	0	0	0
	Pionidae	*Piona cumberlandensis*	0	0	1	0	0	0	0	0	0	0	0	0
	Unionicolidae	*Koenikea* sp.	0	0	0	0	0	0	0	1	0	0	0	0
		Neumania sp.	2	2	1	2	0	0	0	0	0	4	0	3
		Recifella sp.	0	0	0	2	0	0	0	0	0	0	0	3
		Unionicolidae sp.	0	0	0	0	0	1	0	0	0	0	0	0
Pseudoscorpiones	**Olpiidae**	Olpiidae sp.	0	0	0	0	0	0	0	0	0	1	0	0
CRUSTACEA														
Malacostraca														
Amphipoda	**Paramelitidae**	*Chydaekata* sp. E	0	0	0	0	0	0	0	0	1	0	0	0
		Paramelitidae sp.	0	0	0	0	0	0	0	0	2	0	0	0
Decapoda	**Parastacidae**	*Cherax quadricarinatus*	0	0	0	0	0	0	0	0	2	0	0	0
HEXAPODA														
Collembolla														
Entomobryoidea		Entomobryoidea sp.	1	2	0	1	0	0	0	0	0	2	1	0
Symphypleona		Symphypleona sp.	2	1	2	3	2	0	0	0	0	0	0	0
Insecta														
Coleoptera	**Carabidae**	Carabidae sp. (L)	2	0	0	0	0	0	0	0	0	1	0	0
	Dytiscidae	*Allodessus bistrigatus*	1	0	0	0	3	0	1	0	0	0	0	0
		Austrodytes sp. (L)	0	0	0	0	0	0	0	0	0	0	2	0
		Bidessini sp. (L)	3	4	2	2	3	1	2	0	0	3	0	0
		Copelatus irregularis	0	0	0	0	0	0	0	0	0	1	0	0
		Cybister sp. (L)	0	2	0	2	0	1	0	0	0	0	0	0
		Cybister tripunctatus	1	0	0	0	0	0	0	0	0	0	0	0
		Dytiscidae sp. (L)	1	4	2	0	0	0	0	0	0	0	0	0
		Hydaticus daemeli	0	0	0	0	0	0	0	0	0	0	1	0
		Hydaticus sp. (L)	0	4	0	0	0	0	0	0	0	0	0	0
		Hydroglyphus grammopterus	1	0	0	0	2	0	0	0	0	2	0	0
		Hydroglyphus leai	0	0	1	0	0	0	0	0	0	0	0	0
		Hydroglyphus orthogrammus	2	2	0	0	4	3	4	0	0	3	2	0
		Hydrovatus opacus	0	0	2	0	0	0	0	0	0	0	1	1
		Hydrovatus sp.	0	0	0	0	0	0	1	0	0	2	0	0
		Hydrovatus sp. (L)	0	0	0	0	0	0	0	0	0	0	2	0
		Hyphydrus elegans	0	0	0	0	0	0	0	0	0	1	0	0
		Hyphydrus lyratus	0	0	0	0	0	1	0	0	0	0	0	0
		Hyphydrus sp. (L)	2	4	2	2	0	0	2	0	0	0	0	0
		Laccophilus sp. (L)	1	0	0	0	0	0	0	0	0	0	0	0
		Limbodessus compactus	1	0	2	1	2	0	0	0	0	1	0	1
		Necterosoma regulare	0	1	1	0	0	0	0	0	0	0	0	0
		Necterosoma sp. (L)	0	0	0	2	0	0	0	0	0	0	0	0
		Neobidessodes denticulatus	0	2	0	0	0	0	0	0	0	0	0	0
		Platynectes decempunctatus var. *decempunctatus*	0	0	0	0	0	0	0	0	0	0	2	0
		Platynectes sp. (L)	0	0	1	0	0	0	0	0	0	0	0	0
		Rhantaticus sp. (L)	0	3	0	0	0	0	0	0	0	0	0	0
		Tiporus sp. (L)	0	0	0	2	0	0	0	0	0	0	0	0
		Tiporus tambreyi	0	1	2	0	0	0	0	0	0	2	0	2
	Elmidae	*Austrolimnius* sp.	0	0	0	0	0	0	0	0	0	0	0	2
		Austrolimnius sp. (L)	1	0	0	0	0	0	0	0	1	0	0	2
	Gyrinidae	*Dineutus australis*	1	2	0	0	0	0	0	0	0	0	2	0
		Dineutus australis (L)	2	3	0	2	0	0	0	0	0	0	0	0
		Macrogyrus gibbosus	0	0	0	0	0	0	0	0	0	0	1	0
		Macrogyrus sp. (L)	0	0	0	0	0	0	1	0	0	0	0	0
	Haliplidae	*Haliplus pinderi*	1	0	0	0	0	0	0	0	0	0	0	0

			Study Area						Reference Sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF1**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**
	Heteroceridae	Heteroceridae sp. (L)	0	0	1	0	0	0	0	0	0	0	0	0
	Hydraenidae	*Hydraena* sp.	0	2	2	0	2	0	0	0	0	3	1	0
	Hydrochidae	*Hydrochus eurypleuron*	0	0	0	0	0	0	0	0	0	1	0	0
		Hydrochus interioris	0	1	0	0	0	0	0	1	0	2	0	0
		Hydrochus macroaquilonius	0	0	0	0	0	0	0	0	0	2	0	0
		Hydrochus obscuroaeneus	1	3	0	0	2	0	0	0	0	3	0	2
		Hydrochus sp. P2	0	0	0	0	0	0	0	0	0	1	0	0
	Hydrophilidae	*Agraphydrus coomani*	0	0	0	0	1	0	0	1	0	1	0	0
		Anacaena horni	0	2	0	0	0	0	0	0	0	2	2	0
		Berosus approximans	0	0	0	0	0	1	0	0	0	0	0	0
		Berosus dallasi	0	0	2	0	1	0	0	0	0	0	0	0
		Berosus sp. (L)	2	3	3	3	1	2	0	0	0	0	0	0
		Chaetarthria sp. (L)	0	0	0	0	2	2	0	0	0	0	0	0
		Enochrus deserticola	0	2	0	0	2	0	0	0	0	1	1	0
		Enochrus sp. (L)	2	0	0	0	2	0	0	0	0	0	0	0
		Helochares sp. (L)	2	3	1	0	2	0	0	0	0	2	2	0
		Helochares tatei	0	1	0	0	0	0	0	0	0	0	0	0
		Hydrophilidae sp. (L)	2	3	0	2	2	0	0	0	0	0	0	1
		Hydrophilus sp. (L)	0	0	0	2	0	0	0	0	0	0	0	0
		Paracymus sp. (L)	0	0	0	2	0	0	0	0	0	0	0	0
		Paracymus spenceri	3	2	0	1	1	1	0	0	0	0	1	0
		Regimbartia attenuata	0	2	0	1	2	1	0	1	0	2	0	0
		Regimbartia sp. (L)	2	0	0	0	2	0	0	0	0	0	0	0
		Sternolophus australis	1	0	0	0	0	0	0	0	0	0	1	0
		Sternolophus immarginatus	0	1	0	0	0	0	0	0	0	0	0	0
		Sternolophus marginicollis	2	2	0	0	0	0	1	0	0	0	2	2
		Sternolophus sp. (L)	2	5	1	0	2	0	0	0	0	2	0	0
	Limnichidae	Limnichidae sp. C	0	0	0	0	0	0	0	0	0	0	1	0
	Scirtidae	Scirtidae sp. (L)	0	0	0	2	0	0	0	2	2	3	0	2
	Staphylinidae	Staphylinidae sp.	0	0	0	0	1	0	0	0	0	0	0	0
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	2	1	0	0	0	0	0	0	0	1	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	2	3	2	0	2	0	0	0	2	1	0	0
		Ceratopogoninae sp.	3	3	3	3	3	2	2	1	1	2	2	3
		Dasyhelea sp.	3	4	4	2	4	1	2	1	0	1	3	2
		Forcipomyiinae sp.	2	4	2	0	3	0	0	0	2	1	0	0
	Chironomidae	*Ablabesmyia hilli*	2	3	2	3	0	2	3	0	0	2	0	0
		Chironomidae sp. (P)	2	3	3	2	2	3	2	2	2	3	2	3
		Chironomus aff. *alternans*	0	4	3	0	3	0	0	0	0	3	0	3
		Cladopelma curtivalva	0	0	0	0	0	0	0	2	0	0	0	0
		Cladotanytarsus sp.	0	0	0	0	0	2	0	2	0	0	1	2
		Corynoneura sp.	0	0	0	0	0	0	0	0	1	0	0	0
		Cricotopus albitarsis	0	0	2	0	0	0	0	0	2	0	2	0
		Cricotopus sp. 2	0	0	3	0	0	0	0	0	0	0	0	0
		Cryptochironomus griseidorsum	3	0	0	2	0	0	0	0	0	0	1	0
		Dicrotendipes sp. \`CA1\`	3	4	4	3	2	2	0	0	2	2	2	3
		Dicrotendipes jobetus	0	0	0	0	0	0	0	0	0	0	2	0
		Dicrotendipes sp. P4	0	0	0	0	2	0	0	0	0	0	1	0
		Kiefferulus intertinctus	3	0	0	0	0	0	0	0	0	3	0	0
		Larsia ?albiceps	3	4	3	3	3	3	3	3	2	2	3	3
		Nanocladius sp.	0	0	2	0	1	1	0	0	0	0	0	0
		nr. *Gymnometriocnemus* sp.	0	0	3	0	0	0	2	2	0	0	0	0
		Parachironomus sp.	0	0	0	0	0	0	0	2	0	0	0	0
		Paramerina sp. 1	0	4	3	0	2	0	0	0	2	4	3	3
		Polypedilum (Pentapedilum) leei	0	0	0	0	0	3	4	0	0	0	0	0
		Polypedilum nr. *vespertinum*	0	0	0	2	0	0	0	0	0	0	0	0
		Polypedilum nubifer	3	0	0	0	0	0	0	0	0	0	2	0
		Polypedilum sp. K1	0	0	0	2	0	0	0	0	0	0	0	2
		Polypedilum watsoni	0	0	0	2	0	0	2	0	0	0	0	0

			Study Area						Reference Sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF1**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**
		Procladius sp.	0	3	4	3	0	3	2	3	0	2	0	3
		Rheocricotopus sp.	2	0	3	0	0	0	0	2	0	0	0	3
		Rheotanytarsus sp.	0	0	0	0	0	0	0	1	0	0	0	0
		Stenochironomus watsoni	0	0	0	2	2	2	0	0	0	0	0	0
		Tanytarsus sp.	4	4	4	3	0	2	3	2	1	3	3	3
		Thienemanniella sp.	0	0	2	0	0	0	0	2	0	0	2	0
	Culicidae	*Aedes* sp.	0	0	0	0	0	1	0	0	0	0	0	0
		Anopheles sp.	2	4	2	3	1	0	1	0	0	2	0	0
		Culex sp.	3	4	1	3	3	1	1	0	0	3	0	0
		Culicidae sp. (P)	0	0	0	2	0	0	0	0	0	0	0	0
	Dolichopodidae	Dolichopodidae sp.	1	0	1	0	1	1	0	0	0	1	0	2
	Ephydridae	Ephydridae sp.	0	0	2	0	0	0	0	0	0	0	0	0
	Muscidae	Muscidae sp.	0	0	0	0	0	0	0	1	0	0	0	0
	Psychodidae	Psychodidae sp.	0	0	0	0	0	0	0	0	1	0	0	0
	Scatopsidae	Scatopsidae sp.	0	0	0	0	0	0	0	0	0	2	0	0
	Simuliidae	Simuliidae sp.	0	0	4	0	0	0	0	2	0	0	3	2
		Simuliidae sp. (P)	0	0	0	0	0	0	0	0	0	0	0	1
	Stratiomyidae	Stratiomyidae sp.	0	4	0	0	0	0	0	2	1	0	0	0
	Tabanidae	Tabanidae sp.	2	3	2	0	1	0	0	0	0	0	0	0
	Tipulidae	Tipulidae sp.	1	1	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	**Baetidae**	Baetidae sp.	4	0	5	3	4	2	2	2	4	3	3	3
		Cloeon fluviatile	0	2	0	0	0	0	0	0	0	0	0	2
		Cloeon sp. Red Stripe	4	5	3	2	3	1	1	0	0	2	3	0
		Offadens G1 sp. WA2	0	0	0	0	0	0	0	2	0	0	0	0
		Pseudocloeon hypodelum	0	0	0	0	0	0	0	0	3	0	0	3
		Pseudocloeon sp.	0	0	2	0	0	0	0	0	0	0	0	0
	Caenidae	Caenidae sp.	0	3	0	3	1	1	0	3	3	3	0	3
		Tasmanocoenis sp.	0	0	0	0	0	0	0	0	0	0	2	0
		Tasmanocoenis sp. M	0	0	4	2	0	0	0	0	0	0	0	2
		Tasmanocoenis sp. P/arcuata	0	2	4	3	0	2	0	2	1	2	2	2
Hemiptera	**Belostomatidae**	Belostomatidae sp.	0	0	0	0	0	0	0	0	0	0	2	0
		Diplonychus eques	0	2	0	0	0	0	0	0	0	0	2	0
	Gerridae	Gerridae sp.	0	2	2	2	1	2	0	1	0	0	0	2
		Limnogonus fossarum gilguy	2	2	2	0	1	0	0	2	0	0	2	0
		Limnogonus luctuosus	0	0	0	0	0	1	0	1	0	2	2	2
		Limnogonus sp.	0	0	0	0	0	0	0	0	0	0	0	0
		Rhagadotarsus anomalus	0	0	0	0	0	0	0	0	0	2	0	0
	Hebridae	Hebridae sp.	0	1	0	0	2	0	0	0	0	0	0	0
		Hebrus axillaris	1	1	0	0	1	0	0	0	0	1	0	0
Corixoidea		Corixoidea sp.	0	0	1	2	2	0	1	0	0	0	0	0
	Micronectidae	*Austronecta bartzarum*	0	0	0	0	0	0	0	1	0	0	0	0
		Micronecta lansburyi	0	0	0	0	0	0	1	0	0	0	0	0
		Micronecta sp.	0	0	0	0	1	0	0	0	0	0	0	0
	Notonectidae	*Anisops elstoni*	0	1	0	0	0	0	0	0	0	0	0	0
		Anisops hackeri	0	2	0	0	0	0	0	0	0	0	1	0
		Anisops nabillus	0	0	0	0	0	0	0	0	0	0	1	0
		Anisops sp.	0	2	0	0	0	0	0	0	0	0	1	0
		Enithares woodwardi	0	0	0	0	0	0	0	0	0	0	1	0
		Notonectidae sp.	2	3	0	0	0	0	0	0	0	0	1	0
	Pleidae	*Paraplea brunni*	0	2	1	3	1	0	0	0	0	3	2	0
	Veliidae	*Microvelia* sp.	0	0	0	2	0	0	0	0	0	0	0	0
		Nesidovelia peramoena	0	1	0	0	1	0	0	0	0	2	0	0
		Nesidovelia sp.	0	0	0	0	0	0	0	0	0	3	0	0
		Veliidae sp.	1	3	0	0	3	0	0	0	0	0	0	0
Lepidoptera	**Crambidae**	Acentropinae sp.	0	0	2	0	0	0	0	0	1	2	0	0
		Margarosticha sp. 3	0	0	0	0	0	0	0	2	0	0	0	1
Odonata														
Anisoptera		Anisoptera sp.	4	2	3	3	4	2	3	2	1	3	3	2

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	Aeshnidae	*Adversaeschna brevistyla*	0	0	0	2	0	0	0	0	0	0	0	0
		Aeshnidae sp.	0	3	3	3	0	0	2	1	1	2	0	0
		Hemianax papuensis	4	2	1	1	0	0	1	0	0	0	3	0
	Corduliidae	*Hemicordulia tau*	0	0	0	1	0	0	2	1	0	1	0	0
	Gomphidae	*Austrogomphus gordoni*	0	0	0	0	0	0	0	1	0	0	0	0
		Gomphidae sp.	0	0	0	2	0	0	0	0	0	0	0	0
	Libellulidae	*Diplacodes haematodes*	0	0	2	2	2	0	0	1	2	0	2	2
		Orthetrum caledonicum	0	0	0	2	0	0	1	0	0	0	0	0
		Orthetrum migratum	0	0	0	0	0	0	0	0	0	0	2	0
		Tramea sp.	0	0	0	0	0	0	0	0	0	0	2	0
		Zyxomma elgneri	0	0	0	0	0	0	0	0	0	2	0	0
	Lindeniidae	*Ictinogomphus dobsoni*	0	0	0	0	0	0	0	0	0	2	1	0
Zygoptera		Zygoptera sp.	2	3	3	3	1	0	2	1	3	3	2	2
	Coenagrionidae	*Argiocnemis rubescens*	0	1	0	0	2	0	2	0	0	2	2	2
		Ischnura aurora	1	0	0	3	0	1	1	0	0	0	0	0
		Pseudagrion aureofrons	0	1	0	2	0	0	0	1	2	1	0	2
	Isostictidae	*Eurysticta coolawanyah*	0	0	0	1	0	0	0	2	0	2	0	0
Trichoptera	**Ecnomidae**	Ecnomidae sp.	0	0	0	0	0	0	0	0	0	0	0	0
		Ecnomus pilbarensis	0	0	0	2	0	1	2	0	0	2	0	2
	Hydropsychidae	*Cheumatopsyche wellsae*	0	1	0	0	0	0	0	3	3	0	0	4
	Hydroptilidae	*Hellyethira* sp.	0	0	1	0	0	0	0	0	0	0	0	0
		Hydroptilidae sp.	0	1	2	0	0	0	0	0	0	0	0	0
		Orthotrichia sp.	0	0	0	2	0	0	0	0	0	0	0	0
	Leptoceridae	Leptoceridae sp.	0	0	2	1	0	0	0	0	0	1	0	2
		Leptocerus sp. AV2	0	0	0	0	0	0	0	0	0	0	0	1
		Oecetis sp.	0	0	2	2	0	0	0	0	0	0	0	0
		Oecetis sp. Pilbara 4	0	0	2	1	0	2	0	1	0	2	0	1
		Triplectides australicus	0	0	0	0	0	0	0	0	0	1	0	0
		Triplectides ciuskus seductus	0	0	0	0	0	0	0	0	0	0	1	2
	Philopotamidae	*Chimarra* sp.	0	0	0	0	0	0	0	1	0	0	0	0
		Chimarra sp. AV17	0	0	0	0	0	0	0	0	0	0	0	4
		Philopotamidae sp.	0	0	0	0	0	0	0	0	1	0	0	3
	Polycentropodidae	*Paranyctiophylax* sp. AV5	0	0	1	0	0	0	0	0	0	0	0	0
		Trichoptera sp.	0	0	2	0	0	0	0	0	0	0	0	0
		Taxa richness	**70**	**88**	**80**	**77**	**64**	**44**	**35**	**52**	**35**	**75**	**67**	**62**