MAC Phase 4
Aquatic monitoring Dry 2022 and Wet 2023

Report to BHP Western Australia Iron Ore

18 November 2024

Document Status				
Revision No.	Author	Review / Approved for Issue	Approved for Issue to Name	Date
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2	Kim Nguyen	Jess Delaney	Suzi Wild (BHP)	18/11/2024

Executive Summary

Biologic Environmental Survey (Biologic) was commissioned by BHP Western Australia Iron Ore (WAIO) to undertake a detailed, 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 Survey Area). The Survey Area lies to the north of the current BHP WAIO MAC operation, within the East Pilbara region of Western Australia (WA). The Survey Area, along with Reference sites sampled elsewhere, comprised the Study Area for this project.

Sampling was undertaken in the dry season of 2022 (Dry 2022) and wet season of 2023 (Wet 2023) as part of this survey, with a total of 12 sites sampled, comprising six in the Survey Area (named MarC1 to MarC6) and six Reference sites. This survey represents the third aquatic ecosystem survey within this reach of Marillana Creek, with previous sampling undertaken in the Dry 2020, Wet 2021, Dry 2021 and Wet 2022. All previously established sampling locations held water in the Dry 2022. However, in the Wet 2023, two Survey Area sites were dry. Pools within 1 km downstream of MarC6 were inundated at the time, and therefore targeted for sampling using the full suite of aquatic ecosystem sampling methods (named MarC6a and MarC6b). One Reference site, MACREF1 located on a tributary of Yandicoogina Creek, was also dry in the Wet 2023.

The aquatic survey included habitat assessments and sampling of water quality, macrophytes (submerged and emergent) and dominant riparian vegetation, zooplankton, hyporheos fauna, macroinvertebrates and fish. Sediments were collected at dry sites in order to run rehydration trials. Methods followed those used in similar surveys, including the Pilbara Biological Survey (PBS), National Monitoring River Health Initiative, and recent surveys undertaken by Biologic for other BHP projects nearby.

Riparian vegetation throughout the Survey Area is characterised by an open overstorey of *Eucalyptus camaldulensis*, *Melaleuca argentea* and *M. glomerata* over *Cyperus vaginatus*. Weeds were sporadic throughout the Survey Area, but were not present in high diversity, density, or abundance. Baseline aquatic surveys found the Survey Area supports Groundwater Dependent Ecosystems (GDEs) of varying levels of significance, based on the presence of High to Very High GDE indicator flora taxa. During the current survey, many of the Groundwater Dependent Vegetation (GDV) taxa were dead or showing signs of decline, including mature *M. argentea* at MarC3 and MarC4.

Surface waters across the Survey Area ranged from fresh to brackish, with circum-neutral to slightly basic pH, low dissolved oxygen (DO), and generally low concentrations of nutrients and dissolved metals. Electrical conductivity (EC), alkalinity and the concentration of major

ions was highly variable across the Survey Area, reflecting the evapoconcentration of ions as pools receded. 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. DO, EC, pH, nitrogen oxides, total nitrogen, total phosphorus, and concentrations of dissolved boron, arsenic, aluminium, and copper). Across the entire baseline sampling period, several analytes were recorded in significantly higher concentration from the Survey Area, in comparison to Reference sites. Such analytes included EC, pH, turbidity, alkalinity, major ions (sodium, magnesium, potassium, chloride and sulfate), total N, and concentrations of dissolved arsenic, boron, cobalt, copper, uranium and vanadium. Further analysis of all baseline data indicated that overall water quality of the Survey Area was significantly different to Reference sites. However, water quality of the Reference site MACREF2, located on Marillana Creek, was statistically similar to the Survey Area.

A diverse range of aquatic fauna and flora was recorded from the Survey Area across all baseline sampling events, including 79 riparian flora taxa, 488 native aquatic invertebrate taxa (across zooplankton, hyporheic, rehydrate and macroinvertebrate lists), two freshwater fish species, and two frog species. Generally, the Survey Area supported relatively high invertebrate taxa richness in surface waters and hyporheic zones for ephemeral pools, including several significant, potentially restricted and/or Pilbara endemic taxa. However, taxa richness has declined over time, particularly of hyporheos and macroinvertebrate fauna. Abundance and taxa richness of fish has also declined over time, as well as GDV richness and general vegetation condition. These changes were notable during the Wet 2023 compared to previous sampling events.

As is common for zooplankton, richness and assemblage composition was highly variable, both spatially and temporally across sampling events. Of note, was the fact that richness of zooplankton was significantly higher in the Survey Area, than Reference sites.

The number of stygobitic fauna recorded from hyporheic zones of the Survey Area was comparable to that of springs elsewhere in the Pilbara, indicating the presence of sub-surface flow in this reach of Marillana Creek. Taxa richness recorded in the Wet 2023 was significantly lower than all other events. There was also a significant interaction between site types and sampling events, indicating that the pattern of change over time was not the same in the Survey Area as Reference sites.

Macroinvertebrate taxa richness in the Survey Area was generally comparable to Reference sites over time, except in the Wet 2023 when it was notably lower. Interestingly, macroinvertebrate richness in the Dry 2021 was comparable to Reference sites, despite only two surface pools in the Survey Area at the time, with these pools likely acting as important refuges for aquatic fauna at that time, when the creek was largely dry and biota would have been under stress. Since the Dry 2021, the continued drying of the creek within the Survey Area led to a negative correlation between macroinvertebrate richness and time, a trend that was not mirrored at Reference sites, despite some sites also having low water levels (BENS and MUNJS) and one site being dry (MACREF1). The low macroinvertebrate richness recorded from the Survey Area in the Wet 2023 came at a time when six sites were successfully sampled. It therefore seems that the increase in length of time between inundation, coupled with the reduced time of inundation, is affecting the macroinvertebrate fauna of the Survey Area currently, with taxa unable to recover between drying events. This was also seen in the reduction in richness of more sensitive odonate taxa from the Survey Area in the Wet 2023. Overall, there was no significant difference in macroinvertebrate taxa richness between site types, but richness recorded in the Wet 2023 was significantly lower than all other preceding sampling events.

One freshwater fish species, the spangled perch (*Leiopotherapon unicolor*), was recorded from the Survey Area in the current survey. The Survey Area has previously been known to support two species of freshwater fish; the Pilbara tandan *Neosilurus* sp., along with the spangled perch. Spangled perch abundance in the Survey Area has steadily declined over time, with the lowest abundance in a single sampling event recorded during the Wet 2023, and all individuals recorded from a single site (MarC6a). In addition, the distribution of spangled perch in the Survey Area has reduced over the baseline sampling period, with no record of the species from MarC2 since the Dry 2020, or from MarC1 and MarC4 since the Wet 2021. While the population persisted in additional pools sampled at that time (MarC3a and MarC6a), spangled perch have been lost from the upper reaches of Marillana Creek since the Dry 2021 and have not dispersed back into this area since.

Other aquatic vertebrate fauna recorded from the Survey Area across all baseline sampling events included the desert tree frog (*Litoria rubella*), and at least one other species of frog that was unable to be determined at the time of the survey, but likely to be either Main's frog (*Cyclorana mainii*), or the Pilbara toadlet (*Uperoleia saxatilis*).

While most taxa recorded from the Survey Area across all baseline sampling events were common, ubiquitous species, several were of significance, either due to being listed (*Ipomoea racemigera*, *Eurysticta coolawanyah*, *Austroagrion pindrina, Hemicordulia koomina, Ictinogomphus dobsoni*), representing new OTUs/species (*Rutacarus* \`sp. Biologic-ACAR022\`, nr *Phyllognathopus* \`sp. Biologic-HARP058\`, Canthocamptidae \`sp. Biologic-HARP059, *Hanseniella* \`sp. Biologic-SYMP055\`, *Hanseniella* \`sp. Biologic-SYMP069\`), having potentially restricted distributions (*Guineaxonopsis* \`sp. Biologic-ACAR013\`, *Rutacarus* \`sp. Biologic-ACAR007\`, *Guineaxonopsis* sp., *Rutacarus* sp., *Wandesia* sp., Bathynellidae sp., *Gomphodella alexanderi*, *Chydaekata* sp. MJ1-UM1, Paramelitidae `sp. Biologic-AMPH024`, *Elaphoidella* sp., *Kinnecaris* `sp. Biologic-HARP037`, *Haliplus fortescueensis*), and/or relatively uncommon Pilbara endemics or with disjunct distributions (*Aspidiobates pilbara*, *Bennelongia* `sp. Biologic-OSTR026`, *Atopobathynella* `sp. Biologic-PBAT019`, *Limnadopsis pilbarensis*).

Results from this and the previous sampling events for the MAC Phase 4 project provide an assessment of the baseline ecological values and health of aquatic systems within the Survey Area.

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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
PBS	Pilbara Biological Survey
PEC	Priority Ecological Community
SRE	Short-range endemic
WAM	Western Australian Museum
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

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 Survey Area; Figure 1.1). The Survey Area occurs to the north of the current BHP WAIO MAC operation, within the East Pilbara region of Western Australia (WA). The Survey Area, along with Reference sites sampled elsewhere, comprised the Study Area for this project.

Two aquatic ecosystem surveys have been undertaken within this reach of Marillana Creek, with surveys conducted in the dry season of 2020 (Dry 2020) and wet season of 2021 (Wet 2021) (Biologic, 2022b), and the dry of 2021 (Dry 2021) and wet of 2022 (Wet 2022) (Biologic, 2023b). These surveys identified the presence of a groundwater dependent ecosystem (GDE) and associated permanent and semi-permanent pools within the Survey Area. 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*). The pools associated with the GDE provide important habitat for aquatic fauna, and were found to support notable ecological values.

While the previous surveys were comprehensive, they do 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 seasonal (wet and dry) sampling 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. In addition, surface water levels in the Survey Area have declined since aquatic monitoring began in the Dry 2020, with all monitoring pools completely drying in the Dry 2021 and adverse effects to groundwater dependent vegetation and the fish community noted (Biologic, 2023b). Therefore, BHP commissioned Biologic to undertake an aquatic survey within the Survey Area in the dry season of 2022 (Dry 2022) and wet of 2023 (Wet 2023) to add to the baseline dataset and monitor the effects of declining water levels on the GDE and ecology of the permanent pools. The scope of works included:

- A detailed, two-season aquatic survey at all previously established sites, including Reference sites.
- Identification of any significant ecological values related to aquatic biota and their habitats within the Survey Area.

- An assessment of the seasonal, temporal and spatial variation in water quality and aquatic fauna across the baseline, incorporating data from previous surveys (Biologic, 2022b, 2023b).

1.2 Compliance

Environmental legislation and regulation relating to aquatic ecosystems include:

- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Cwlth)
- *Biodiversity Conservation Act 2016* (WA) (BC Act)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000; ANZG, 2018)
- *Rights in Water and Irrigation Act 1914* (WA) (RIWI).

Three key environmental factors relate to aquatic ecosystems, as defined by the Western Australian Environmental Protection Authority (EPA). These include Inland Waters, Terrestrial Fauna, and Flora and Vegetation (EPA, 2023).

Inland Waters -

Defined by the EPA as: *"The occurrence, distribution, connectivity, movement, and quantity (hydrological regimes) of inland water including its chemical, physical, biological and aesthetic characteristics (quality)"* (EPA, 2018).

EPA's objective with respect to the Inland Waters factor is:

- "to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected" (EPA, 2018).

The EPA is primarily focused on impacts to significant ecosystems. In relation to the Pilbara, significant ecosystems include (but are not limited to):

- wetlands listed in the Directory of Important Wetlands in Australia
- wetlands protected by Environmental Protection Policies under Part III of the *Environmental Protection Act 1986*
- wild rivers, as identified by the Australian Heritage Commission and Department of Water and Environmental Regulation
- wetland types which may be poorly represented in the conservation reserves system
- springs and pools, particularly in arid areas
- ecosystems which support significant flora, vegetation and fauna species or communities, including migratory waterbirds, bats, and subterranean fauna
- ecosystems which support significant amenity, recreation, and cultural values (EPA, 2018).

Terrestrial Fauna –

Defined by the EPA as: "animals living on the land or using land (including aquatic systems) for part of their lives, and include vertebrates (freshwater fish, amphibians, reptiles, birds, and mammals) and invertebrates" (EPA, 2016b).

EPA's objective for the Terrestrial Fauna factor is:

- to protect terrestrial fauna so that biological diversity and ecological integrity are maintained (EPA, 2016b).

Flora and vegetation –

Flora is defined by the EPA as native vascular plants, while vegetation is the: "groupings of different flora patterned across the landscape that occur in response to environmental conditions" (EPA, 2016a).

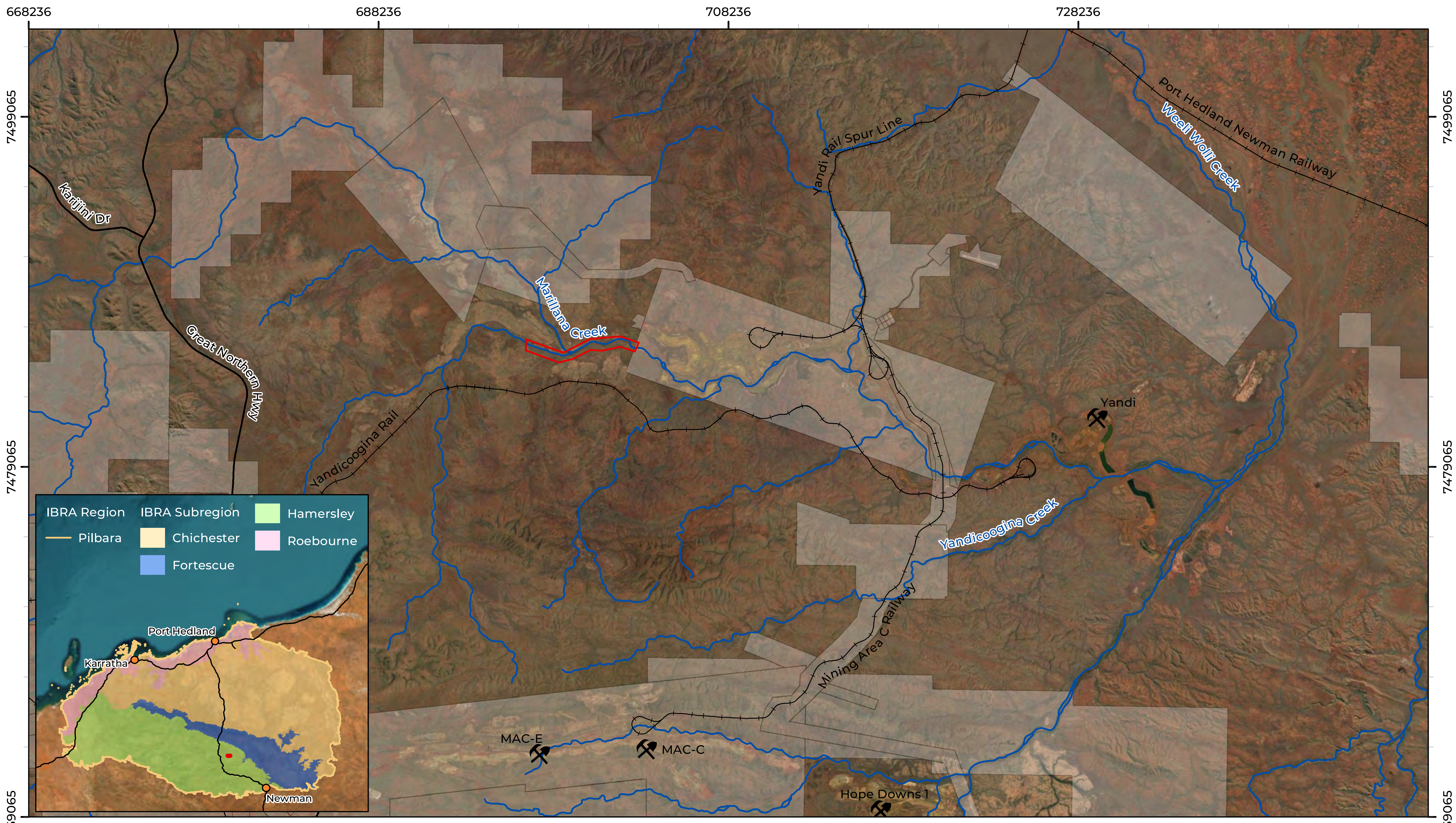
EPA's objective is:

- to protect flora and vegetation so that biological diversity and ecological integrity are maintained (EPA, 2016a).

This survey was carried out in accordance with the relevant guidance, including:

- Environmental Factor Guideline, Inland Waters[1] (EPA, 2018)
- Technical Guidance, Terrestrial Fauna Surveys (EPA, 2016c)
- Assessing and Managing Water Quality in Temporary Waters (Smith *et al.*, 2020)
- BHP WAIO's Aquatic Fauna Assessment Methods Procedure (0098594) (BHP, 2022)
- Best practice aquatic fauna sampling as referenced by the Pilbara Biological Survey (Pinder *et al.*, 2010), and National Monitoring River Health Initiative (Choy & Thompson, 1995)
- Recent aquatic ecosystem surveys undertaken by Biologic for this (Biologic, 2022b, 2023b), and other BHP projects in the East Pilbara (Biologic, 2020, 2021, 2022e, 2023d, 2023e, 2023g).

[1] There is currently no technical guidance for the Inland Waters factor.



LEGEND

- Survey Area
- Current BHP Tenure
- Operating Mine
- State Road
- Rail
- Major Surface Hydrology

Biologic

Scale 1:200,000

0 4 8 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 20/12/2023

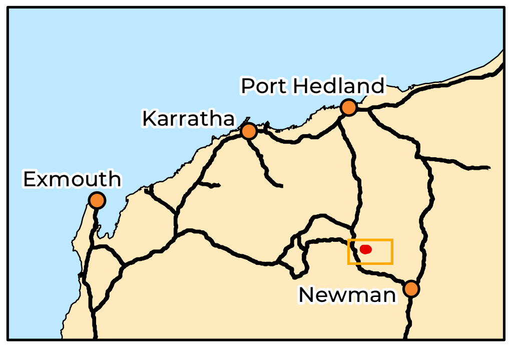


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Figure 1.1: Survey Area and regional context

2 Environment

2.1 Biogeography

The Survey 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 Survey 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, 2003).

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, 2003). 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 Survey 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 Survey 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 Survey Area.

Marillana Creek is currently affected by mining operations downstream of the Survey Area. The BHP Yandi mine currently dewater developing pit areas and discharge into Marillana Creek, approximately 23 km downstream of the Survey 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 Survey Area, just upstream of the confluence with Weeli Wolli Creek.

2.3 Groundwater Dependent Ecosystems (GDEs)

Groundwater-Dependent Ecosystems (or GDEs) rely on 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 which includes cave and aquifer ecosystems (BoM, 2021).

Above-ground terrestrial GDEs are typically characterised by the presence of flora species that rely on groundwater (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).

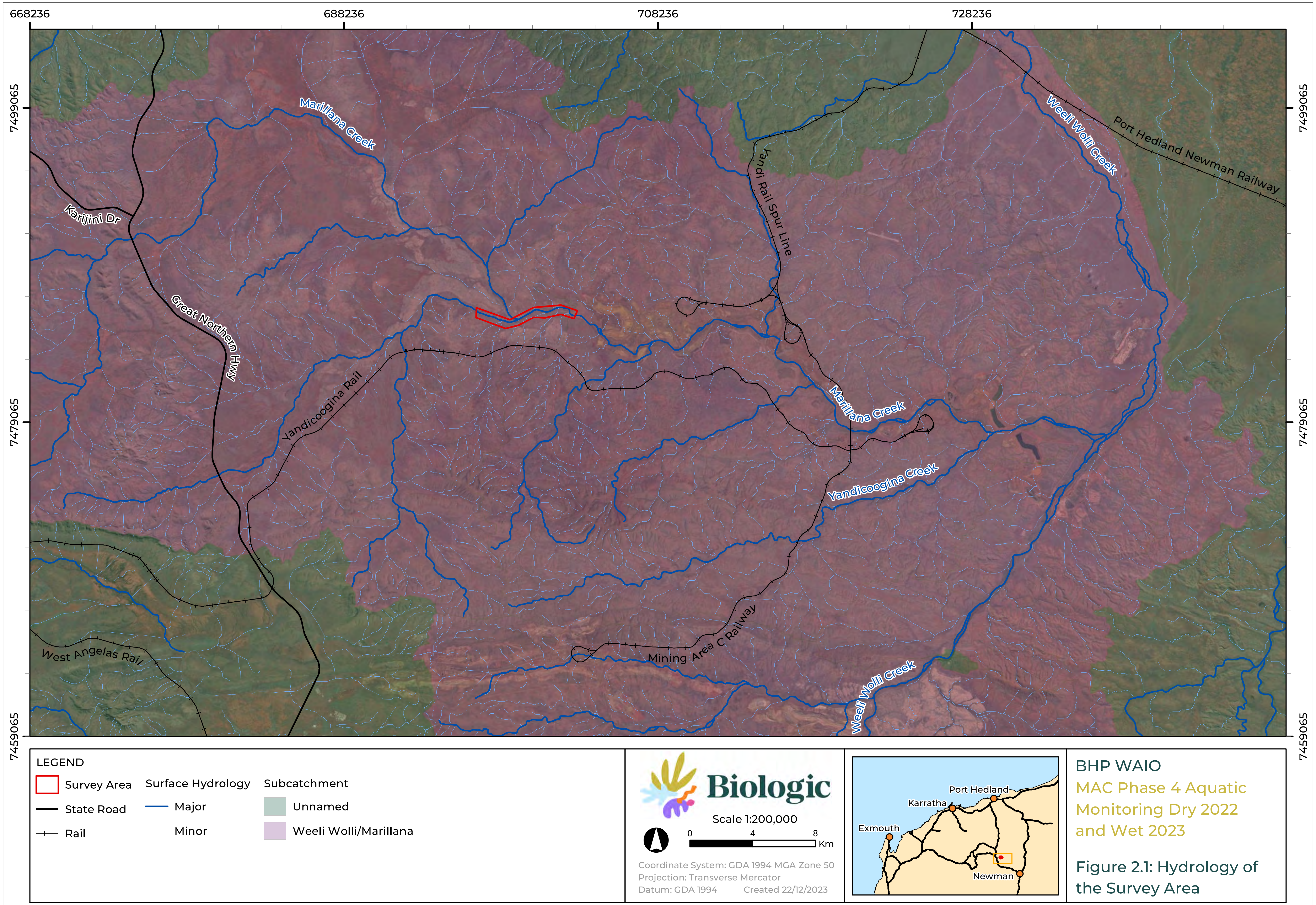

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Figure 2.1: Hydrology of the Survey Area

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 in a channel iron deposit aquifer. 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 absence of GDVs.

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 (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.

2.3.1 Groundwater Dependent Species

Above-ground GDEs are typically characterised by the presence of flora species that rely on groundwater. 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 areas where they have access to groundwater to 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.

Facultative phreatophytes 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 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.

The Survey Area is known to support both obligate (*Melaleuca argentea*), and facultative phreatophytes (*Eucalyptus camaldulensis* subsp. *obtusa* and *Eucalyptus victrix*). Groundwater dependence and environmental water requirements are well 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), but there is little information regarding the groundwater use strategies of understorey species. Recent work on Pilbara GDEs has led to the further classification of GDVs, including understorey species, with species ranked according to their correlation with shallow groundwater, from low-level mesophytic and/or hydrophytic[2] indicator species through to very high-level indicator species (Rio Tinto, 2022). The groundwater dependence of species recorded from the Survey Area was assessed using this framework.

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 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 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 around 200 – 350 millimetres (mm) (predominantly in January, February and March), although rainfall may vary widely from year to year (van Etten, 2009). Temperatures vary considerably throughout the year with average maximum summer temperatures reaching 35 °C to 40 °C and winter temperatures generally fluctuating between 22 °C and 30 °C.

[2] 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.

3 Methods

3.1 Field Survey and Laboratory Team

Field surveys were conducted by Biologic aquatic ecologists Jessica Delaney (Principal Zoologist | Manager of Aquatic Ecology), Kim Nguyen (Senior Aquatic Ecologist), Alex Riemer (Senior Aquatic Ecologist), Syngeon Rodman (Senior Zoologist | Manager of Subterranean Fauna), Courtney Wilkins (Aquatic Ecologist), and Siobhan Paget (Aquatic Ecologist | Zoologist). All members of the field team have extensive experience undertaking aquatic ecosystem surveys throughout the Pilbara, with a combined experience of over 70 years.

Macroinvertebrate and hyporheos specimens were identified in-house by Alex Riemer, Kim Nguyen, Siobhan Paget, Vanessa Nici and Courtney Wilkins. Micro-crustacea were identified by Alex Riemer, Giulia Perina (Taxonomist), Juliana Pille Arnold (Senior Invertebrate Zoologist) and Dr Robert Walsh (Australian Water Life). The latter also processed and identified specimens within the zooplankton samples. Genetic analysis was undertaken in-house on selected micro-crustacea and hyporheos specimens by Stephanie Floeckner (Geneticist) and Joel Huey (Principal Geneticist). Flora samples (submerged and emergent macrophytes) were identified by Biologic's Flora Team, including Rachel Meissner, in conjunction with Alex Riemer and Christopher Hofmeester.

3.2 Licences

Aquatic ecology sampling was conducted under DBCA Fauna Taking (Biological Assessment Regulation 27), and DBCA Flora Taking (Biological Assessment Regulation 62) licences, as well as the Department of Primary Industries and Resource Development (DPIRD) Instrument of Exemption to the *Fish Resources Management Act 1994 Section 7 (2)* (Table 3.1). Fieldwork activities were also approved by Murdoch University's animal ethics committee, under Biologic's DPIRD licence to use animals for scientific purposes.

Table 3.1: Licence and exemption information under which the current survey was undertaken

Type	Licence Number	Valid	Issued To
DBCA Fauna Taking (Biological Assessment Regulation 27)	BA27000290-2	28/02/2022-28/02/2023	Jessica Delaney
	BA27000290-3	17/03/2023-16/03/2024	Jessica Delaney
DBCA Flora Taking (Biological Assessment Regulation 62)	FB62000095-2	16/05/2022-15/05/2025	Jessica Delaney
	FB62000428	5/05/2022-4/05/2025	Kim Nguyen
	FB62000429	5/05/2022-4/05/2025	Alex Riemer
DPIRD Instrument of Exemption to the Fish Resources Management Act	250976722	20/04/2022 - 20/04/2025	Jessica Delaney
DPIRD Licence to use animals for scientific purposes	U244/ 2022-2024	01/01/2022 - 31/12/2024	Biologic

3.3 Survey Timing, Weather and River Conditions

The field survey comprised two sampling events. The dry season survey (hereafter referred to as Dry 2022) was undertaken between the 9th and 12th of September 2022. Average maximum temperature (27.4°C) in September 2022 was 3.1 °C cooler than the long-term average maximum for the month. In the months preceding the survey, Newman received 22.8 mm of rain in June 2022, above the long-term average of 15.8 mm, while July and August 2022 recorded below average rainfall. Although conditions were dry at the time of the survey, Newman did receive 57.2 mm of rainfall in September 2022, which was notably higher than the long-term average of 4.7 mm (Figure 3.1).

The wet season survey (Wet 2023) was undertaken between the 31st of March and 3rd of April 2023, when average maximum daytime temperatures (29.6 °C) was 2.6 °C cooler than the April long-term average maximum temperature. Newman received below average rainfall in January and February 2023, recording 45.8 mm and 34.0 mm, respectively. However, total rainfall in March 2023 reached 118.4 mm, which was almost three times greater than the long-term average of 40.8 mm (Figure 3.1).

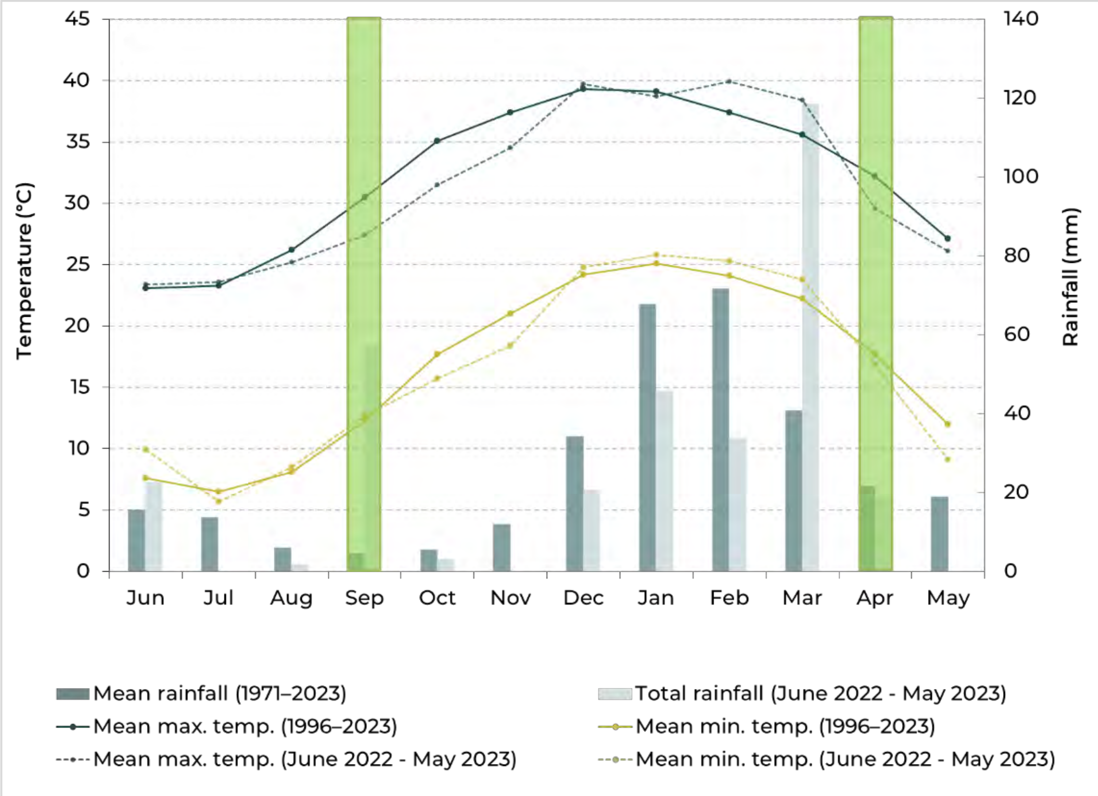


Figure 3.1: Total and long-term average monthly temperature (°C) and rainfall (mm) recorded from the Newman BoM gauging station in the months preceding the Marillana Creek aquatic surveys

Green bars indicate wet and dry season survey timing.

The Flat Rocks GS, station number 505011, is located on Marillana Creek approximately 18 km north-west of the Survey Area (DWER, 2023). Like Newman Aero, Flat Rocks GS reported 80.2 mm in September 2022, well above the monthly average rainfall of 6.1 mm for the area (Figure 3.2). The majority of this rainfall occurred in the week prior to the Dry 2022 survey. As a result, Marillana Creek was recently flushed, with many pools along its length. In the months prior to the Wet 2023, the Flat Rocks GS recorded below average rainfall (Figure 3.2). Much of Marillana Creek at the time of the Wet 2023 survey was dry, though surface water was present at some locations within the Survey Area, particularly in the section furthest downstream. The dry conditions during the Wet 2023 was noticeable more broadly across the East Pilbara, with some Reference pools also having low water levels (i,e. MUNJS and BENS) and one site being dry (MACREF1) at the time of sampling).

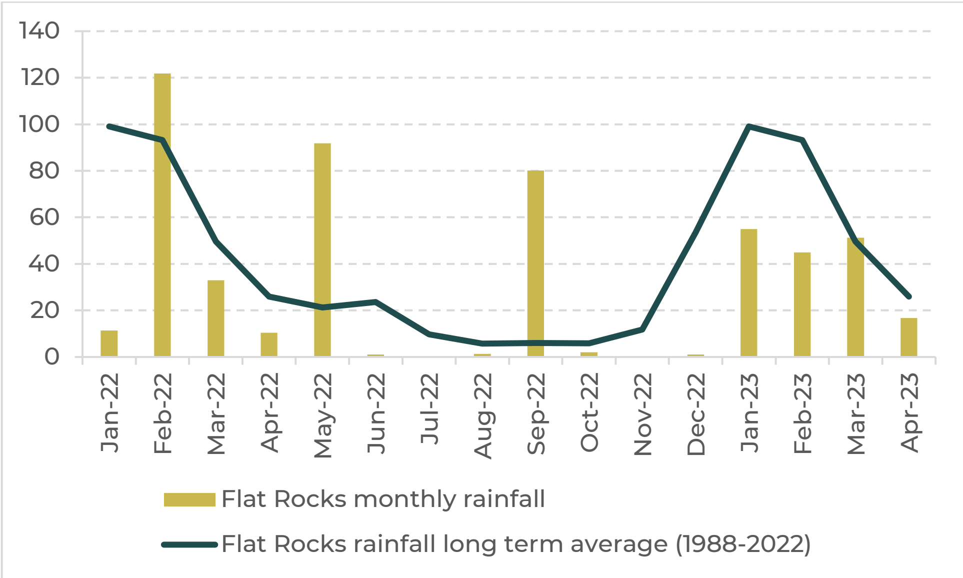


Figure 3.2 Monthly rainfall data (mm) at the DWER Flat Rocks GS on Marillana Creek, including monthly totals between Jan-21 and Apr-22 and long-term averages (1988-2021)

As previously reported (Biologic, 2023b), the streamflow gauging station at Flat Rocks on Marillana Creek (station number 708001) was damaged during a major flood and has not provided information since February 2021 (DWER, 2023). Long-term average annual streamflow, recorded from Flat Rocks GS between 1988 and 2020, is 6,995.97 ML. Streamflow in the Pilbara occurs as a direct response to rainfall, with monthly flows typically highest in January and February, before receding over the course of the year. The relationship between rainfall and streamflow on Marillana Creek are such that high flows occur during years of heavy rainfall.

3.4 Site Selection

A total of 12 sites were sampled in each season, six in the Survey Area and six Reference sites located elsewhere (Table 3.2 and Figure 3.3). In the Dry 2022, all previously established sampling locations held water and were successfully sampled, however, in the Wet 2023, two Survey Area sites were dry. Pools within 1 km of MarC6 were inundated at the time, and therefore targeted for sampling using the full suite of aquatic ecosystem sampling methods (named MarC6a and MarC6b). Sediment samples were collected from MarC1 and MarC2, to allow rehydrate-emergence trials to be undertaken in the laboratory, and provide information on aquatic ecosystem values in the absence of water.

One Reference site was located just outside the Survey Area, on Marillana Creek, upstream of the confluence with the un-named tributary (Figure 3.3). All other Reference sites were located on creeks and systems well outside the Survey 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. Due to access constraints, not all Reference sites could be sampled on all occasions, but an alternative (Running Waters), was sampled at these times.

Survey 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 3.3). Since the Dry 2021, additional sites downstream of MarC6 have been added to the program when established monitoring sites were dry.

Reference Sites

- MAC Reference 1 (MACREF1): permanent pool and riffle sequences on a tributary of Yandicoogina Creek, between BHP's MAC operations to the southwest and Yandi operations to the north. ~ 11 km southeast of the Survey Area.
- MAC Reference 2 (MACREF2): series of permanent pools and riffles on Marillana Creek, upstream of the confluence with the un-named tributary, just outside the Survey Area.
- Weeli Wolli Spring (WWS): spring site on Weeli Wolli Creek, within the Weeli Wolli Spring Priority 1 Priority Ecological Community (PEC). 31 km to the southeast of the Survey Area.
- Ben's Oasis (BENS): spring site on Weeli Wolli Creek, which is the second occurrence of the Weeli Wolli Spring P1 PEC. Located 41 km southeast of the Survey Area.
- Munjina Spring (MUNJS): a spring site on Munjina Creek, within the P2 PEC: *Riparian flora and plant communities of springs and river pools with high water permanence of the Pilbara*. This site was not able to be accessed in the Dry 2020 and Wet 2021, but has been sampled since the Dry 2021.
- Skull Springs (SS): spring site on the Davis River. Listed as a wetland of subregional significance by Kendrick and McKenzie (2003) due to the presence of springs, large permanent pools, large fish fauna, waterbird use and richness of aquatic vegetation. Lies ~ 215 km to the northeast of the Survey Area.
- Running Waters (RW): spring site on the Davis River, 23 km downstream of SS. Also designated a wetland of subregional significance for the same ecological values as SS. This site replaces other reference sites when they are dry and has not been sampled on all occasions for this program.

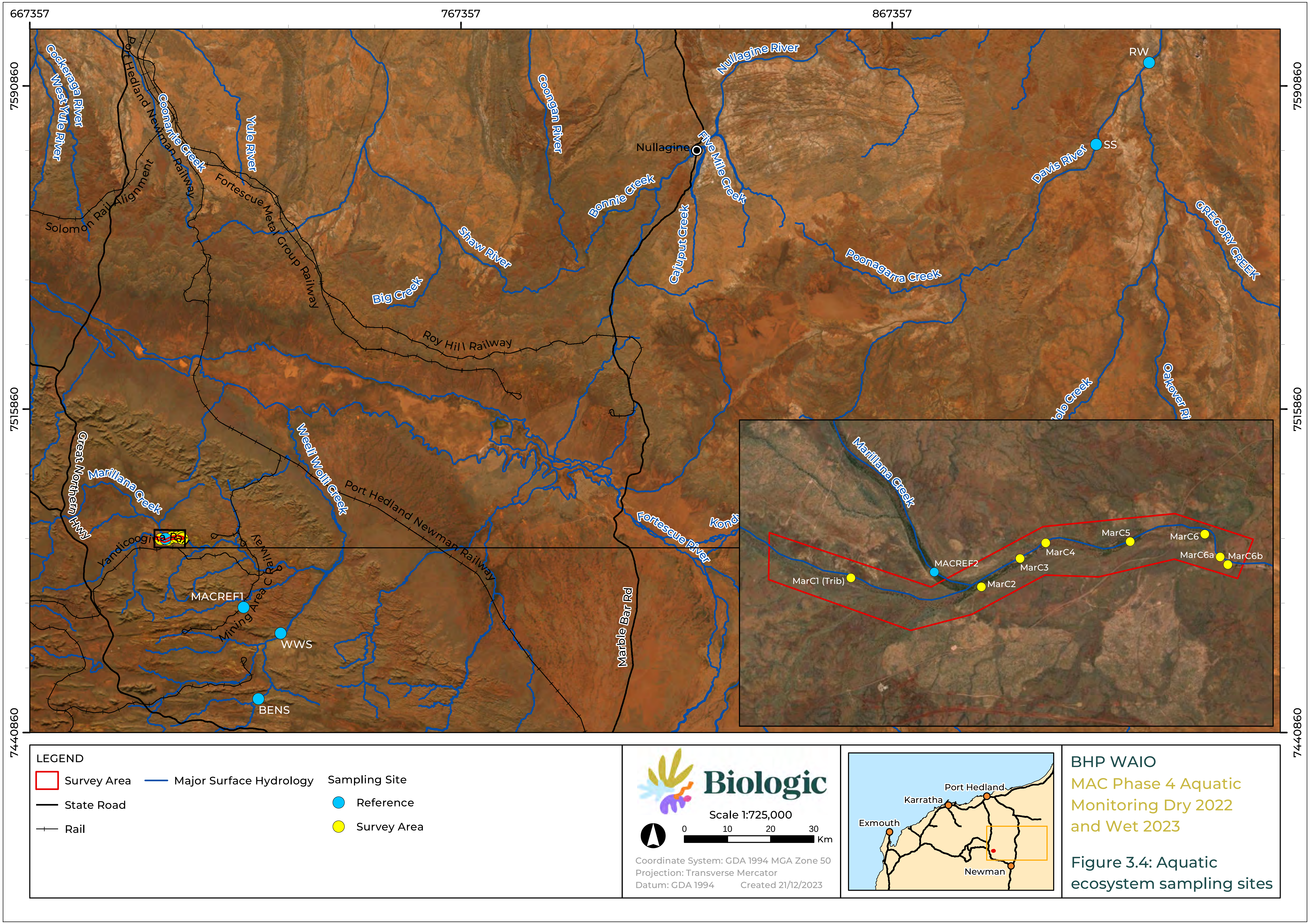


Figure 3.4: Aquatic ecosystem sampling sites

Table 3.2: Site information and sampling effort for all baseline sampling events

Type	Creek/System	Site	Site Code	Dry 2020	Wet 2021	Dry 2021	Wet 2022	Dry 2022	Wet 2023
Survey Area	Trib of Marillana Creek	Marillana Creek 1	MarC1	✓	✓	×	✓	✓	×
	Marillana Creek	Marillana Creek 2	MarC2	✓	✓	×	✓	✓	×
		Marillana Creek 3	MarC3	✓	✓	✓	✓	✓	✓
		Marillana Creek 4	MarC4	✓	✓	×	✓	✓	✓
		Marillana Creek 5	MarC5	✓	✓	×	✓	✓	✓
		Marillana Creek 6	MarC6	✓	✓	×	✓	✓	✓
		Marillana Creek 6a	MarC6a	-	-	✓	-	-	✓^
		Marillana Creek 6b	MarC6b	-	-	-	-	-	✓
Reference		Mining Area C Reference 2	MACREF2	✓	✓	✓^	✓^	✓^	✓
	Trib of Yandicoogina Creek	Mining Area C Reference 1	MACREF1	✓^	✓^	✓^	✓^	✓^	×f
	Weeli Wolli Creek	Weeli Wolli Spring	WWS	✓	✓	✓	✓	✓	✓
		Bens Oasis	BENS	✓	✓	✓	✓	✓	✓
	Munjina Creek	Munjina Spring	MUNJS	-	-	✓	✓	✓	✓
	Davis River	Skull Springs	SS	✓	✓	✓	✓	✓	✓
		Running Waters	RW	✓	✓	-	-	-	✓

✓ full suite of methods completed

^ no hypo due to substrate

× dry at time of sampling but sediments collected, and rehydration-emergence trials undertaken

f flora sampled

\- not sampled

- Skull Spring (SS): spring site on the Davis River. Designated a wetland of subregional significance by Kendrick and McKenzie (2003) 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 Survey Area.
- Running Waters (RW): spring site on the Davis River, 23 km downstream of Skull Springs. Running Waters was also designated a wetland of subregional significance by Kendrick and McKenzie (2003) for the same ecological values as Skull Springs. This site was sampled in the Dry 2020 and Wet 2021, when MUNJS was unable to be accessed (Table 3.2). Data for this site from the Wet 2023 was also included in this survey, as MACREF1 was dry at the time of sampling. However, as riparian flora data was able to be collected from MACREF1 in the Wet 2023, those data were included here.

3.5 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 included percent cover by inorganic sediment, submerged macrophyte, floating macrophyte, emergent macrophyte, algae, large woody debris (LWD), detritus, roots, and trailing vegetation. Substrate composition included percent cover by bedrock, boulders, cobbles, pebbles, gravel, sand, silt, and clay. Maximum water depth was measured with a graduated pole.

3.6 Water Quality

Water quality variables were recorded *in situ* at each site with a portable YSI Pro Plus multimeter. 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. Water quality variables 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)

- 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 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.

3.7 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.

3.8 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.

3.9 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 (~ 20 cm deep, 40 cm diameter) in alluvial sediments adjacent to the water's edge (Plate 3.1). The hole was swept with a modified 110 µm mesh plankton net immediately once it had filled with water, over the course of sampling, and 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).

Plate 3.1: Sampling the hyporheos using the Karaman method at MarC1 in the Dry 2022 (photo by Biologic ©)

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[3] fauna present were removed by sorting under a low power dissecting microscope. Specimens were

[3] 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).

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.

3.10 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 (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 the $\log_{10}$ scale abundance classes. All macroinvertebrate groups were identified using in-house expertise.

3.11 Rehydrate Emergence Trials

Sediments were collected from dry sites in the Wet 2023 (MarC1, MarC2 and MACREF1) 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 (Smith *et al.*, 2020).

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 sample was rehydrated in tanks flooded with 7 L of dechlorinated filtered water. Rehydration was undertaken in a controlled temperature room maintained under conditions comparable to 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 on algal pellets for the duration of the emergence trials. Emergent fauna and macrophytes were identified to the lowest level possible, and abundance recorded on a log_{10} abundance scale.

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.

3.12 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 3.2) 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[4]) measured (Plate 3.2). All fish were released alive to the site where they were collected.

Plate 3.2: Measuring a spangled perchat MarC6a in the Wet 2023 (photo by Biologic ©)

3.13 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.

[4] 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).

Locations of introduced redclaw were reported to DPIRD in accordance with licence conditions.

3.14 Data Analysis

3.14.1 Water Quality

In the absence of site-specific guideline values (SSGVs) for the Survey 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 A 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[5].
- 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 continual improvement in ecosystem condition. For toxicants, the 90% or 80% species protection DGVs may be applied.

[5] 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.

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).
- 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.

3.14.1.1 Statistical Analysis

3.14.2 Water Quality

Baseline water quality of the Survey Area collected between the Dry 2020 and Wet 2023 was characterised using both univariate and multivariate techniques. For values below the limit of detection (LOD), a value equal to half the LOD was used (analytes with values mostly below the LOD were removed prior to analysis). Boxplots were produced in SPSS (subscription build 1.0.0.1447) to examine the range in baseline conditions within the Survey Area and at Reference sites. The boxplots display minimum, 20^{th} percentile, median, 75^{th} percentile, maximum, and outlier concentrations for several selected water quality analytes. Two-way ANOVA was also used to assess temporal and spatial variability, by examining differences in concentrations of major analytes between site types (Survey Area vs Reference sites) and sampling events (Dry 2020, Wet 2021, Dry 2021, Wet 2022, Dry 2022 and Wet 2023).

Water quality data were further analysed using multivariate techniques in PRIMER v7 (Clarke & Gorley, 2015). Principal Components Analysis (PCA) was undertaken to reduce the large dataset to a subset of variables which best explain the variation amongst samples. PCA is well suited and commonly used to examine variation within environmental datasets. Prior to analysis, draftsman plots were prepared to assess whether the analytes were normally distributed, and collinear variables removed (i.e. hardness, alkalinity, Na, Mg, Cl, and S_SO4 were all correlated with EC, so the latter variable was included in the analysis as a surrogate for all the other related analytes). Transformations were made, where necessary, and then the water quality dataset was normalised to account for the differing scales and units within the data.

3.14.3 Macrophytes

Baseline flora data collected across all sampling events undertaken since the Dry 2020 were compiled into one dataset for further analysis. Total macrophyte (submerged and emergent) and GDV taxa richness was calculated for each site in each sampling event, and box plots created to show variation in richness across the baseline, similar to water quality (see above for water quality). Two-way ANOVA was also undertaken to test for significant differences in average macrophyte (plus GDV) richness between site types and sampling events. Equality of variances was assessed using the Levene's test (Levene, 1960).

3.14.4 Invertebrates

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

- Stygobite – obligate groundwater species, with special adaptations to survive such conditions such as small size, elongated body, lack of eyes, and loss of body pigmentation.
- 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.
- 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 habitats).

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 International Union for Conservation of Nature (IUCN), and Priority Fauna recognised by the DBCA (see Appendix B). In addition, species were assigned to one of the following conservation categories based on species' distributions:

- Cosmopolitan – species is found widely across the world.

- Australasian – species is found across Australia, New Guinea and neighbouring islands, including those of Indonesia.
- Australian endemic – species is only found in Australia.
- Northern Australia – species with distributions across the northern, tropical regions of the Australian continent.
- North-western Australia – found across northern W.A., including the Pilbara and Kimberley regions.
- Western Australian endemic – only known from W.A. (is restricted to, but is widely distributed across the state).
- Pilbara endemic - restricted to the Pilbara region of Western Australia.
- Short range endemic (SRE) – an SRE is a species occupying 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.
- Indeterminate distribution – taxa could not be assigned to one of the above, as there is currently insufficient knowledge on either its distribution or taxonomy to assess its level of endemism.

Baseline invertebrate data was characterised using boxplots prepared in SPSS to examine the variation in taxa richness (hyporheos fauna, zooplankton, and macroinvertebrates) within the Survey Area and at Reference sites, across the baseline sampling period. Two-way ANOVA was also used to assess temporal and spatial variability, by examining differences in richness between site types (Survey Area vs Reference sites) and sampling events (Dry 2020, Wet 2021, Dry 2021, Wet 2022, Dry 2022 and Wet 2023).

Invertebrate assemblage data (zooplankton and macroinvertebrates) 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-factor permutational multivariate analysis of variance (PERMANOVA). Multivariate analysis was undertaken on the complete amalgamated dataset, which incorporated all sampling events conducted across the baseline.

Using macroinvertebrate data from the Survey Area 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), to assess the influence of environmental condition and macroinvertebrates within the Survey Area. 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.

3.14.5 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 age class analysis for all fish 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

Boxplots were prepared to display variation in the abundance of the main freshwater fish species recorded across the baseline sampling period. Two-way ANOVA was also undertaken to test for significant differences in average abundances between site types and sampling events. Equality of variances was assessed using the Levene's test (Levene, 1960).

4 Results

4.1 Habitat Assessment

Riparian vegetation throughout the Survey Area is characterised by an open overstorey of *Eucalyptus camaldulensis*, *Melaleuca argentea* and *M. glomerata* over *Cyperus vaginatus* (Table 4.1 and Appendix C). Weeds were sporadic throughout the Survey Area, but were not present in high diversity, density, or abundance. Impacts of cattle were apparent throughout the Survey Area, including grazing of sedges and trampling of banks. No other major disturbances were noted, other than lowering water levels and pool drying. Although surface water was present at all sites in the Dry 2022, two sites were dry in the following Wet 2023 (MarC1 and MarC2). These sites are located in the upstream section of the Survey Area, within the area previously classified as a high significance GDE (Biologic, 2022a, 2022b). One Reference site was also dry in the Wet 2023 (MACREF1), while other Reference sites were notably receded (BENS, MUNJS; Table 4.1).

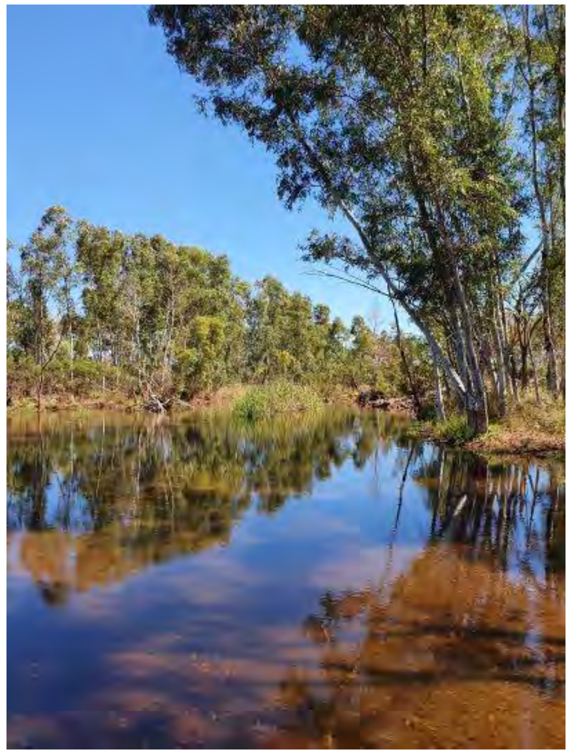
Although several GDV taxa were present throughout the Survey Area, vegetation condition was variable. Stands of *M. argentea* showed signs of decline in both seasons, particularly at MarC3 and MarC4. In the Wet 2023, macrophytes such as *Typha domingensis* and *Schoenoplectus subulatus* were dead or dying at several sites.

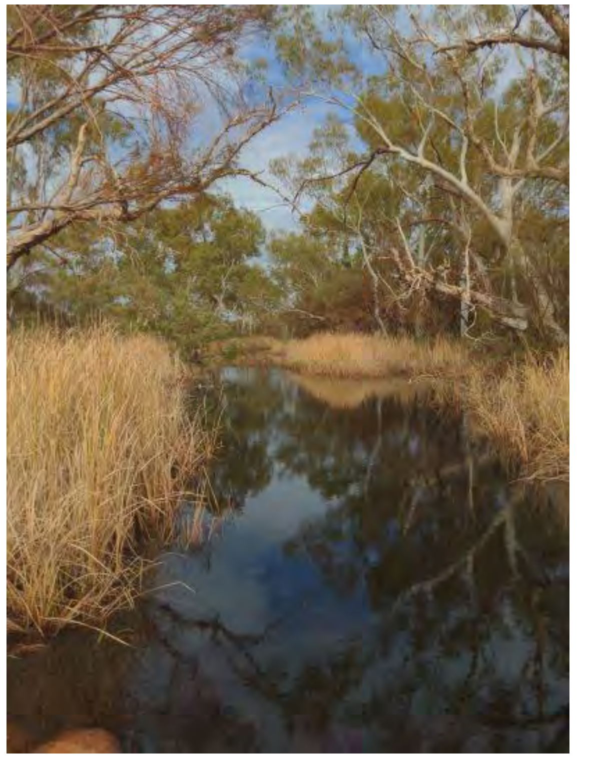
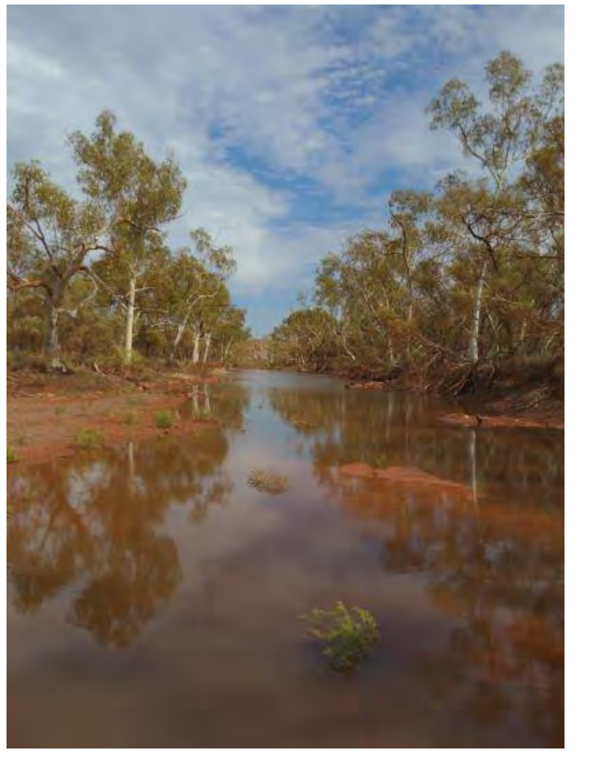
While most sites in the Survey Area were dominated by transmissive substrates such as pebbles and gravel, bedrock was more dominant at MarC3, MarC6a and MarC6b. MarC6 had comparatively low levels of bedrock, and was instead dominated by clay and gravel. Most sites recorded some contribution of sand and 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 Survey Area in the Dry 2022, comprising complex heterogenous substrates with which to support aquatic fauna, including submerged and emergent macrophytes, LWD, algae and detritus. Habitat diversity was lower in the Wet 2023, with the most apparent seasonal change due to loss of submerged macrophyte and algae across the Survey Area. Open sediment also became the most dominant habitat type at all Survey Area sites in the wet season, with a reduction in macrophytes, algae cover and roots. Reference sites were comparable in habitat diversity to Survey Area sites and showed little seasonal change. The exception was MACREF1, which was dry in the Wet 2023, despite being considered a groundwater dependent permanent pool based on previous surveys and presence of GDVs, including *Imperata cylindrica* (Biologic, 2022b, 2023b).

Table 4.1: Summary of aquatic habitats sampled, including site photographs

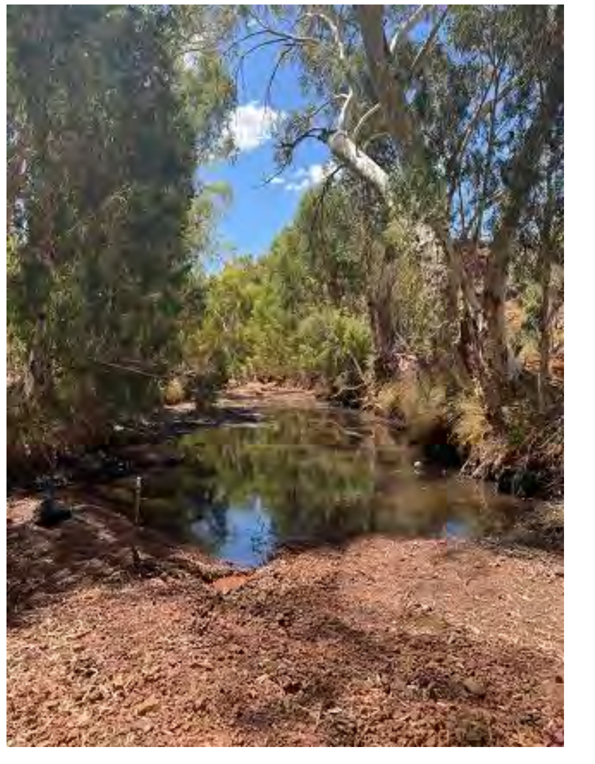
Site	Pool type	Site description	Pool Size	Maximum Depth	Site photograph	
					Dry 2022	Wet 2023
MarC1 (tributary)	Small pools	Series of semi-permanent, shallow pools and riffles located on an un-named tributary of Marillana Creek. Open overstorey of *Melaleuca argentea*, *M. glomerata*, *M. bracteata* and *Acacia* spp. In-stream habitat comprising emergent macrophytes (*Cyperus vaginatus*, *Schoenoplectus subulatus*, *Eleocharis geniculata* and *Typha domingensis*), submerged charophyte (*Chara fibrosa*), algae, LWD, trailing vegetation, detritus, root mats, and open sediment. Mineral substrate dominated by pebbles and gravel, with small amounts of bedrock, cobbles, sand, and silt. This site was dry at the time of the Wet 2023 survey. *Typha domingensis* and *Schoenoplectus subulatus* were dead or dying.	Dry 2020 = 180 x 5 m Wet 2021 = 200 m x 5 m Dry 2021 = dry Wet 2022 = 200 m x 4 m Dry 2022 = 120 m x 4 m Wet 2023 = dry.	Dry 2020 = 0.2 m Wet 2021 = 0.2 m Dry 2021 = dry Wet 2022 = 0.4 m Dry 2022 = 0.4 m Wet 2023 = dry.		
MarC2	Small pools	Series of semi-permanent, shallow pools located on the main channel of Marillana Creek, downstream of the confluence with the un-named tributary. Riparian vegetation including *Eucalyptus camaldulensis*, *Melaleuca argentea*, *M. glomerata*, *M. bracteata*, *Acacia ampliceps* and *A. coriaceae* subsp. *pendens*. In-stream habitat comprising submerged charophytes (*Chara fibrosa*) 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, silt and cobbles also present. Site was dry at the time of the Wet 2023 survey. Dead *Typha domingensis*.	Dry 2020 = 100 x 8 m Wet 2021 = 100 m x 10 m Dry 2021 = dry Wet 2022 = 100 m x 4 m Dry 2022 = 110 m x 4 m Wet 2023 = dry.	Dry 2020 = 0.3 m Wet 2021 = 0.4 m Dry 2021 = dry Wet 2022 = 0.5 m Dry 2022 = 0.3 m Wet 2023 = dry.		

Site	Pool type	Site description	Pool Size	Maximum Depth	Site photograph	
					Dry 2022	Wet 2023
MarC3	Small pool	Long open pool over bedrock. *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 in the wet season, as well as some submerged macrophyte (*Vallisneria nana*) and charophytes (*Chara globularis*, *Nitella* cf. *furcata*), LWD, detritus, roots, and trailing vegetation. Substrate was dominated by bedrock with some gravel. In the wet season, *M. argentea* showed continued signs of senescence that was noted in the previous dry season. The Typha stands were mostly dead, and there were no submerged macrophytes.	Dry 2020 = 100 m x 20 m Wet 2021 = 60 m x 20 m Dry 2021 = main pool was dry, but a pool located 140 m downstream was 21 m x 9 m Wet 2022 = 220 m x 18 m Dry 2022 = 220 m x 16 m Wet 2023 = 30 m x 7 m.	Dry 2020 = 0.6 m Wet 2021 = 0.6 m Dry 2021 = 0.6 m Wet 2022 = 1.0 m Dry 2022 = 1.2 m Wet 2023 = 0.8 m.		
MarC4	Small pool	A small semi-permanent pool. Riparian vegetation consisting of *Eucalyptus camaldulensis*, *Melaleuca argentea*, *M. bracteata* and *M. glomerata*. In-stream habitat comprising submerged macrophyte (*Vallisneria nana*) and charophytes (*Chara fibrosa*), 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 were noted as being in poor condition in the Wet 2022, with continuing decline in the Dry 2022 and Wet 2023. *Typha* stands were dead in the Wet 2023.	Dry 2020 = 15 m x 11 m Wet 2021 = 30 m x 15 m Dry 2021 = dry Wet 2022 = 40 m x 13 m Dry 2022 = 150 m x 27 m Wet 2023 = 22 m x 12 m.	Dry 2020 = 0.7 m Wet 2021 = 0.4 m Dry 2021 = dry Wet 2022 = 1.2 m Dry 2022 = 1.65 m Wet 2023 = 1.0 m.		

Site	Pool type	Site description	Pool Size	Maximum Depth	Site photograph	
					Dry 2022	Wet 2023
MarC5	Small pool	Series of semi-permanent, shallow pools. Riparian vegetation including *Eucalyptus camaldulensis*, *Melaleuca argentea*, *M. bracteata* and various *Acacia* spp. In-stream habitat predominantly open sediment, with some submerged macrophyte (*Vallisneria nana*, *Potamogeton tepperi*) and *Chara fibrosa* charophytes, emergent macrophytes (*Typha domingensis* and *Cyperus vaginatus*), algae, detritus, LWD and roots. Mineral substrate dominated by gravel and pebbles. The *Typha* stands were in very poor condition in the Wet 2023. No submerged macrophytes were present at this time.	Dry 2020 = 35 m x 7 m Wet 2021 = 300 m x 15 m Dry 2021 = dry Wet 2022 = 180 m x 10 m Dry 2022 = 250 m x 13 m Wet 2023 = 200 m x 10 m.	Dry 2020 = 0.3 m Wet 2021 = 1.8 m Dry 2021 = dry Wet 2022 = 1.5 m Dry 2022 = 1.5 m Wet 2023 = 0.9 m.		
MarC6	Small pool	Semi-permanent pool colloquially referred to as Flat Rocks (Streamtec, 2004). Likely was permanent historically. Although located upstream of current mining operations, this site is thought to be impacted by drawdown from the nearby BHP WAIO Yandi operations (WRM, 2018). 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 macrophytes (*Cyperus vaginatus* and *Typha domingensis*). Submerged macrophytes present in the Dry 2022, comprised of *Najas tenuifolia*, *Vallisneria* sp., *Ruppia* sp. and *Potamogeton tepperi*. Small amounts of detritus, LWD roots and algae also present. Substrate comprising clay, gravel, cobbles, sand, and silt.	Dry 2020 = 20 m x 20 m Wet 2021 = 200 m x 30 m Dry 2021 = dry Wet 2022 = 250 m x 20 m Dry 2022 = 200 m x 15 m Wet 2023 = 180 m x 11 m.	Dry 2020 = 0.15 m Wet 2021 = 1.5 m Dry 2021 = dry Wet 2022 = 1.5 m Dry 2022 = 1.1 m Wet 2023 = 1.0 m.		

Site	Pool type	Site description	Pool Size	Maximum Depth	Site photograph	
					Dry 2022	Wet 2023
MarC6a	Permanent creek pool	The upstream end of a large permanent bedrock pool, located downstream of MarC6 within the Survey Area and outside of the active BHP Yandi tenement. *Eucalyptus* sp., *Melaleuca argentea* and *M. glomerata* over sedges (*Typha domingensis*, *Schoenoplectus subulatus*, *Cyperus vaginatus* and *C. squarrosus*). Many sedges in poor condition. In-stream habitat mostly open sediment, with submerged macrophyte (*Potomogeton tepperi* and *Ruppia* sp.), emergent sedges, algae, detritus, LWD and trailing vegetation. Predominantly bedrock substrate with small amounts of boulders, gravel, sand and clay.	Dry 2020 = not sampled Wet 2021 = not sampled Dry 2021 = 300 m x 15 m Wet 2022 = not sampled Dry 2022 = not sampled Wet 2023 = 300 m x 21 m.	Dry 2020 = N/A Wet 2021 = N/A Dry 2021 = 2.0 m Wet 2022 = N/A Dry 2022 = N/A Wet 2023 = 2.0 m.	Not sampled in this survey.	
MarC6b	Permanent creek pool	The downstream end of a large permanent bedrock pool, located downstream of MarC6 within the Survey Area and outside of the active BHP Yandi tenement. *Melaleuca argentea* and *M. glomerata* over sedges (*Typha domingensis*, *Schoenoplectus subulatus* and *Cyperus vaginatus*). Sedges mostly dead. In-stream habitat dominated by open sediment, with submerged macrophyte (*Potomogeton tepperi* and *Ruppia* sp.), emergent sedges, detritus, LWD and trailing vegetation. Predominantly bedrock substrate with small amounts of boulders, pebbles, gravel, sand, silt and clay.	Dry 2020 = not sampled Wet 2021 = not sampled Dry 2021 = not sampled Wet 2022 = not sampled Dry 2022 = not sampled Wet 2023 = 300 m x 21 m.	Dry 2020 = N/A Wet 2021 = N/A Dry 2021 = N/A Wet 2022 = N/A Dry 2022 = N/A Wet 2023 = 2.0 m.	Not sampled in this survey.	

Site	Pool type	Site description	Pool Size	Maximum Depth	Site photograph	
					Dry 2022	Wet 2023
MACREF2	Permanent creek pool	Long series of permanent pools and riffles sequences on Marillana Creek, located upstream of the confluence with the un-named tributary. Riparian vegetation characterised by *Eucalyptus camaldulensis*, *E. victrix*, *Melaleuca argentea, M. bracteata*, 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.	Dry 2020 = 250 m x 10 m Wet 2021 = 270 m x 8 m Dry 2021 = 300 m x 5 m Wet 2022 = 250 m x 10 m Dry 2022 = 200 m x 15 m Wet 2023 = 200 m x 15 m.	Dry 2020 = 0.6 m Wet 2021 = 0.6 m Dry 2021 = 0.5 m Wet 2022 = 0.5 m Dry 2022 = 0.5 m Wet 2023 = 0.8 m.		
MACREF1	Permanent creek pool	Series of permanent pools and riffles on a tributary of Yandicoogina Creek. *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 fibrosa*), LWD, detritus, roots and trailing vegetation. Predominantly bedrock substrate, with small amounts of gravel, sand and silt. Much of the *Typha domingensis* and *Schoenoplectus subulatus* were dead at the time of the Wet 2023 survey. The highly invasive weed *Bidens bipinnata* was recorded in the Dry 2022.	Dry 2020 = 200 m x 15 Wet 2021 = 200 m x 15 m Dry 2021 = 180 m x 10 m Wet 2022 = 180 m x 11 m Dry 2022 = 70 m x 7 m Wet 2023 = dry.	Dry 2020 = 1.3 m Wet 2021 = 1.4 m Dry 2021 = 0.4 m Wet 2022 = 1.0 m Dry 2022 = 1.2 m Wet 2023 = dry.		

Site	Pool type	Site description	Pool Size	Maximum Depth	Site photograph	
					Dry 2022	Wet 2023
WWS	Spring	Permanent spring on Weeli Wolli Creek comprising a series of pools and interconnecting riffles. Located within Rio Tinto's HD1 discharge area – surface flows maintained by discharge from spurs currently. Overstorey vegetation comprising *Melaleuca argentea* and *Eucalyptus camaldulensis* over a dense shrub layer. Emergent macrophyte comprising *Cyperus vaginatus,* and *Schoenoplectus subulatus*. Fringing *Lobelia arnhemiaca* present in both seasons. WWS is a Priority 1 PEC. Substrate comprising primarily gravel, pebbles, sand, and cobbles.	Dry 2020 = 100 m x 10 m Wet 2021 = 100 m x 11 m Dry 2021 = 100 m x 12 m Wet 2022 = 100 m x 11 m Dry 2022 =90 m x 4 m Wet 2023 =100 x 10 m.	Dry 2020 = 1.3 m Wet 2021 = 1.1 m Dry 2021 = 1.2 m Wet 2022 = 1.6 m Dry 2022 =1.1 m Wet 2023 =1 m.		
BENS	Spring	Series of pools and riffles on Weeli Wolli Creek, upstream of the main spring. Second occurrence of the WWS PEC, located upstream on Weeli Wolli Creek. Riparian vegetation consisting of *Eucalyptus camaldulensis* and *Melaleuca argentea* woodland over *Acacia* spp. shrubland, and sparse sedges (*Cyperus vaginatus*). *Stylidium weeliwolli* (P3) fringing on banks during the dry season, but not the wet season. Detritus and LWD present in-stream. Mineral substrate dominated by transmissive gravel and pebbles, with some sand, silt, bedrock, and boulders. Pool levels in the Wet 2023 were the lowest recorded during MAC surveys.	Dry 2020 = 60 m x 15 m Wet 2021 = 60 m x 16 m Dry 2021 = 100 m x 10 m Wet 2022 = 110 m x 15 m Dry 2022 = 200 m x 11 m Wet 2023 = 30 m x 7 m.	Dry 2020 = 1.1 m Wet 2021 = 1.6 m Dry 2021 = 1.2 m Wet 2022 = 1.6 m Dry 2022 = 1.5 m Wet 2023 = 0.7 m.		

Site	Pool type	Site description	Pool Size	Maximum Depth	Site photograph	
					Dry 2022	Wet 2023
MUNJS	Permanent creek pools	A series of long permanent pools over bedrock, with numerous riffle sections. Riparian vegetation comprising *Eucalyptus camaldulensis, Melaleuca argentea* and *Melaleuca bracteata*. Emergent macrophytes included *Typha domingensis, Cyperus vaginatus, Schoenoplectus subulatus, Machaerina juncea, Machaerina rubiginosa,* and *Eleocharis geniculata*. *Chara* spp., *Vallisneria annua* and *Potamogeton tepperi* submerged macrophytes present in-stream. No fish. No obvious signs of disturbance. *Stylidium fluminense* fringing throughout in the dry. Mineral substrate almost exclusively bedrock overlain by silt and organics. The main pool was markedly receded in the Wet 2023, having dropped more than 3.5 m since the preceding dry season survey. There was no flow into or out of the pool at this time, unlike all previous surveys at MUNJS since the Dry 2019.	Dry 2020 = N/A Wet 2021 = N/A Dry 2021 = 400 m x 15 m Wet 2022 = 400 m x 15 m Dry 2022 = 150 m x 12 m Wet 2023 = 15 m x 5 m.	Dry 2020 = N/A Wet 2021 = N/A Dry 2021 = 3.4 m Wet 2022 = 4.5 m Dry 2022 = 4.5 m Wet 2023 = 0.95 m.		
SS	Spring	Permanent spring flowing into a series of pools via a braided channel. Riparian vegetation comprising *Melaleuca argentea* and Acacia coriacea subsp. pendens, as well as sedges (*Cyperus difformis, Cyperus vaginatus Fimbristylis sieberiana* (P3), *Schoenoplectus subulatus* and *Eleocharis geniculata*). High diversity of submerged macrophytes including *Chara fibrosa, Najas marina, Vallisneria annua, Vallisneria nana, Potamogeton tepperi* and *Ruppia* sp. The P2 Priority flora (ground creeper) *Ipomoea racemigera* present. Fringing *Lobelia arnhemiaca* present in the wet season. Mineral substrate heterogenous, dominated by gravel, pebbles, and sand. Disturbances included cattle impacts and introduced vegetation (such as Mexican poppy *Argemone ochroleuca* subsp. *ochroleuca*).	Dry 2020 = 250 m x 22 m Wet 2021 = 250 m x 25 m Dry 2021 = 200 m x 22 m Wet 2022 = 250 m 22 m Dry 2022 = 200 m x 22 m Wet 2023 = 200 m x 18 m.	Dry 2020 = 2.5 m Wet 2021 = 1.5 m Dry 2021 = 1.2 m Wet 2022 = 1.2 m Dry 2022 = 1.3 m Wet 2023 = 1.05 m.		

Site	Pool type	Site description	Pool Size	Maximum Depth	Site photograph	
					Dry 2022	Wet 2023
RW	Spring	Permanent groundwater fed pool and riffles. *Melaleuca argentea* woodland over *Cyperus vaginatus* and *Typha domingensis*. In-stream habitat predominantly open sediment and detritus, with some LWD, submerged macrophyte, root mats, algae, and trailing vegetation also present. Bedrock substrate dominant upstream, with pebbles, gravel, sand, and silt present in the main pool. Disturbances include introduced redclaw and tourists (vehicle tracks through the creek and camping).	Dry 2020 = 300 m x 10 m Wet 2021 = 300 m x 20 m Dry 2021 = N/A Wet 2022 = N/A Dry 2022 = N/A Wet 2023 = 300 m x 21 m.	Dry 2020 = 1.8 m Wet 2021 = 4.0 m Dry 2021 = N/A Wet 2022 = N/A Dry 2022 = N/A Wet 2023 = 2.0 m.	Not sampled in this survey	

4.1.1 Characterisation of Baseline Habitat

The drying conditions experienced within the Survey Area were evident in the decline in habitat conditions across the baseline (Figure 4.1). Average in stream cover by submerged macrophytes has decreased over time (r = 0.77), from 22.17% in the Dry 2020 to 0% in the Wet 2023, despite four of the original sampling sites holding water at this time. The low cover in the Dry 2021, was influenced by the lack of water in the creek at that time, with only two sites being inundated. Although there was some recovery in submerged macrophyte cover in the Wet 2022, it then continued to decline to the Wet 2023 (Figure 4.1). Reference sites also underwent a reduction in submerged macrophyte cover over time (r = 0.87; Figure 4.1). Although this decline was not as pronounced at Reference sites (average of 11.8% in the Dry 2020 to 3.5% in the Wet 2023), the linear correlation was strong because there were no major increases in cover over the same time period (Figure 4.1). Importantly, cover by submerged macrophytes was greater than Reference sites in the initial sampling event, but has since been generally lower, other than in the Wet 2022 (Figure 4.1).

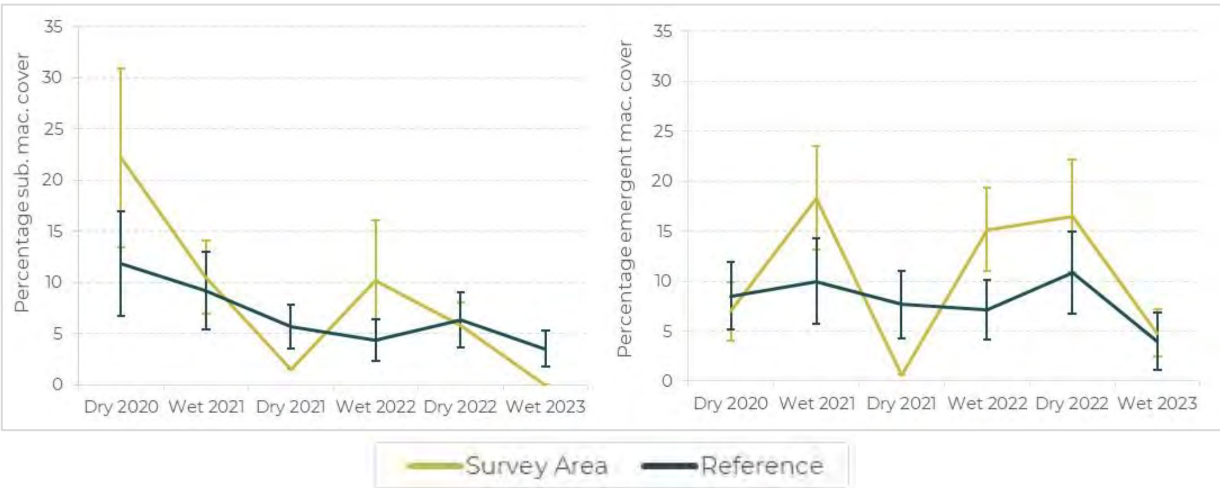


Figure 4.1: Average percent macrophyte cover (±se) recorded in each sampling event

Average percent cover by emergent macrophytes was highly variable in the Survey Area over time, but relatively consistent at Reference sites (Figure 4.1). In the Survey Area, change was seasonal, with generally higher cover in the wet (except Wet 2023), when pools were more full and reeds and rushes were immediately adjacent to the water's edge. Pools contracting in the dry season meant that emergent macrophytes were either dead or dying, or no longer providing habitat for in-stream aquatic fauna as they were positioned too far from the water's edge. The lack of seasonal change at Reference sites is due to their permanence, with limited contraction of pools in the dry. The exception to this was the lower cover in the Wet 2023, which was influenced by the low water levels at MUNJS and BENS, as well as dry conditions at MACREF1.

4.2 Water Quality

All raw water quality data are provided in Appendix D.

4.2.1 In situ

DO in the Survey Area was below the ANZG (2018) DGV at three sites in the dry season (MarC1, MarC2 and MarC4), and five in the wet (all sites except MarC6a; Figure 4.2). DO at Reference sites was also low, with all but two measurements falling below the lower DGV (MACREF2 and SS, both in the Dry 2022). EC within the Survey Area was highly variable, ranging from fresh (147.7 µS/cm at MarC6 in the Wet 2023) to brackish (2,068 µS/cm at MarC2 in Dry 2022; Figure 4.2). All Survey Area sites sampled in the Dry 2022 exceeded the ANZG (2018) DGV for EC, with only two sites (MarC1 and MarC6) recording EC that was indicative of freshwaters, while all other sites were brackish. In contrast, most sites (except MarC4) were fresh in the Wet 2023. All Reference sites recorded EC greater than the DGV in both seasons. MACREF2 was brackish in both seasons (1,591 µS/cm in the Dry 2022 and 1,827 µS/cm in the Wet 2023).

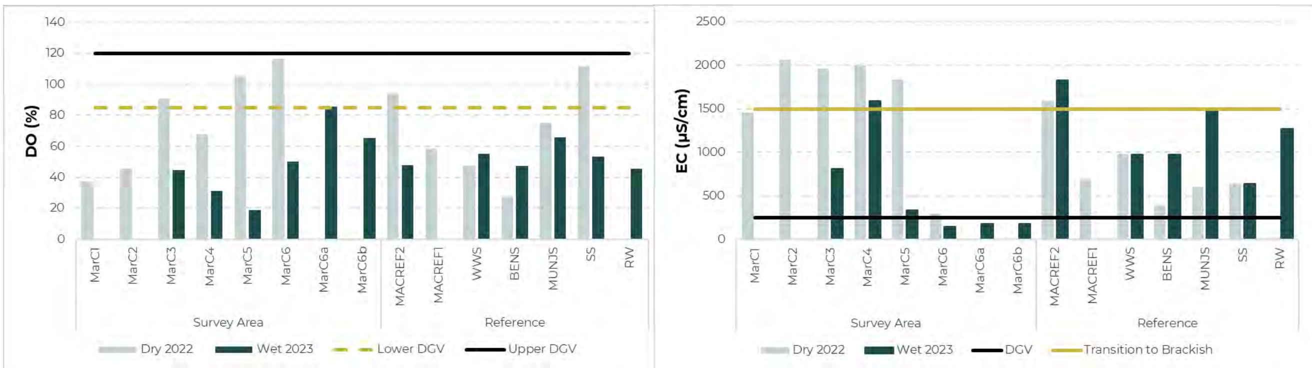


Figure 4.2: DO and EC recorded in both seasons

Surface water pH in the Survey Area was circum-neutral to slightly basic, with little variation between sites (Appendix D). Lowest pH was recorded from MarC1 in the Dry 2022 (7.24), while highest was recorded from MarC6 in the Dry 2022 (8.39). Reference sites ranged in pH from 6.92 at MACREF1 in the Dry 2022, to 8.71 at MUNJS in the Wet 2023. In the Dry 2022, exceedances of the upper ANZG (2018) DGV were recorded from two sites in the Survey Area (MarC5 and MarC6), and two Reference sites (MACREF2 and SS). Reference site MUNJS also exceeded the upper DGV in both seasons. No pH value was of ecological concern.

4.2.2 Ionic Composition and Alkalinity

In the Survey Area, surface water at nearly all sites were dominated by HCO_3 anions in both seasons. The exceptions were MarC5 in the Dry 2022, and MarC4 in the Wet 2023. On these occasions, Cl was dominant. Cation dominance was variable between sites. In the Dry 2022, MarC1 was dominated by Ca cations, while MarC2 through to MarC6 were dominated by Na. In the Wet 2023, MarC3 through to MarC5 were dominated by Na cations, while MarC6, MarC6a and MarC6b recorded higher concentrations of Ca. Reference site MACREF1 was dominated by Na and HCO_3 ions in the Dry 2022, as was MACREF2 in both seasons. Weeli Wolli Creek Reference sites (WWS and BENS) were dominated by Ca and HCO_3, but in the Wet 2023, concentrations of Mg were slightly greater than Ca. MUNJS was dominated by Na and Cl in both seasons, while SS experienced some seasonal variation, with Ca and HCO_3 dominance in the Dry 2022, and Na and HCO_3 in the Wet 2023.

The lowest alkalinity was recorded from MarC6a in the Wet 2023 (40 mg/L). Alkalinity of less than 20 mg/L is considered low, with the system having limited ability to buffer against rapid changes in pH. Therefore, surface waters of all Survey Area and Reference sites are considered to be well-buffered.

4.2.3 Water Clarity

Turbidity was generally low, and below ANZG (2018) DGVs, at both Survey Area and Reference sites (Appendix D). The only exception was MarC6 in the Wet 2023, where turbidity was 21 NTU. This was in excess of the DGV of 15 NTU.

4.2.4 Nutrients

Concentrations of nitrogen nutrients were low and below ANZG (2018) toxicity DGVs. N_NH_3 concentrations in the Survey Area were below the limit of detection (LOD; < 0.01 mg/L) at several sites (MarC3 and MarC4 in the Dry 2022, and MarC6 in both seasons). The highest ammonia concentration, of both Survey Area and Reference sites, was recorded from MarC4 in the Wet 2023. All values were below the ANZG (2018) 99% toxicity DGV (i.e. < 0.32 mg/L; Appendix D). Concentrations of N_NO_3 were also below the LOD at several sites. All N_NO_3 concentrations fell below the ANZG (2018) 99% toxicity DGV[6], including Survey Area and Reference sites, with the highest concentration recorded from MarC4 and SS (0.25 mg/L at both sites in the Wet 2023).

Concentrations of N_NOx and total N did exceed eutrophication DGVs, although seasonal variability was noted (Figure 4.3). In the Dry 2022, one Survey Area site recorded concentrations of N_NOx and total N (MarC6) in excess of eutrophication DGVs, while in the Wet 2023, nearly all Survey Area sites recorded elevated N_NOx (all but MarC5), and all sites recorded high total N (Figure 4.3). Reference sites WWS and SS recorded elevated N_NOx in

[6] There is no current, available toxicity DGV for N_NO_3. Historic ANZECC & ARMCANZ (2000) GVs were found to be erroneous and notably low/conservative (ANZG, 2018). It was anticipated that values would be updated in the recent online, interactive version of the ANZECC guidelines (ANZG, 2018), however this has not been the case. In the absence of updated ANZECC DGVs for N_NO_3, ANZG (2018) suggest referring to the current New Zealand nitrate toxicity guidelines, specifically the 'Grading' GVs published in the '*Updating Nitrate Toxicity Effects on Freshwater Aquatic Species*' report (NIWA, 2013).

both seasons, while total N at MUNJS and SS exceeded the eutrophication DGV in the Wet 2023. Concentrations of both N_NOx and total N were generally greater in the Wet 2023, than the preceding dry season.

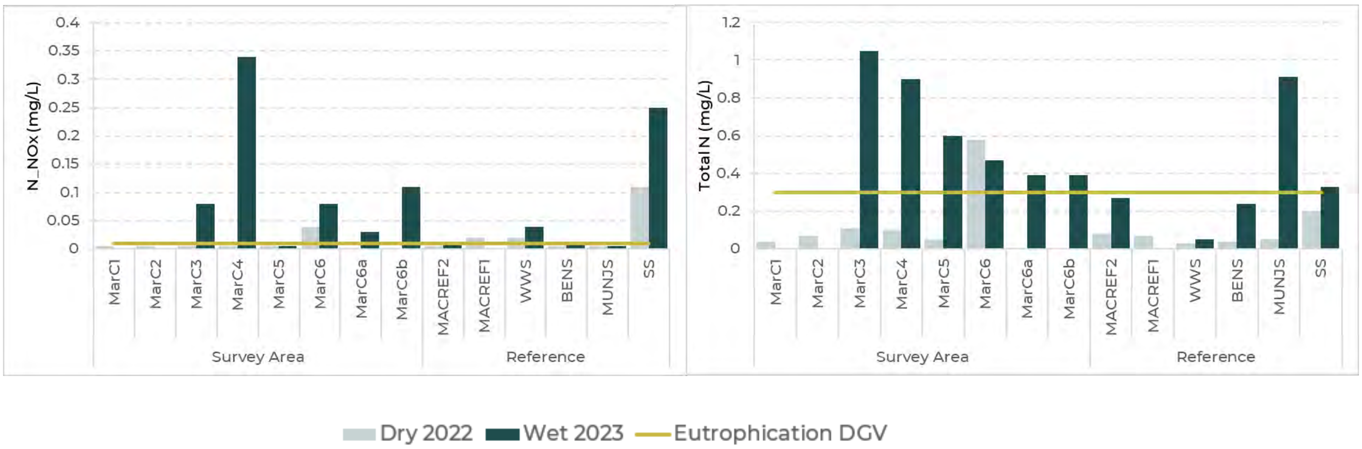


Figure 4.3: Concentrations of N_NOx and total N recorded from each site

Concentrations of total phosphorus were variable across sites and seasons, ranging from below LOD (at most sites in the Dry 2022) to 0.064 mg/L at Reference site MACREF2 in the Wet 2023 (Figure 4.4). Concentrations of total P were in excess of the eutrophication DGV at most sites in at least one season, except MarC1, MarC2, and MACREF1 (Figure 4.4). Concentrations of total P were generally higher in the Wet 2023.

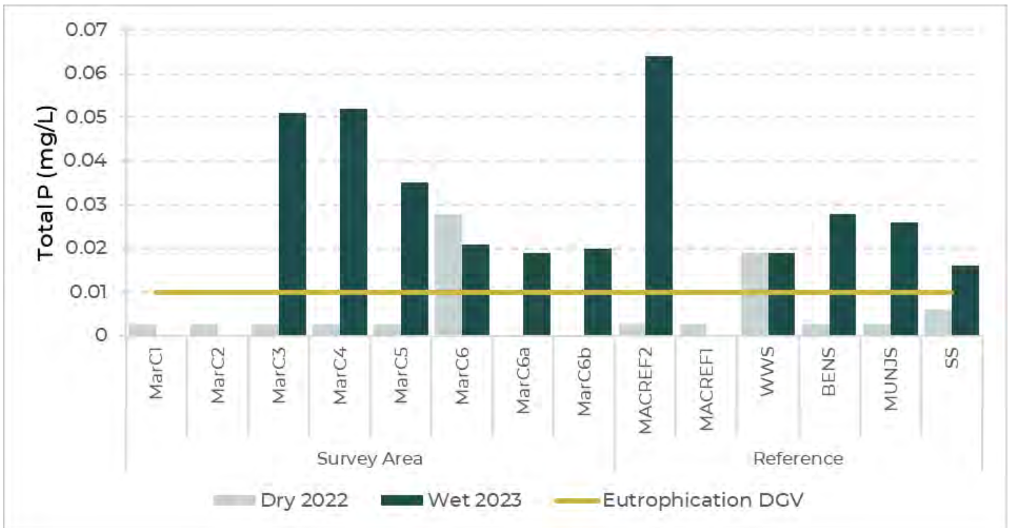


Figure 4.4: Concentrations of total P recorded from each site

4.2.5 Dissolved Metals

Concentrations of most of the dissolved metals recorded from the Survey Area were low, and below ANZG (2018) 99% toxicity DGVs (Appendix D). However, four dissolved metals were recorded in concentrations exceeding DGVs at some sites. These were:

- Dissolved boron (dB) – exceeded the 99% toxicity DGV at all Survey Area and Reference sites in the Dry 2022 (except BENS), and most sites in the Wet 2023 (except MarC6, MarC6a and MarC6b) (Figure 4.5). Concentrations of dB were also in excess of the 95% toxicity DGV at Survey Area sites MarC2 and MarC3 (Dry 2023), and MarC4 and Reference site MACREF2 (both seasons).
- Dissolved arsenic (dAs) – exceeded the 99% toxicity DGV at Survey Area sites MarC3 and MarC4 in the Wet 2023, as well as Reference site MUNJS (Figure 4.5).
- Dissolved aluminium (dAl) – exceeded the 99% DGV at MarC6 in the Dry 2022, and the 95% DGV at MarC5, MarC6, MarC6A and MarC6B in the Wet 2023 (Figure 4.6).
- Dissolved copper (dCu) – was in excess of the 95% DGV at MarC6 in the Dry 2022, and MarC3, MarC4, MarC5 and MarC6 in the Wet 2023 (Figure 4.6). Given HMGVs for dCu are not considered to be sufficiently conservative to protect key sensitive aquatic biota (Markich *et al.*, 2005), dCu DGVs were not modified for hardness.

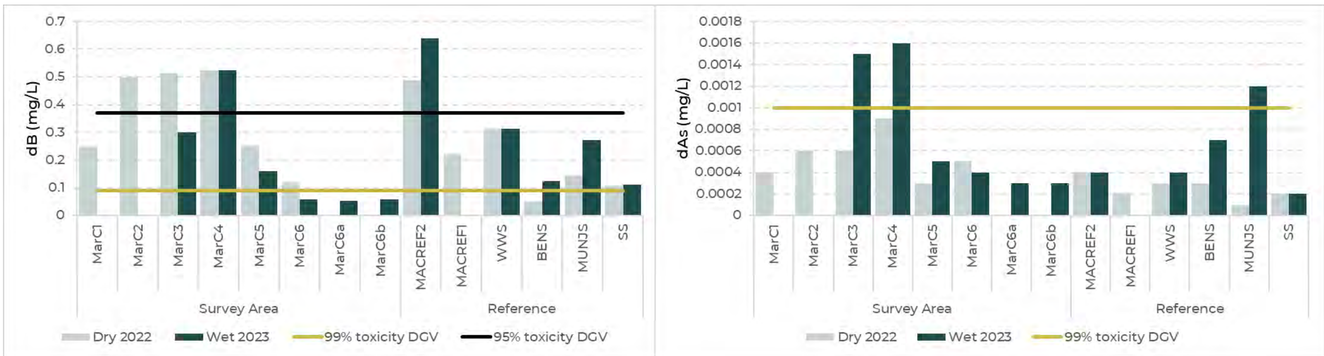


Figure 4.5: Concentrations of dB and dAs recorded from each site

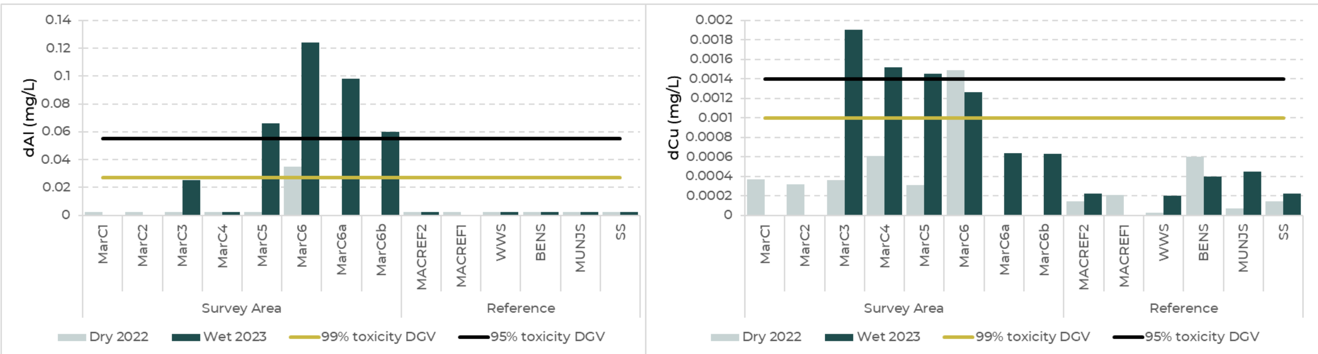


Figure 4.6: Concentrations of dAl and dCu recorded from each site

4.2.6 Characterisation of Baseline Water Quality

4.2.6.1 Univariate analysis

In-situ

The variability in several in situ water quality analytes across sampling events was considerably greater in the Survey Area compared to Reference sites, especially for EC, DO and alkalinity (Figure 4.7). This likely reflects the receding water levels and drying within the Survey Area in some sampling events, which did not occur at Reference sites. Median EC in the Survey Area was brackish (1,610.50 µS/cm), and notably higher than that recorded from Reference sites (945.5 µS/cm). Overall, EC was significantly higher within the Survey Area (Two-way ANOVA; df = 1, $p < 0.001$). There was also a significant difference in EC between sampling events (df = 1, $p = 0.002$), with significantly lower EC recorded in the Wet 2023.

Median DO, pH, and TSS were all similar between the Survey Area and Reference sites. Median DO fell below the lower ANZG (2018) DGV at both site types (66.5% in the Survey Area, and 66.8% in Reference sites; Figure 4.7). There was no significant difference in DO saturation between site types, but there was between sampling events, with significantly lower DO recorded in the Wet 2023 than all other events, and highest in the Dry 2020 (Two-way ANOVA; df = 5, $p = 0.042$). Despite the similar medians, there was a significant difference in average pH and turbidity between site types, with significantly higher levels recorded from the Survey Area (Two-way ANOVA; df = 1, $p \leq 0.019$; Figure 4.7). Turbidity was significantly different between sampling events (df = 5, $p = 0.001$), with significantly highest levels recorded in the Wet 2023.

Ionic composition

Median alkalinity was similar between the Survey Area (329 mg/L) and Reference sites (303 mg/L). Despite this, there was a significant difference in average alkalinity between site types, with significantly higher levels recorded from the Survey Area (Two-way ANOVA; df = 1, $p \leq 0.019$; Figure 4.7). Concentrations were more variable over the baseline within the Survey Area than Reference sites.

The Survey Area recorded considerably greater variation in the concentration of major ions across all sampling events than Reference sites (Figure 4.8). Again, this likely reflects the drying which has occurred in the Survey Area, with evapoconcentration of ions as pools receded. Median concentrations of all major ions were greater in the Survey Area than Reference sites, although this difference was marginal for HCO_3 (Figure 4.8). The differences in average concentration were significant for Na, Mg, K, Cl, and S_SO_4.

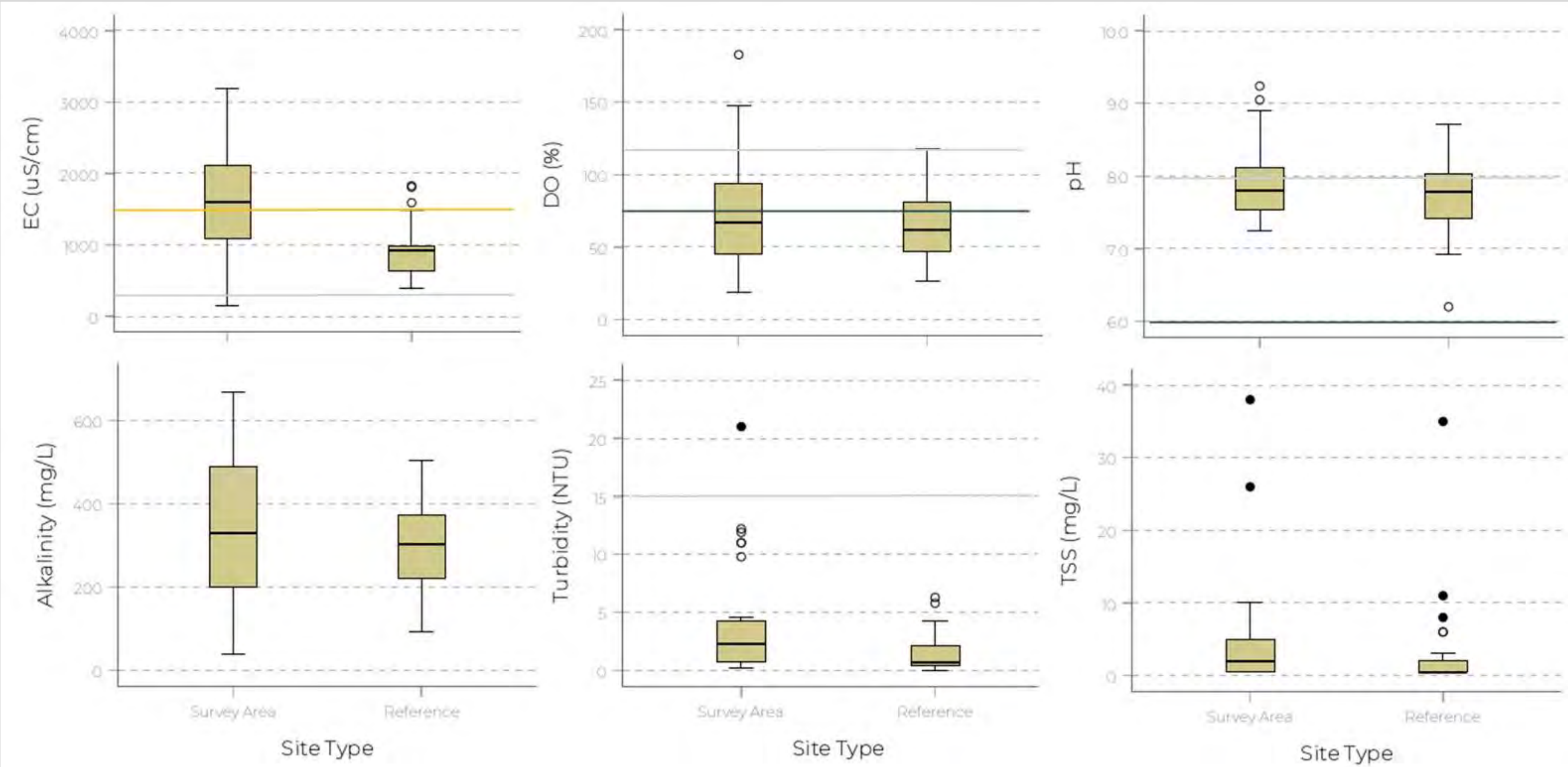


Figure 4.7: Box and whisker plot showing variability in selected water quality parameters across all sampling events

Where, the bottom of the box = 25th percentile, middle line = median, top of the box = 75th percentile, and the bottom and top whiskers represent the minimum and maximum concentration, respectively.

= lower ANZG (2018) DGV, = DGV (or upper DGV for pH and DO), and , = transition to brackish waters

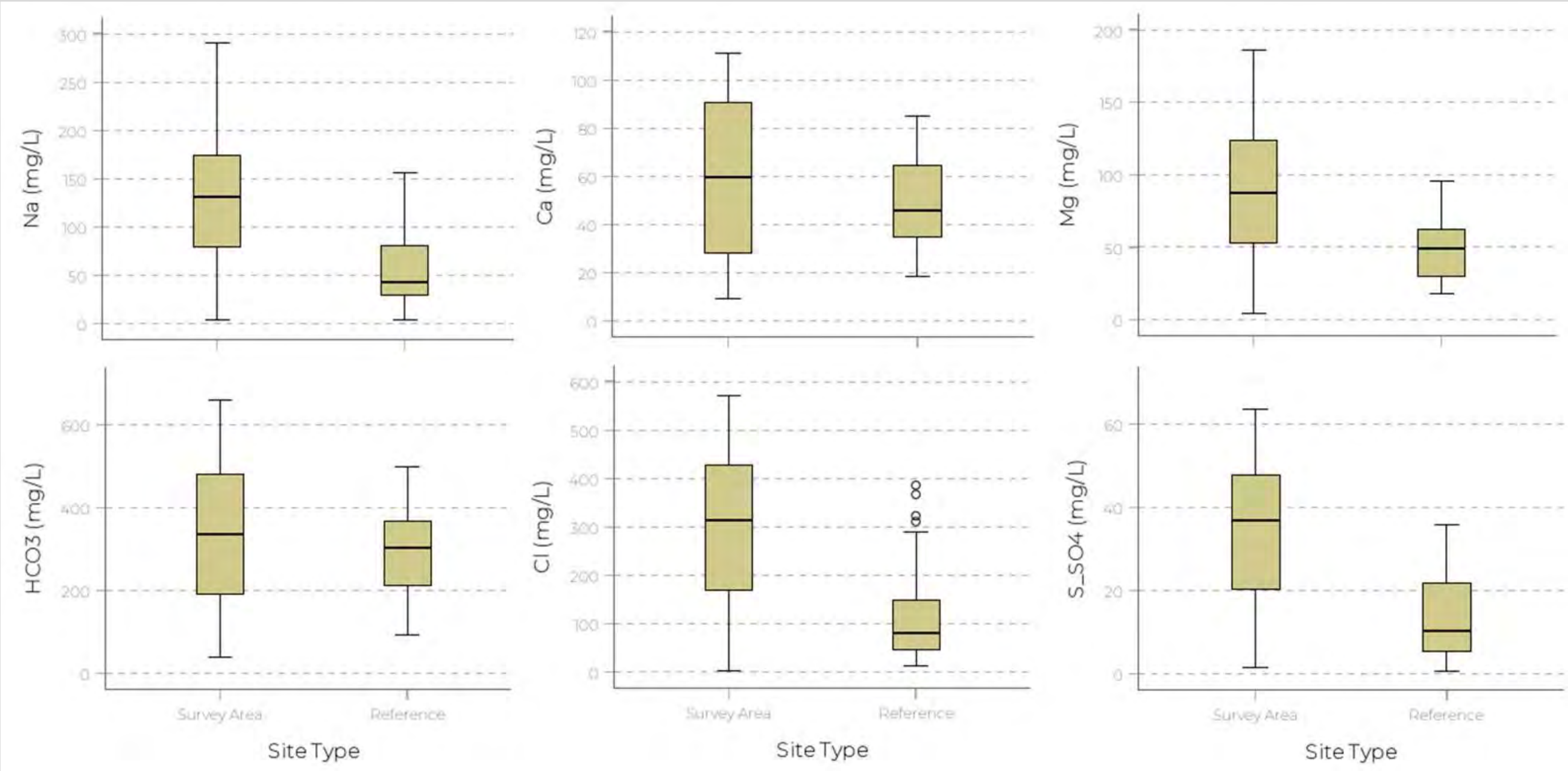


Figure 4.8: Box and whisker plot showing variability in ionic concentrations across all sampling events

Where, the bottom of the box = 25th percentile, middle line = median, top of the box = 75th percentile, and the bottom and top whiskers represent the minimum and maximum richness, respectively.

Nutrients

There was relatively minor variation in N_NO_3 and N_NOx concentrations across the baseline, with the exception of some outliers (Figure 4.9). Median concentrations of N_NH_3 and N_NO_3 were similar between Survey Area and Reference sites, while median total N was slightly greater within the Survey Area (0.26 mg/L) than Reference sites (0.155 mg/L). Both median concentrations fell below the total N eutrophication DGV. Overall, most nutrients recorded statically similar average concentrations between site type (Two-way ANOVA; df = 1, $p \geq 0.05$), with the exception of total N which was significantly higher in the Survey Area ($p = 0.024$). Variation was evident across the baseline for N_NH3, total N and total P, all of which recorded significantly different concentrations between sampling events (df = 5, $p \leq 0.001$). The median concentrations of total P were below the eutrophication DGV in both the Survey Area and Reference sites (Figure 4.9).

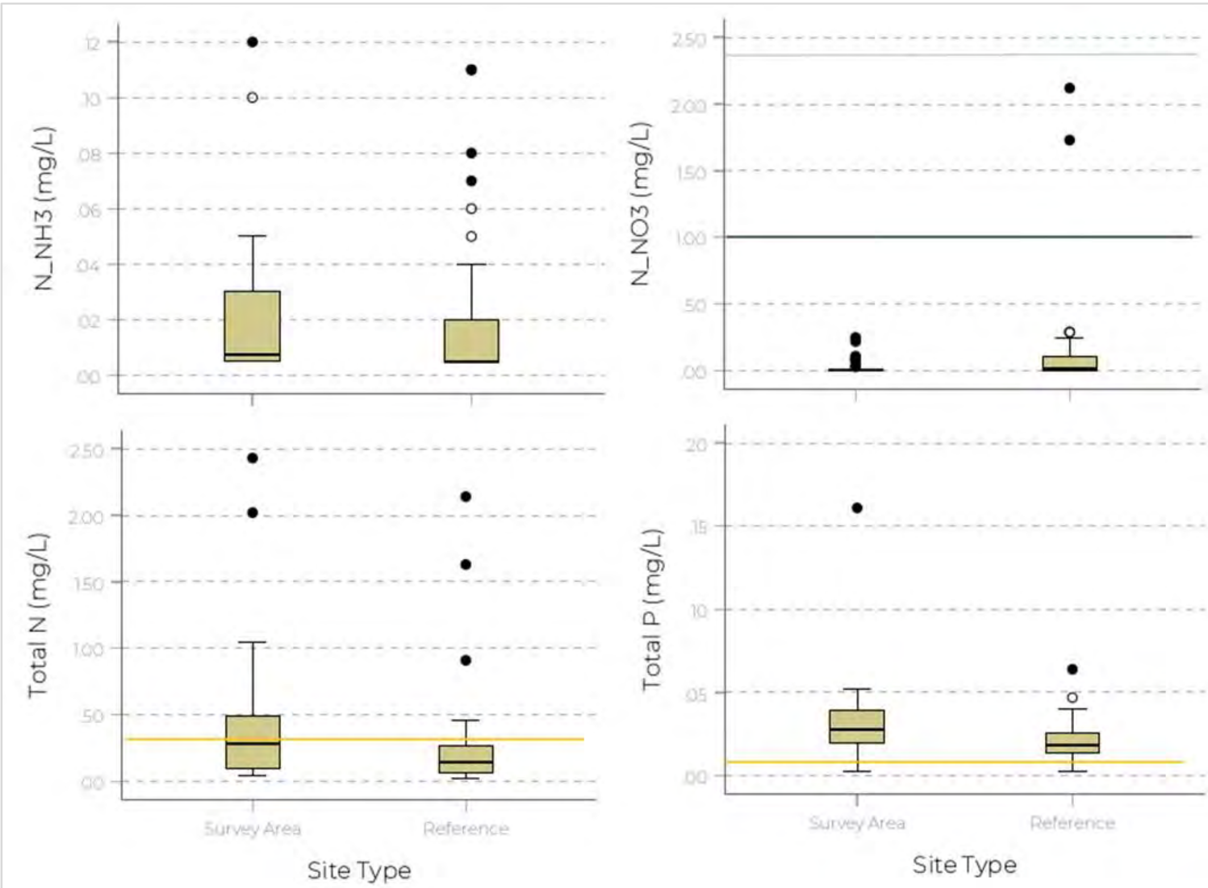


Figure 4.9: Box and whisker plot showing variability in nutrient concentrations across all sampling events

Where, the bottom of the box = 25th percentile, middle line = median, top of the box = 75th percentile, and the bottom and top whiskers represent the minimum and maximum richness, respectively.

= ANZG (2018) 99% toxicity DGV, = 95% toxicity DGV, and , = eutrophication DGV

Dissolved metals

Median concentrations of most dissolved metals fell below the corresponding ANZG (2018) DGVs, with the exception of dB, which was in excess of the 95% toxicity DGV in the Survey Area, and the 99% toxicity DGV at Reference sites (Figure 4.10). As with other water quality analytes, the variability in concentrations of dissolved metals across the baseline was notably greater within the Survey Area than Reference sites (Figure 4.10).

Median concentrations of several dissolved metals were higher in the Survey Area for dAs (Survey Area = 0.006 mg/L, Reference = 0.0003 mg/L), dB (Survey Area = 0.38 mg/L, Reference = 0.20 mg/L), dCo (Survey Area = 0.002 mg/L, Reference = 0.00005 mg/L), dCu (Survey Area = 0.0004 mg/L, Reference = 0.0002 mg/L), dU (Survey Area = 0.0016 mg/L, Reference = 0.0005 mg/L), and dV (Survey Area = 0.0035 mg/L, Reference = 0.0016 mg/L). Of the dissolved metals analysed, average concentrations of dAl, dAs, dB, dCo, dCu, dFe, dMo, dU, and dV were all significantly higher in the Survey Area (Two-way ANOVA; df = 1, $p \leq 0.018$) than Reference sites. Variation across the baseline was evident with some analytes recording significantly different concentrations between sampling events, including dAl, dAs, dU (df = 5, $p \leq 0.019$).

4.2.6.2 Multivariate analysis

Spatial and temporal variation in water quality was analysed using Principal Components Analysis (PCA). Together, PC1 and PC2 explained close to 50% of the variation amongst water quality samples (Table 4.2). Generally, the Survey Area separated from Reference sites along PC1, with the former recording greater EC, and concentrations of Ca, HCO_3, dB and dU than the latter (Figure 4.11). Within the Survey Area, samples also separated along PC2, with some samples having greater turbidity, dCu and total N than others (Figure 4.11). Water quality of the Marillana Creek Reference site (MACREF2) was similar to the Survey Area, with samples overlapping in PCA ordination space.

Table 4.2: PCA results of variation amongst water quality samples

Principal Component	Eigen value	% Variation	Cumulative % Variation
1	4.58	26.9	26.9
2	3.30	19.4	46.3
3	1.81	10.7	57.0
4	1.47	8.7	65.7
5	1.44	8.4	74.1

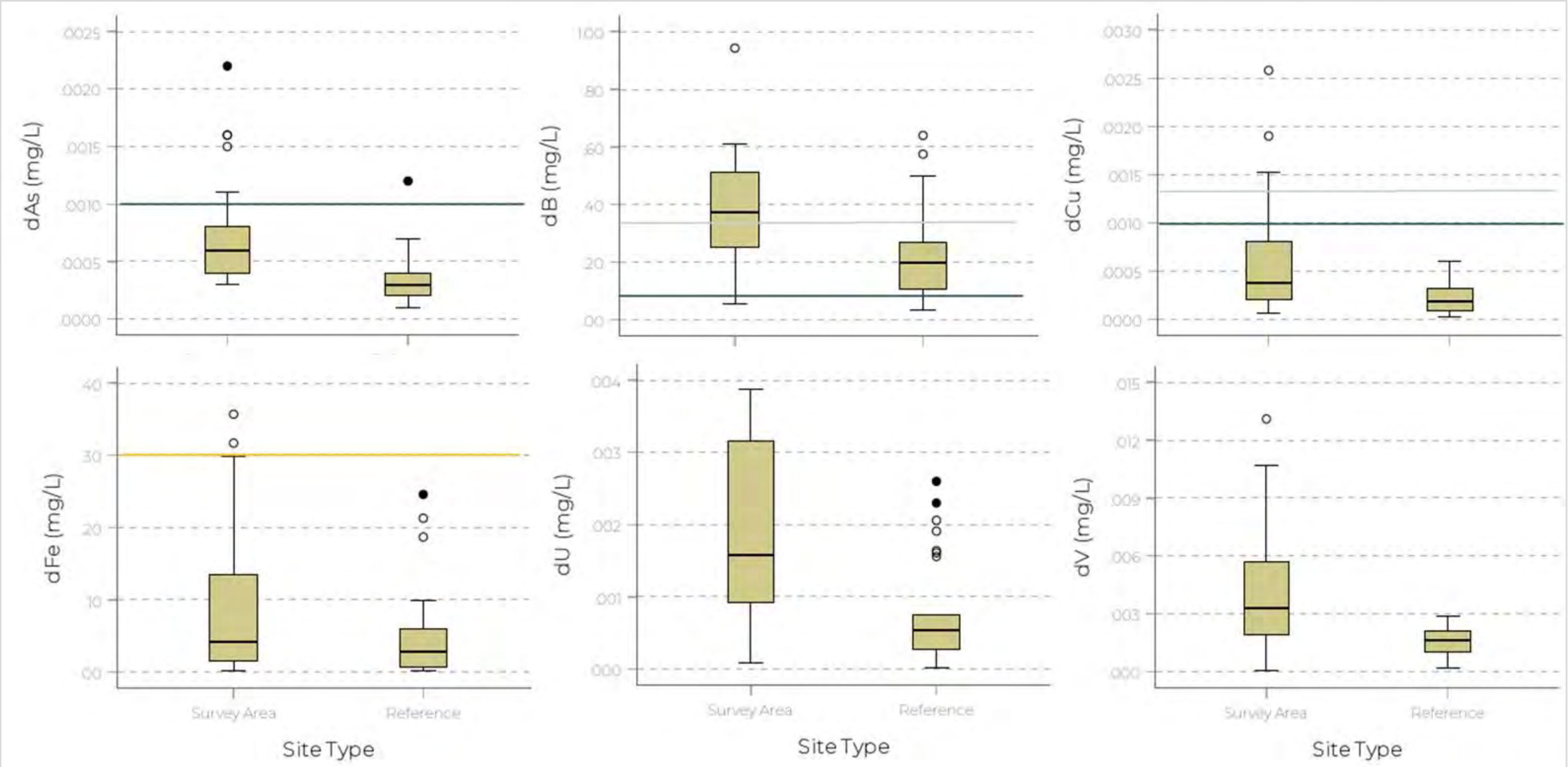


Figure 4.10: Box and whisker plot showing variability in dissolved metal concentrations across all sampling events

Where, the bottom of the box = 25th percentile, middle line = median, top of the box = 75th percentile, and the bottom and top whiskers represent the minimum and maximum richness, respectively.

= ANZG (2018) 99% toxicity DGV, = 95% toxicity DGV, and , = low reliability trigger

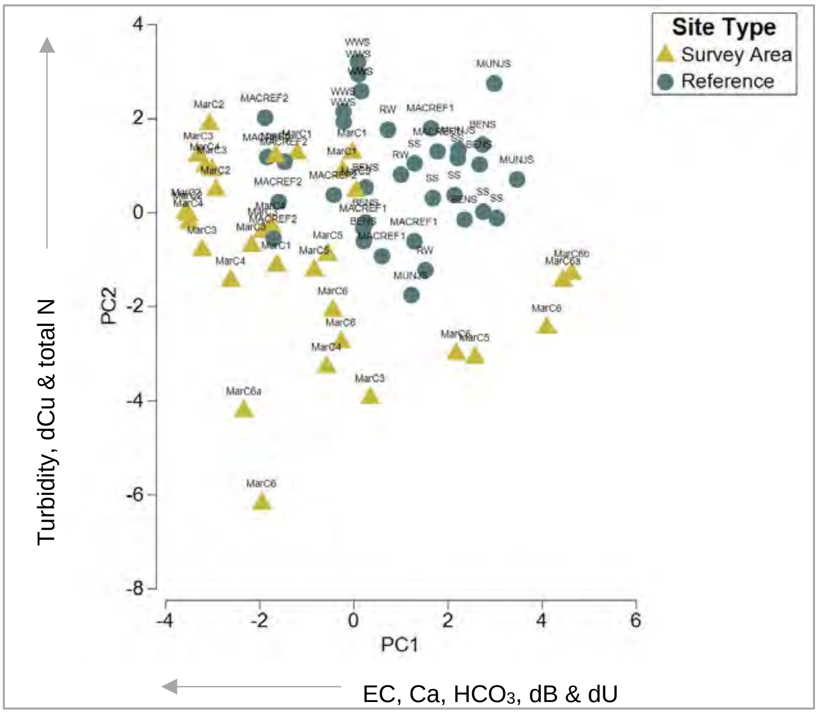


Figure 4.11: PCA of all water quality data, with samples identified by site type.

Temporal variability amongst water quality samples was high, with no clear separation by sampling events (Figure 4.12). Within site types, there was some separation based on event, with the Survey Area samples from the Dry 2020 forming a relatively tight cluster, as did those from the Dry 2022, and Wet 2021 (Figure 4.12).

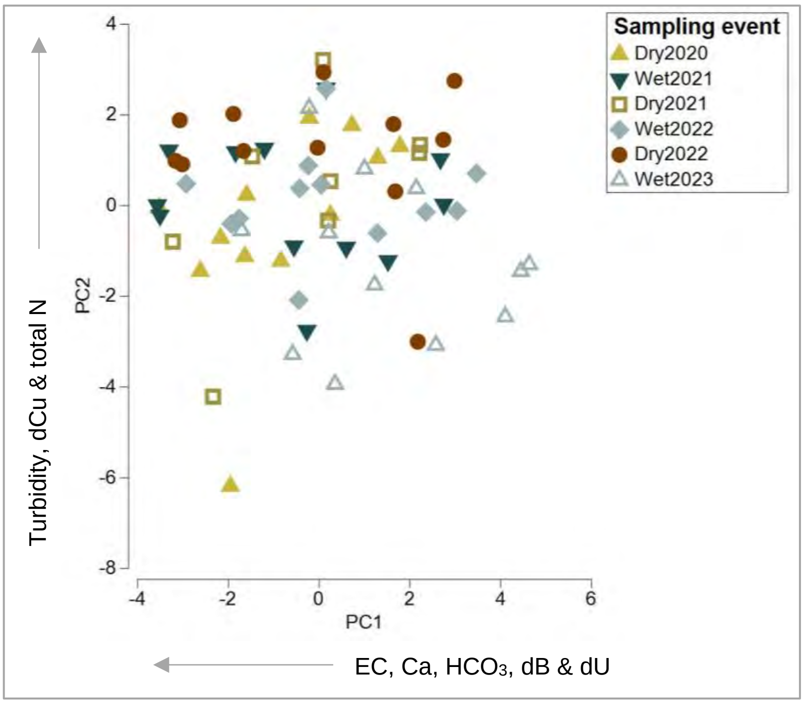


Figure 4.12: PCA of all water quality data, with samples identified by sampling event.

Overall, there was a significant difference in water quality between site types (Two factor PERMANOVA; df = 1, pseudo-F = 11.15, p <0.0001) and between sampling events (df = 5, pseudo-F = 3.55, p < 0.0001). Importantly, not all creeks were significantly different from one another. Water quality of the Survey Area was statistically similar to MACREF2 (also located on Marillana Creek), but significantly different to that recorded from all other creeks (Weeli Wolli Creek, the tributary of Yandicoogina Creek, Munjina Creek and the Davis River).

4.3 Macrophytes

4.3.1 Macrophyte Taxa Composition and Richness

A total of 71 riparian flora taxa was recorded from the Survey Area, and 91 from Reference sites. Within the Survey Area, richness ranged from 22 to 30 per site, with the greatest richness recorded from MarC1. The number of riparian flora taxa recorded from Reference sites ranged between 13 and 45, with the maximum number of taxa recorded from MACREF1 (see Appendix E for the full flora list).

The Survey Area supported 13 macrophyte taxa, eight of which were submerged macrophytes (*Chara fibrosa*, *C. globularis*, *Nitella* cf. *furcata*, *Najas tenuifolia*, *Vallisneria* sp., *V. nana*, *Potamogeton tepperi* and *Ruppia* sp.). The remaining five emergent macrophyte taxa included *Cyperus squarrosus*, *C. vaginatus*, *Eleocharis geniculata*, *Schoenoplectus subulatas* and *Typha domingensis.* Two additional submerged macrophytes (*Najas marina* and *Vallisneria annua*) and four emergent macrophytes (*Cladium procerum*, ?*Fimbristylis* sp., *F. sieberiana* and *Machaerina rubiginosa*) were recorded from Reference sites.

The greatest submerged macrophyte richness within the Survey Area was 4 taxa (from MarC6), while at Reference sites it was 6 (from SS). Emergent macrophyte richness was also greatest from Reference sites, with WWS and SS both recording 5 taxa, in comparison to the Survey Area which recorded a maximum of 3 emergent macrophyte taxa (from MarC1, MarC4 and MarC6a).

4.3.2 Significant Flora

One significant flora species was recorded from the Survey Area, the creeping annual *Ipomoea racemigera* (Plate 4.1). This species was recorded from MarC6a and MarC6b. It is currently listed by the DBCA as a Priority 2 species, based on it being known only from a small number of populations. *Ipomoea racemigera* was also recorded from Reference site SS.

Additional significant flora species were recorded from Reference sites. The Priority 3 species, *Stylidium weeliwolli* (DBCA, 2023), was recorded from BENS. This species is an annual herb, found at the edge of watercourses. The perennial sedge, *Fimbristylis sieberiana* was recorded from MACREF1, and is also a Priority 3 species (DBCA, 2023). It occurs along pool edges and sandstone cliffs. The Priority 2 species *Cladium procerum* (DBCA, 2023) was recorded from WWS. This is a perennial sedge which occurs around perennial pools and has a restricted distribution.

Plate 4.1: *Ipomoea racemigera* recorded from MarC6a and MarC6b (photo by Biologic ©).

4.3.3 Introduced Flora

Seven introduced flora species were recorded from the Survey Area. These were:

- flax-leaf fleabane (*Erigeron bonariensis*) - MarC2, as well as Reference site MACREF1
- clustered yellowtop (*Flaveria trinervia*) - from MarC4
- common sowthistle (*Sonchus oleraceus*) - MarC2, as well as Reference sites MACREF1 and MACREF2
- mimosa bush (*Vachellia farnesiana*) - MarC2, MarC5 and MarC6, as well as Reference site MACREF2
- buffel grass (*Cenchrus ciliaris*) - MarC2
- couch grass (*Cynodon dactylon*) - MarC3 and MarC4
- awnless barnyard grass (*Echinochloa colona*) - MarC4, MarC5, MarC6, MarC6a and MarC6b.

None of these species are listed as Weeds of National Significance (WoNS) or Declared Pests (DPIRD, 2022). However nearly all of are considered to be highly invasive and able to establish rapidly (DBCA, 2013).

4.3.4 Characterisation of Baseline Macrophytes

4.3.4.1 Richness

In total, 79 dominant riparian flora taxa have been recorded from the Survey Area across all baseline sampling events, with individual site richness ranging from 28 (MarC4) to 36 taxa (MarC1 and MarC6). Of these, 16 were macrophytes (10 submerged and 6 emergent). At Reference sites, dominant riparian flora richness ranged from 23 (BENS) to 55 (MACREF1).

The highest macrophyte (submerged and emergent) richness recorded in the Survey Area was from MarC4 and MarC6 (8 taxa each; Figure 4.13). This was lower than the greatest macrophyte richness recorded from Reference sites (13 taxa recorded from SS; Figure 4.13). Total richness of GDV and macrophyte taxa was lower at MarC6a and MarC6b than the rest of the Survey Area. In the upstream area, total richness was similar, if not greater than that recorded from Reference sites (Figure 4.13).

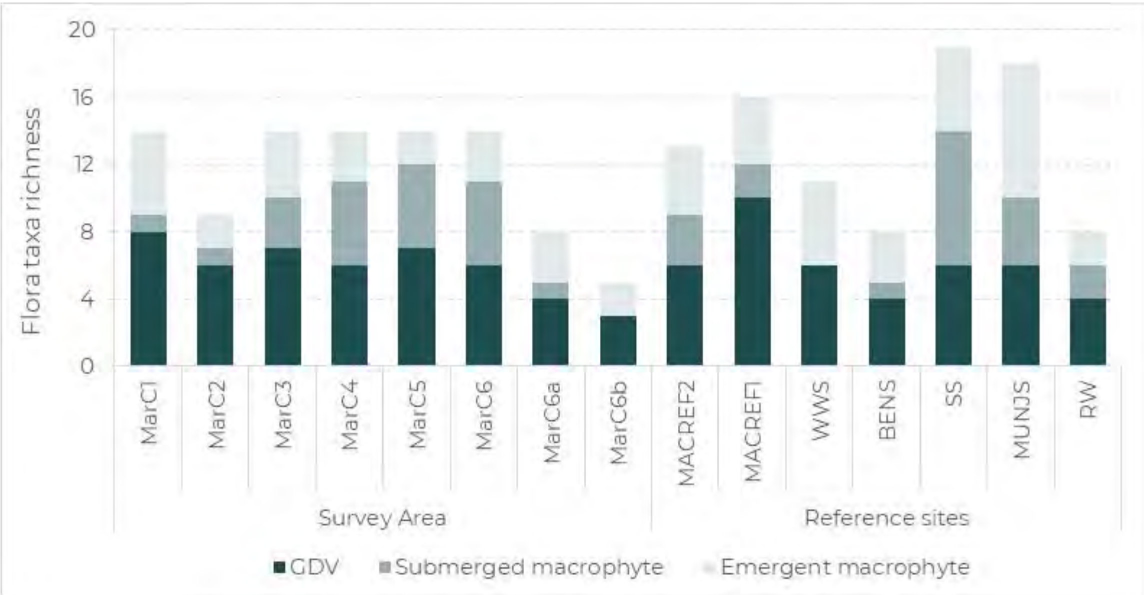


Figure 4.13: Combined submerged, emergent and groundwater dependent vegetation (GDV) taxa richness recorded during the baseline

Given the low number of macrophyte (plus GDV) taxa recorded overall, variation in richness was relatively high across the baseline, in both the Survey Area and at Reference sites, but particularly the latter (Figure 4.14). The range in richness in the Survey Area was 8 (3-11), compared with 11 at Reference sites (2-13). Of note, however, was the fact that median richness was the same in both site types (median = 8; Figure 4.14).

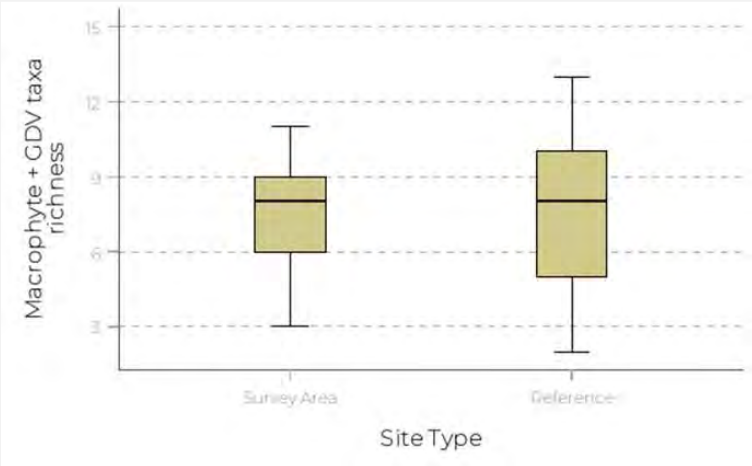


Figure 4.14: Box and whisker plot showing variation in macrophyte (submerged, emergent and GDV) taxa richness over time.

Overall, there was no significant difference in macrophyte (plus GDV) taxa richness between site types (Two-way ANOVA; df = 1, p = 0.969), or between sampling events (df = 5, p = 0.307). There was, however, a significant interaction term (df = 5, p = 0.028), suggesting that the pattern of change over time was different between site types. Average macrophyte (plus DGV) taxa richness in the Survey Area was relatively consistent over time, until the decline between the Dry 2022 and Wet 2023 (Figure 4.15).

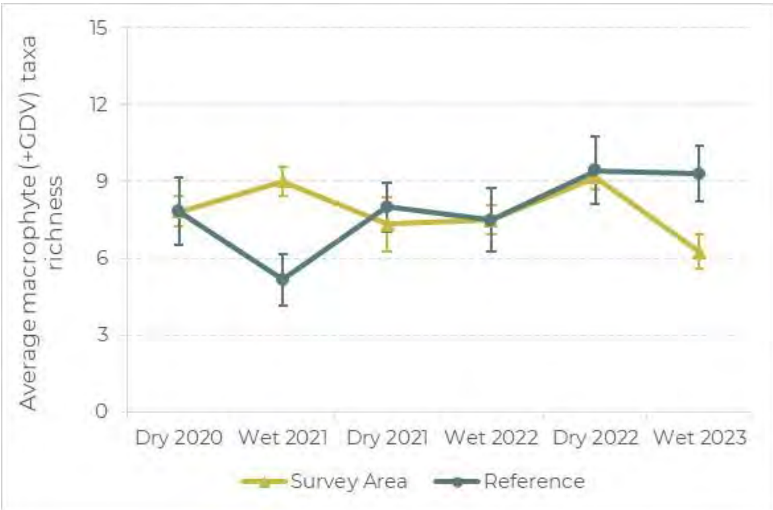


Figure 4.15: Average macrophyte (submerged, emergent and GDV) taxa richness (± se) recorded in each event

No additional weed species were recorded in the current survey that were not identified during previous baseline sampling events. Similarly, no other significant species have been identified from the Survey Area during the aquatic baseline survey.

4.3.4.2 GDE Indicators

The presence of certain flora species can indicate consistently shallow groundwater and/or perennial surface water, and can therefore be used to assess the significance of GDEs (see section 2.3.1). Using the framework developed by Rio Tinto (2022) to classify GDVs based on their mesophytic and/or hydrophytic status, a total of 29 indicator species were present within the Survey Area across the baseline. Of these, 13 were classified as Moderate-High to Very High indicator species (Table 4.3). In some cases, classification of species along this gradient, is dependent on abundance and not simply presence within a system (Table 4.3).

GDV taxa richness was similar across Survey Area sites, with most sites recording nine taxa. This was comparable to Reference sites, where GDV taxa richness ranged from five taxa (BENS) to 12 taxa (MACREF1 and MUNJS). Although the greatest number of GDE indicator species were within the 'Moderate' category (9 taxa), a relatively high number of High indicators was also recorded (5 taxa), especially when considering that Reference sites all represent spring systems, and are known GDEs, and recorded a comparable number of GDE indicator taxa.

Table 4.3: GDE indicator species recorded from the Survey Area during the baseline

Very High	High	Moderate-High	Moderate	Moderate-Low	Low
Melaleuca argentea (mature and abundant)	*Melaleuca argentea* (present, scattered)	*Melaleuca bracteata*	*Acacia coriacea* subsp. *pendens* (abundant)	*Cyperus squarrosus*	*Melaleuca glomerata* (scattered)
Eucalyptus victrix (present in low abundance)	*Eucalyptus camaldulensis* (open forest)	*Adriana tomentosa*	*Atalaya hemiglauca*		*Enteropogon ramosus*
	Acacia ampliceps	**Potamogeton* sp.	*Melaleuca glomerata*		*Chara* sp. (present-isolated)
	Myoporum montanum	**Eleocharis geniculata*	*Cyperus vaginatus* (abundant)		*Stemodia grossa* (abundant)
	**Vallisneria* sp.	*Schenkia australis*	*Echinochloa colona*		*Wahlenbergia tumidifructa*
		Ruppia polycarpa	*Schoenoplectus subulatus*		*Cyperus ixiocarpus*
		Diplachne fusca	*Ammannia baccifera* (present)		
			Typha domingensis (abundant)		
			Najas sp. (present)		

* indicates potential initial groundwater discharge indicator

4.4 Zooplankton

4.4.1 Zooplankton Taxa Composition and Richness

A total of 92 zooplankton taxa[7] was recorded from the Survey Area, with 51 recorded in the Dry 2022 and 58 in the Wet 2023. The zooplankton fauna within the Survey Area comprised Amoebozoa (amoeba; 2 taxa), Ciliophora (ciliates; 6 taxa), Rotifera (rotifers; 38 taxa), Cladocera (water fleas; 12 taxa), Ostracoda (seed shrimp; 19 taxa), and Maxillopoda (Copepoda; 15 taxa; see Appendix F for the full taxa list).

Zooplankton taxa richness varied between sites and sampling events (Figure 4.16). In the Dry 2022, richness ranged from 6 taxa at Reference site MACREF2 on Marillana Creek, to 28 taxa at Survey Area site MarC1 (Figure 4.16). In the Wet 2023, richness was lowest at Reference sites MACREF2 and WWS (both with 11 taxa), and greatest at Survey Area site MarC6a (30 taxa). At sites successfully sampled in both seasons, richness was generally higher in the dry season in comparison to the wet, except at MarC6, MACREF2, BENS and MUNJS.

Zooplankton composition was dominated by rotifers at all Survey Area sites in the Dry 2022, and most in the Wet 2023 (except MarC3, MarC6a and MarC6b). Reference sites also recorded a high proportion of rotifer taxa, although ostracods dominated the assemblage at MACREF2 and MUNJS in the Dry 2022, and maxillopods were dominant at WWS and RW in the Wet 2023 (Figure 4.16). Richness of branchiopods, amoeba and ciliates was generally low across all sites in both seasons (Figure 4.16). Within the Rotifera, the Branchionidae (9 taxa) and Lecanidae (7 taxa) families dominated the composition of Survey Area pools, while chydorids were predominant within the Cladocera (5 of the 12 taxa)

4.4.2 Significant Zooplankton

None of the zooplankton taxa recorded from the Survey Area during the current study are of significance. All are relatively widespread across Australia or the broader Australasian region.

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[7] 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 refer to the lowest level of identification possible (generally genus).

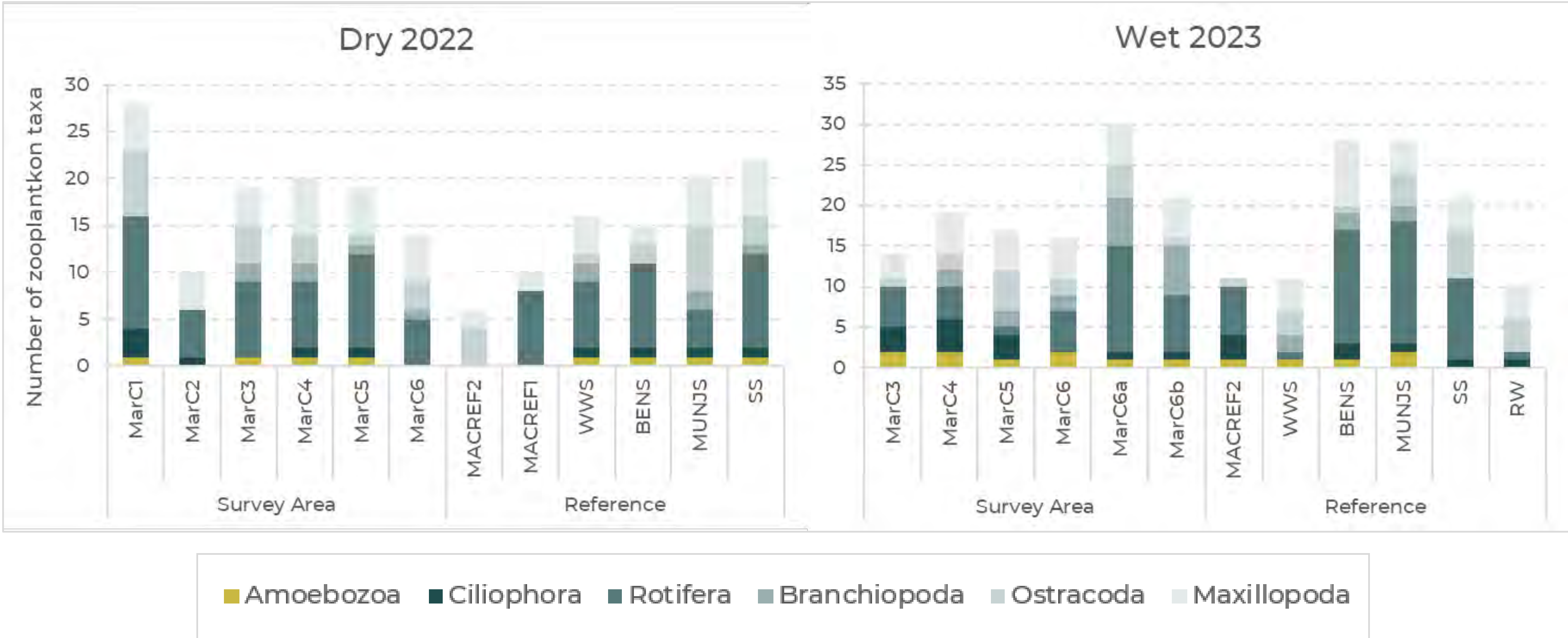


Figure 4.16: Zooplankton composition and richness recorded from each site in the Dry 2022 (left) and Wet 2023 (right)

4.4.3 Characterisation of Baseline Zooplankton Community

4.4.3.1 Richness

A total of 127 zooplankton taxa was recorded from the Survey Area across all sampling events undertaken between the Dry 2020 and Wet 2023 (Table 4.4). Total richness per event ranged from 35 taxa (recorded from the Survey Area in the Dry 2021) to 68 taxa (also from the Survey Area, in Wet 2022; Table 4.4). The low richness recorded from the Survey Area in the Dry 2021 was influenced by the dry conditions along Marillana Creek at that time, with only two sites holding water and able to be sampled for zooplankton. Interestingly, across all sampling events, overall total zooplankton taxa richness from the Survey Area was similar to Reference sites, despite a lower number of sites being sampled in the Survey Area overall (Table 4.4).

Table 4.4: Total zooplankton richness recorded from each site type in each event

Sampling event	Survey Area		Reference Sites	
	n	**Total**	**n**	**Total**
Dry 2020	6	40	6	62
Wet 2021	6	59	6	39
Dry 2021	2	35	6	62
Wet 2022	6	68	6	50
Dry 2022	6	51	6	49
Wet 2023	6	58	6	66
Total – all events	**32**	**127**	**36**	**126**

Zooplankton richness within the Survey Area was highly variable. There was a high number of singleton taxa, with 25% of taxa being recorded on only one occasion (one site in one sampling event), and high species turnover between sampling events. The high variability was reflected in the box and whisker plot, which showed a large difference between the minimum and maximum richness recorded from each site type across all sampling events, especially at Reference sites (Figure 4.17). Median richness was higher in the Survey Area than Reference sites, as was the maximum richness recorded (Figure 4.17).

Taking sample size into account, the greatest average zooplankton taxa richness was recorded from the Survey Area in the Wet 2022 (24.8), while the least was recorded from Reference sites in the Wet 2021 (11.3) (Figure 4.18). Average richness was higher in the Survey Area compared to Reference sites in most sampling events, with the exception of the Dry 2020 and Wet 2023 when similar richness was recorded between site types (Figure 4.18). Overall, the difference in richness between site types was significant, with the Survey Area recording significantly higher richness than Reference sites (Two-way ANOVA; df = 1, p =

0.009. There was no significant difference in zooplankton taxa richness between sampling event (df = 5, p = 0.390), however, and no significant interaction (df = 5, p = 0.136).

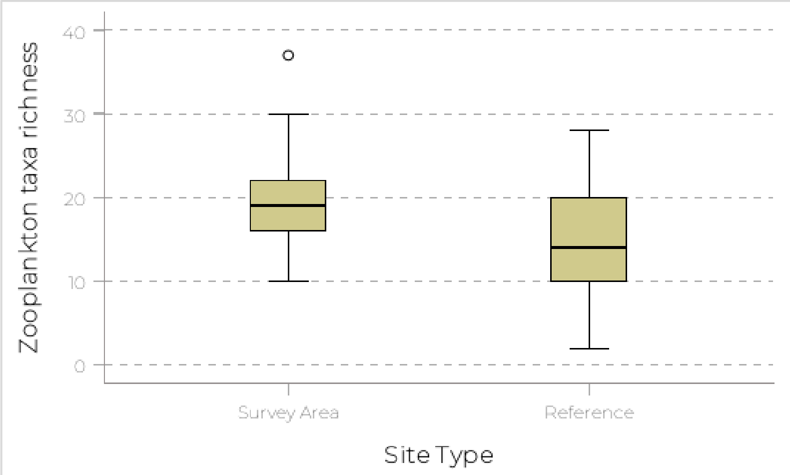


Figure 4.17: Box and whisker plot showing variation in zooplankton taxa richness across all sampling events

Where, the bottom of the box = 25th percentile, middle line = median, top of the box = 75th percentile, and the bottom and top whiskers represent the minimum and maximum richness, respectively.

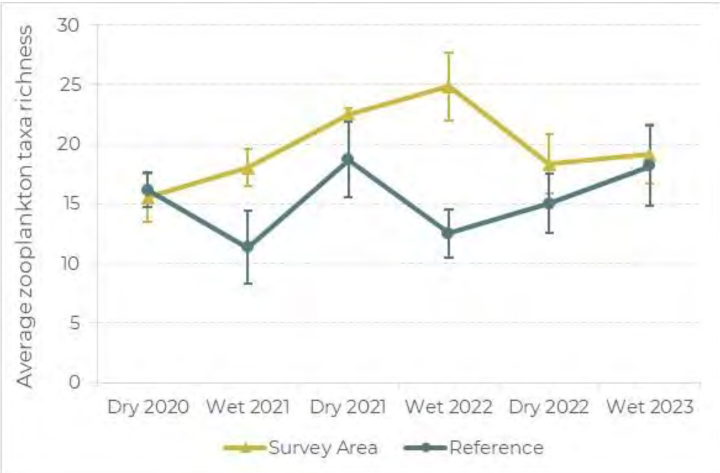


Figure 4.18: Average zooplankton taxa richness (± se) recorded in each event

4.4.3.2 Assemblage

The large variability in zooplankton richness was also evident in the zooplankton assemblages, with samples showing a large spread across ordination space (Figure 4.19). There were no significant cluster groupings based on site type or creek (Figure 4.19 and Figure 4.20), although the Reference site on Marillana Creek, MACREF2 tended to group with Survey Area samples. Pairwise post-hoc comparison of creek differences, indicated that zooplankton assemblages of the Survey Area were barely separable from Yandicoogina, the

Marillana Creek Reference, and the Davis River, but significantly different to Weeli Wolli Creek and Munjina Spring assemblages.

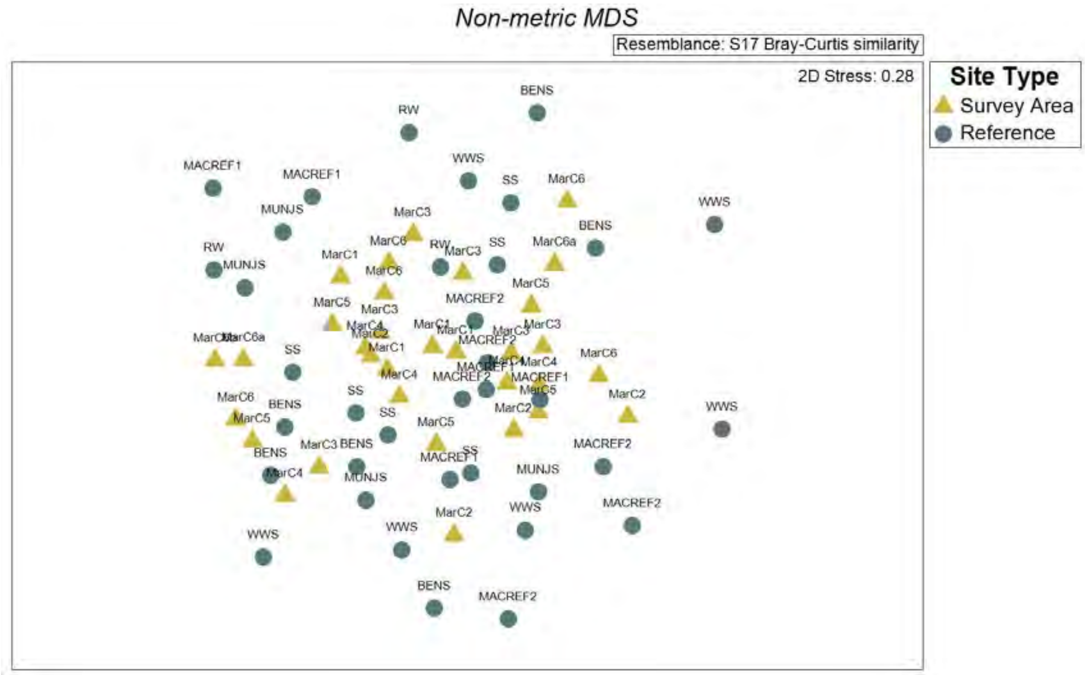


Figure 4.19: nMDS of all zooplankton assemblages, with samples identified by site type

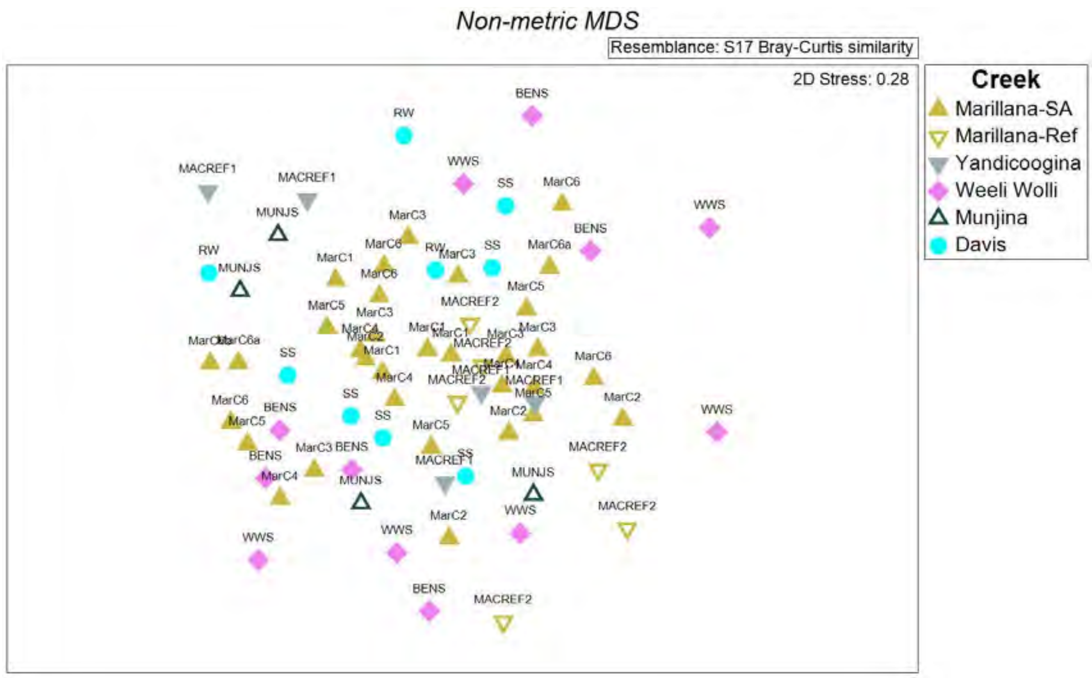


Figure 4.20: nMDS of all zooplankton assemblages, with samples identified by creek

Zooplankton assemblages across the Survey Area and Reference sites were more strongly influenced by temporal change (Figure 4.21). Samples generally separated based on sampling event, although there was some overlap. There was a transition of assemblages over time, with the earliest events separating more strongly from recent events (Figure 4.21).

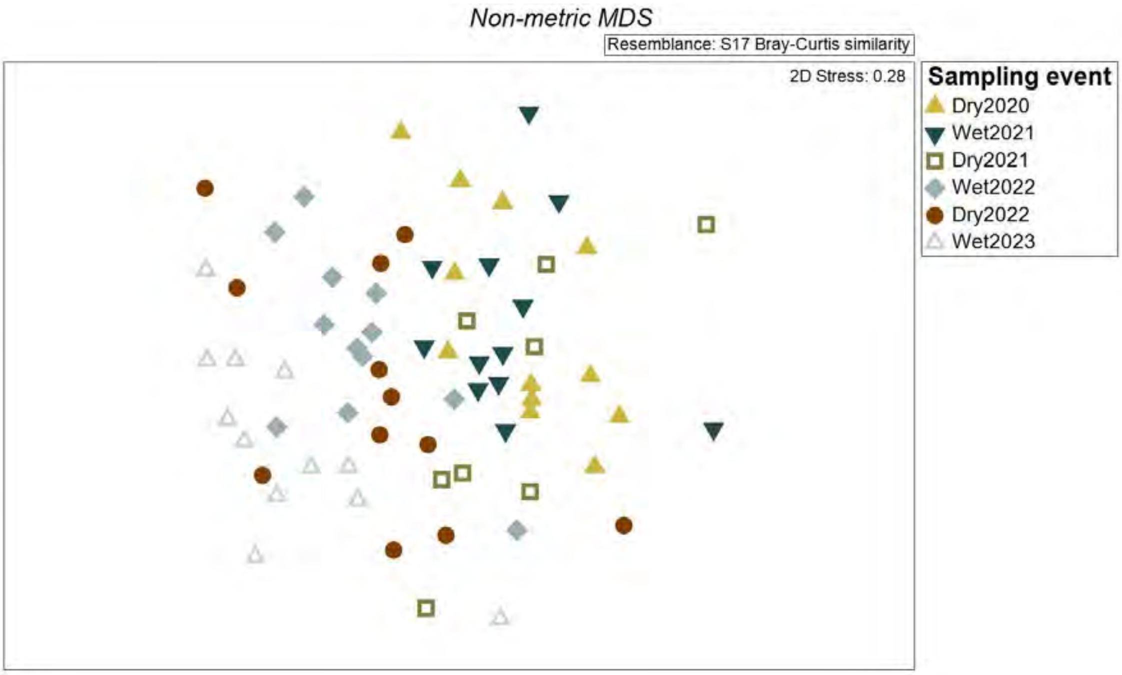


Figure 4.21: nMDS of all zooplankton assemblages, with samples identified by sampling event

Overall, there was a significant difference in zooplankton assemblages between site types (Two factor PERMANOVA; df = 1, pseudo-F = 2.40, $p < 0.001$) and between sampling events (df = 5, pseudo-F = 3.53, $p < 0.001$). There was also a significant interaction term (df = 5, pseudo-F = 1.50, $p = 0.001$), indicating that patterns of change over time in assemblages were not consistent across site types.

4.5 Hyporheos Fauna

4.5.1 Hyporheos Fauna Composition and Richness

Ninety-two invertebrate taxa were recorded from hyporheic zones in the Survey Area, with 80 recorded from five sites in the Dry 2022 and 33 from five sites in the Wet 2023. Invertebrates collected from Survey Area hyporheic zones included Nematoda (roundworm; 1 taxon), Oligochaeta (aquatic segmented worms; six taxa), Hydra (freshwater polyp; 1 taxon), Turbellaria (flatworm; 1 taxon), Polychaeta (aquatic bristle worms; 1 taxon), Gastropoda (freshwater snails; 2 taxa), Acarina (water mites; 12 taxa), Ostracoda (seed shrimp; 6 taxa), Maxillopoda (copepods; 8 taxa), Syncarida (syncarids; 1 taxon), Collembolla (spring tails; 3 taxa), Coleoptera (beetles; 19 taxa), Diptera (two-winged fly larvae; 21 taxa), Ephemeroptera (mayfly larvae; 3 taxa), Anisoptera (dragonfly larvae; 2 taxa), Hemiptera (true bugs; 2 taxa), Trichoptera (caddisfly larvae; 1 taxon), and Symphyla (troglobitic myriapods; 2 taxa; see Appendix G for the full taxa list).

Almost two thirds of the taxa recorded from Survey Area hyporheic zones were stygoxene (64%) and do not have specialised adaptations for groundwater habitats. Troglofauna comprised 2% of the taxa collected, and though terrestrial, were considered of interest and reported here to provide baseline information for the Survey Area (see section 4.5.3 below for further information). Hyporheos fauna[8] made up the remaining taxa collected, with 12% being directly dependent on groundwater for their persistence (4% stygobite and 8% permanent hyporheos stygophiles), and 8% being occasional hyporheos stygophiles. Hyporheos fauna taxa recorded from the Survey Area in the Dry 2022 and Wet 2023 included:

Stygobites

- harpacticoids Harpacticoida `sp. Biologic-HARP058`, Canthocamptidae `sp. Biologic-HARP059` and *Elaphoidella* sp.
- the syncarid *Atopobathynella* `sp. Biologic-PBAT019`

Permanent stygophiles

- water mites *Rutacarus* sp., *Rutacarus* `sp. Biologic-ACAR007`, *Rutacarus* `sp. Biologic-ACAR022`, *Wandesia* `sp. Biologic-ACAR008`, *Wandesia* `sp. Biologic-ACAR009` and *Guineaxonopsis* `sp. Biologic-ACAR011`
- the ostracod *Vestalenula marmonieri*

Occasional hyporheos stygophiles

- oligochaetes *Pristina aequiseta* and *Pristina longiseta*
- ostracods *Candonopsis* cf. *tenuis* (`sp. Biologic-OSTR009`) and *Penthesilenula brasiliensis*
- copepods *Mesocyclops notius* and *Microcyclops varicans*

Possible hyporheic taxa made up 14% of the taxa recorded from the Survey Area, and included higher-level identifications of taxa may have belonged to a stygal or hyporheos species. Such taxa included Oligochaeta sp., Naidinae sp., and Enchytraeidae sp., Aeolosomatidae sp., Acari sp., and Trombidioidea sp., Cyprididae sp., *Vestalenula* sp., Calanoida sp., larval Hydrophilidae sp., larval Scirtidae sp., ?*Australopelopia* sp. and larval baetids.

At sites successfully sampled in both seasons, invertebrate richness within hyporheic zones of the Survey Area was greater in the Dry 2022, while the reverse was true at Reference sites

[8] Hyporheos fauna includes stygobites, permanent hyporheos stygophiles, occasional hyporheos stygophiles and possible hyporheic taxa.

(Figure 4.22). Stygoxenes contributed the greatest proportion of the invertebrate assemblage within hyporheic zones at all sites (Figure 4.22). Occasional hyporheos or possible hyporheic fauna taxa comprised the next greatest richness. Permanent hyporheos stygophiles were more common in the Survey Area in the Dry 2022 than the Wet 2023, while the reverse was true at Reference sites. Four stygobites were recorded from the Survey Area, with the greatest richness in the Dry 2022 recorded from MarC2 and MarC4, as well as Reference site BENS (each with two taxa). In the Wet 2023, the greatest richness of stygobites was recorded from Reference site WWS (Figure 4.22). The highest number of groundwater dependent taxa (stygobites and permanent hyporheos stygophiles combined) was recorded from the Survey Area at MarC2 (12 taxa in the Dry 2022), followed by Reference site WWS (10 taxa in the Wet 2023), and Survey Area sites MarC3, MarC4 and Reference site BENS in the Dry 2022 (each with nine groundwater dependent taxa; Figure 4.22).

4.5.2 Significant Hyporheos Fauna

4.5.2.1 Acari

Water mites morphologically identified as belonging to the *Rutacarus* genus were submitted for molecular analysis (Biologic, 2023a). Some specimens failed to deliver an appropriate sequence (i.e., contamination, and therefore identification remains at *Rutacarus* sp.), while others fell into two separate OTUs. Specimens collected from MarC4 and MarC5 matched a previously known OTU, *Rutacarus* `sp. Biologic-ACAR007` (Figure 4.23). This OTU has a current known linear distance of 42.5 km, having been previously recorded from the Survey Area (MarC4 in the Wet 2021) and the BENS Reference site (Wet 2021) (Biologic, 2023a). Another specimen collected from the hyporheos of MarC4 in the Dry 2022, did not match this OTU, or any other sequence in the available database (Biologic, 2023a). This specimen was therefore assigned to a new OTU; *Rutacarus* `sp. Biologic-ACAR022`. The sequence was more than 16.74% divergent from *Rutacarus* `sp. Biologic-ACAR007` (Biologic, 2023a). Other *Rutacarus* taxa have recently been delineated through molecular analysis, including an additional one from Marillana Creek (and Weeli Wolli Creek) *Rutacarus* `sp. Biologic-ACAR006`(Biologic, 2022c) and *Rutacarus* `sp. Biologic-ACAR005` which is currently known only from Weeli Wolli Creek (Biologic, 2022f) (Figure 4.23). The *Rutacarus* genus is poorly known from 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 north-east of the Survey Area. It is not possible to determine whether the Bamboo Spring *Rutacarus* is the same as one of the species recorded from the Survey Area.

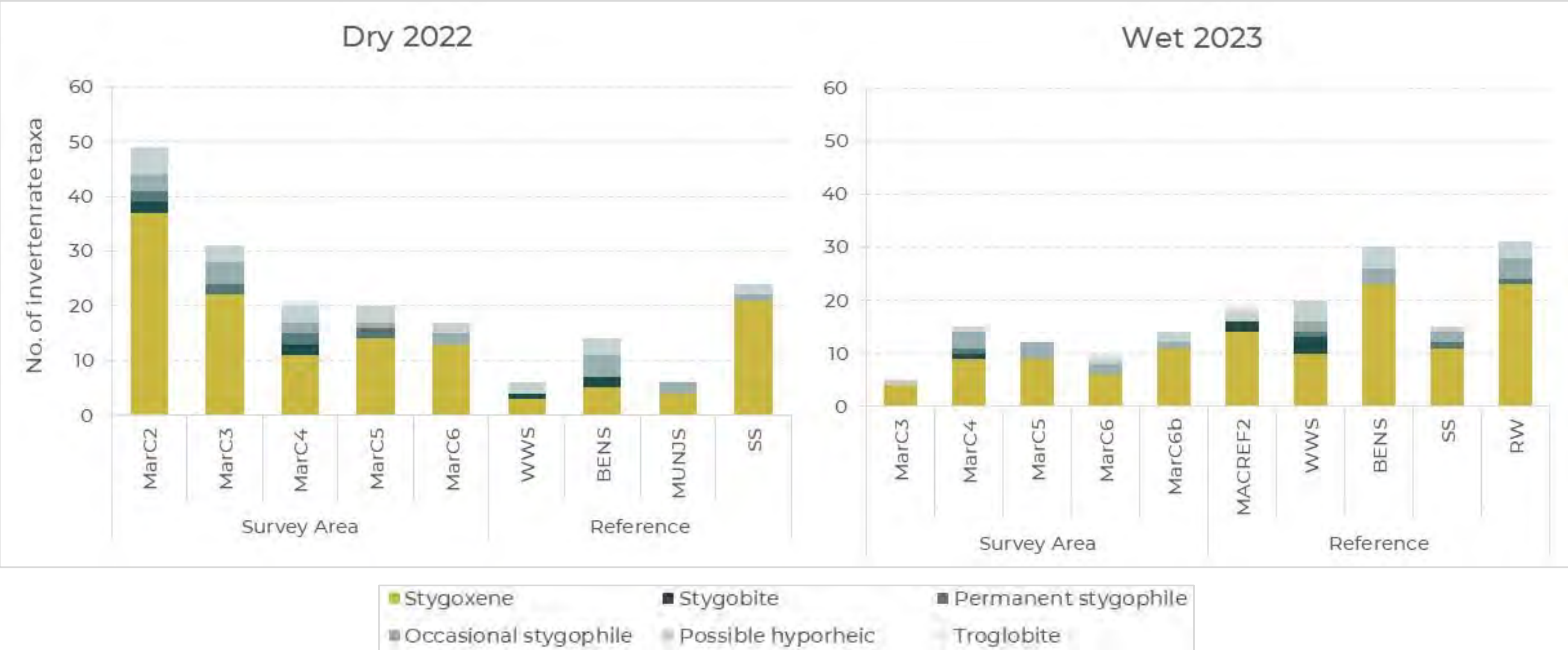
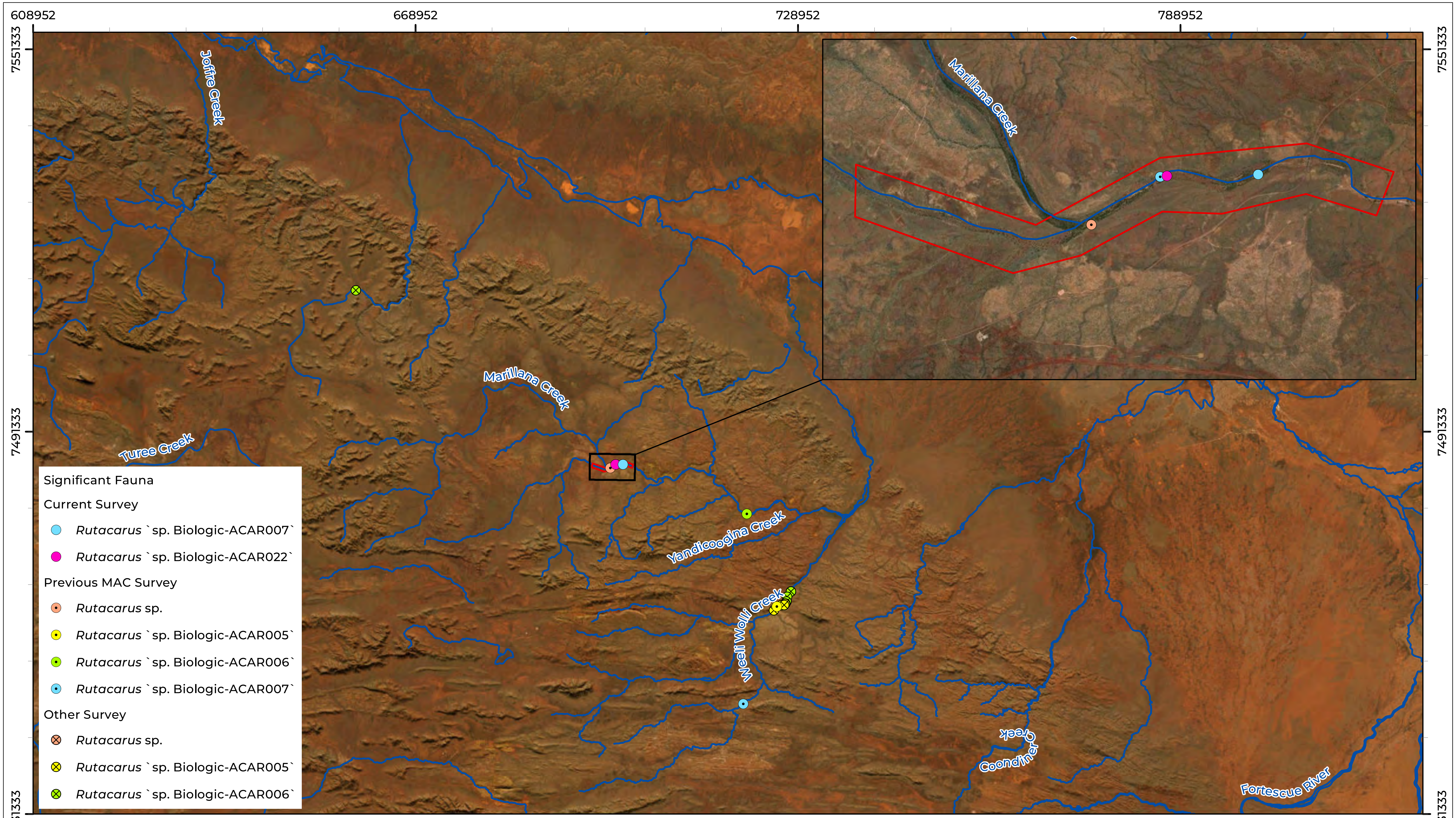


Figure 4.22: Invertebrate composition and richness recorded from hyporheic zones in the Dry 2022 (left) and Wet 2023 (right)



LEGEND

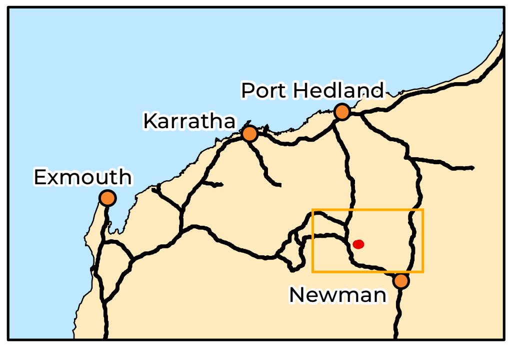
Survey Area — Major Surface Hydrology

Biologic

Scale 1:545,000

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 21/12/2023



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MAC Phase 4 Aquatic Monitoring Dry 2022 and Wet 2023

Figure 4.23: *Rutacarus* water mite records

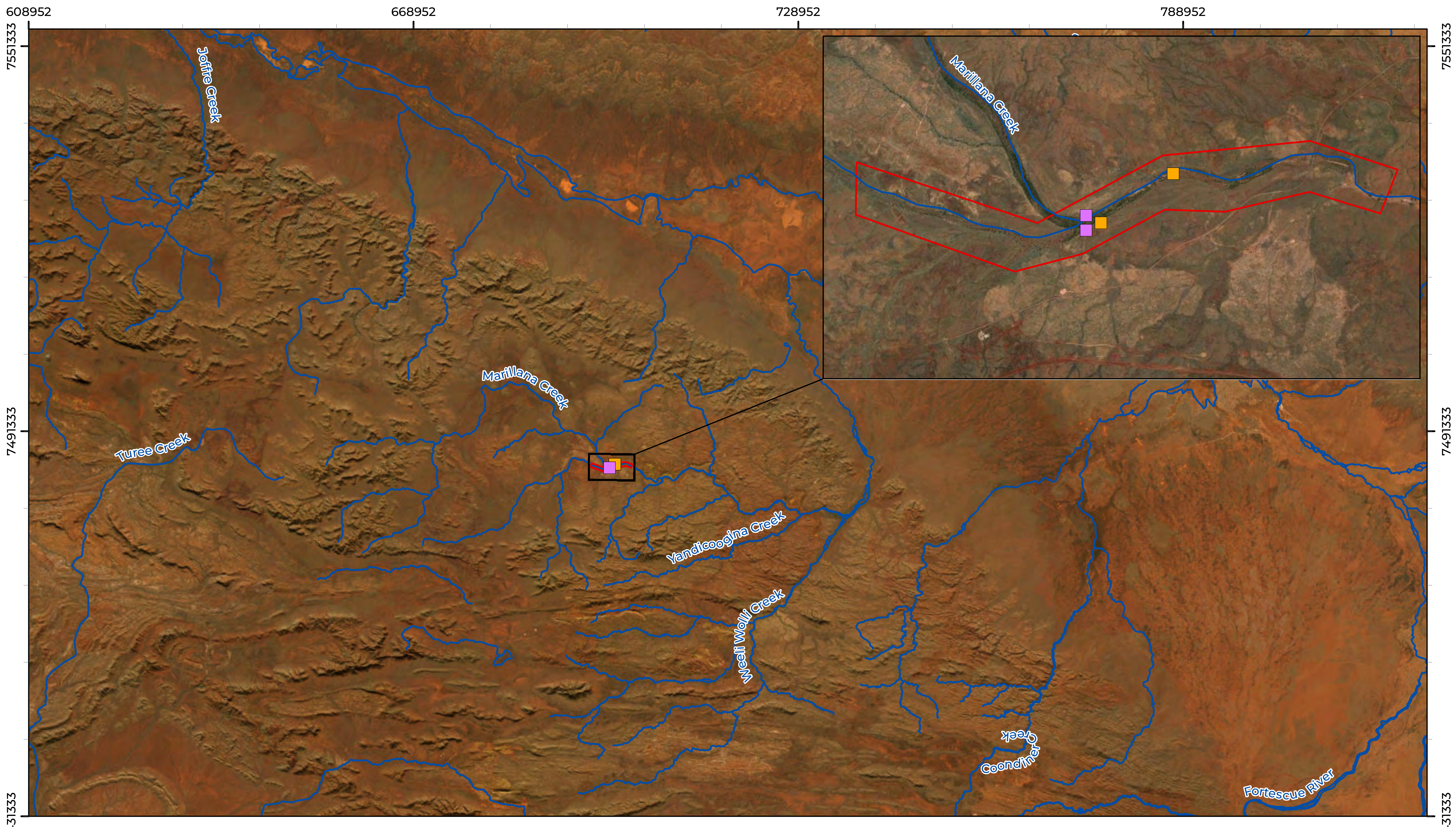
4.5.2.2 Harpacticoids

Two harpacticoid taxa recorded from hyporheic zones of the Survey Area were identified using a combination of morphological and molecular analysis. None of the harpacticoid specimens submitted for molecular work matched previously known OTUs or described species in the available genetic database. Two new OTUs were assigned based on genetic divergence. Canthocamptidae `sp. Biologic-HARP059` was recorded from MarC2 in the Dry 2022 and MarC4 in the Wet 2023, and therefore has a current known linear distribution of 1 km (Figure 4.24). The other OTU was identified as nr *Phyllognathopus* `sp. Biologic-HARP058`. The sequence was nested among GenBank sequences of the genus *Phyllognathopus*, and further morphological examination found it shared several diagnostic characters with the genus. The collection from the hyporheos of MarC2 in the Dry 2022 constitutes the first record of this OTU (Figure 4.24).

4.5.2.3 Syncarids

Molecular analysis of stygal syncarids collected from the Survey Area found sequences of all specimens matched a previously known OTU, *Atopobathynella* `sp. Biologic-PBAT019`. During the current study, *Atopobathynella* `sp. Biologic-PBAT019` was recorded from MarC4 in the Dry 2022 and MACREF2 in Wet 2023. This taxon has previously been recorded from Marillana Creek, but was identified as *Atopobathynella* `sp. Biologic-PBAT042` (recorded from MC10H, downstream of the current Survey Area) and *Atopobathynella* `sp. Biologic-PBAT044` (MC3H, downstream of the current Survey Area). Additional work by Biologic has found that sequences from several previously separate OTUs have an intraspecific genetic distance of less than 7.8%, and therefore several OTUs have been combined within *A.* `sp. Biologic-PBAT019`. This taxon comprises sequences from an unusually large geographic distribution for a species of Parabathynellidae (Figure 4.25), a family which was previously considered to have relatively small ranges (Abrams, 2012; Matthews *et al.*, 2020; Perina *et al.*, 2023). *Atopobathynella* `sp. Biologic-PBAT019` has been recorded from the Turee Creek East sub catchment, the Weeli Wolli sub catchment, and the Fortescue River catchment. There is some uncertainty regarding the PBAT019 OTU, with two main hypotheses based on the current available data

1. These sequences could represent a single OTU with a potential geographic range across three subcatchments (linear range 79.6 km)
2. There could be four distinct OTUs within the PBAT019 lineage.
    - Note: These OTUs would have intraspecific genetic distances of less than 4.7%, and interspecific distances of more than 6%. In this scenario one OTU would also still exhibit an unusual distribution across two regional subcatchments at Turee Creek/Weeli Wolli Creek (Biologic, 2023a).



LEGEND

Survey Area

Major Surface Hydrology

Significant Fauna

Current Survey

Canthocamptidae `sp. Biologic-HARP059`

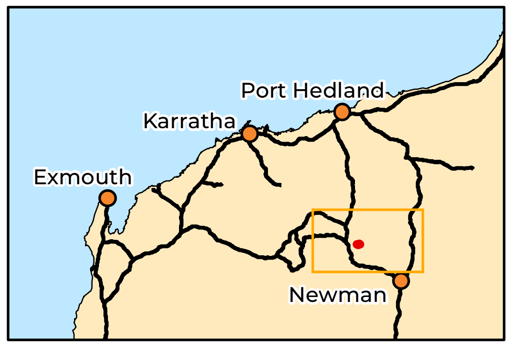
nr *Phyllognathopus* `sp. Biologic-HARP058`

Biologic

Scale 1:545,000

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 22/12/2023



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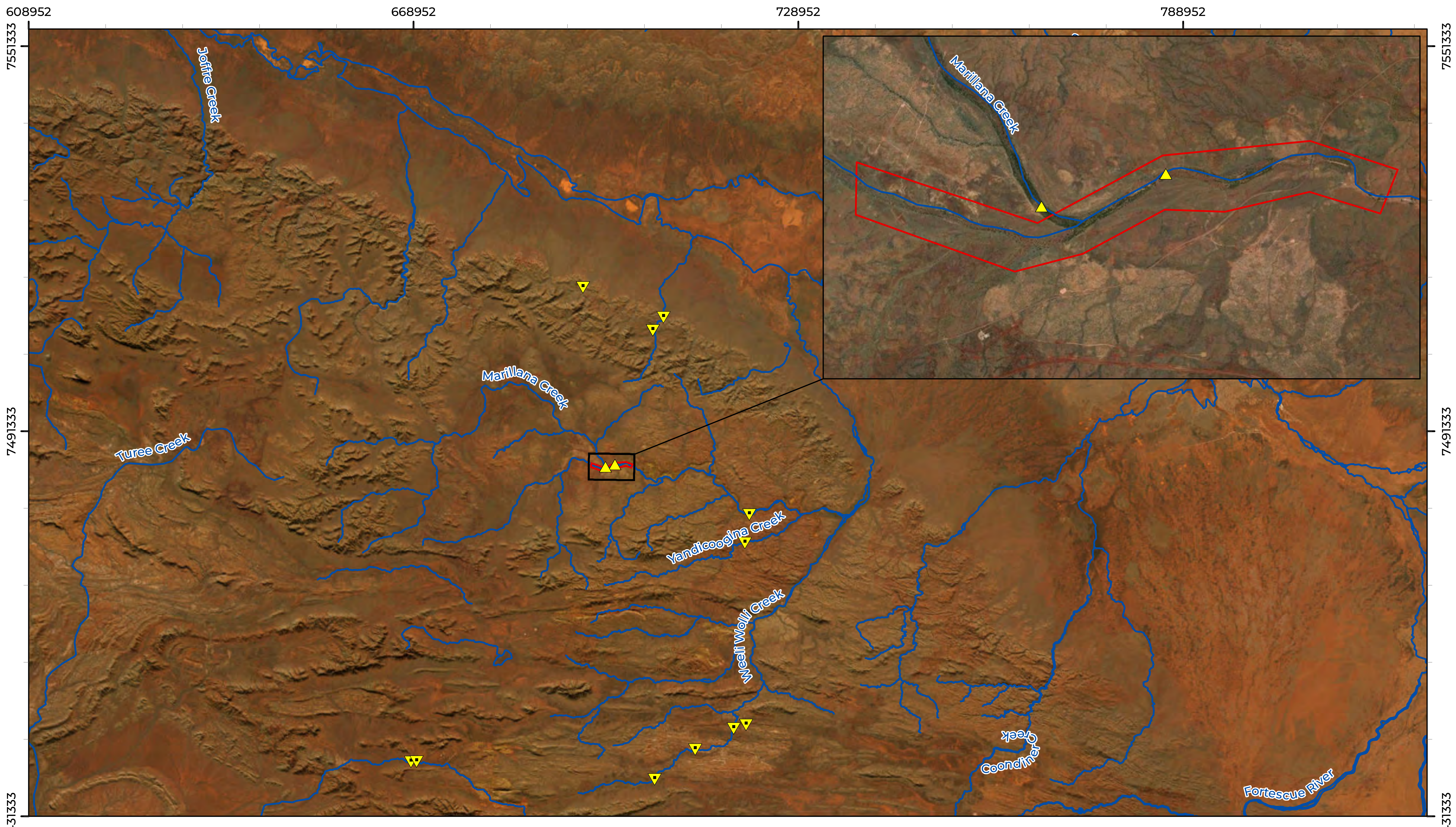
MAC Phase 4 Aquatic Monitoring Dry 2022 and Wet 2023

Figure 4.24: Harpacticoid copepod records



LEGEND

Survey Area

Major Surface Hydrology

Significant Fauna

Current Survey

Atopobathynella `sp. Biologic-PBAT019`

Other Survey

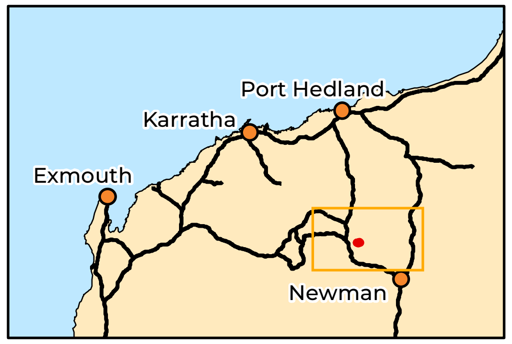
Atopobathynella `sp. Biologic-PBAT019`

Biologic

Scale 1:545,000

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 21/12/2023



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MAC Phase 4 Aquatic Monitoring Dry 2022 and Wet 2023

Figure 4.25: *Atopobanthynella* syncarid records

Caution should be taken regarding the significance of this taxon, given the limited information on this genus generally, and the lack of morphological framework for Pilbara species. *Atopobathynella* `sp. Biologic-PBAT019` should be considered a Potential SRE (Data Deficient) based on current information. Morphological analysis to assess variation within the complex is currently underway, as well as additional molecular work to determine the likely threshold that splits OTUs within this genus.

4.5.3 Troglofauna

Two taxa which represent troglofauna were collected from hyporheic samples within the Survey Area. These taxa were morphologically identified as belonging to the group Symphyla (pseudo-centipede). To provide further clarity on its identity and information on troglofauna species residing in hyporheic zones of Marillana Creek, specimens was submitted for molecular analysis. Specimens collected from MarC4 in the Dry 2022 matched a sequence from a specimen previously collected from the same site in the Dry 2021; *Hanseniella* `sp. Biologic-SYMP055` (Biologic, 2022c). The sequence was more than 10% divergent from its closest relative in the analysis, *Hanseniella* `sp. Biologic-SYMP054`, collected from the hyporheos of nearby Yandicoogina Creek (Biologic, 2022c). These records from MarC4 constitute the only known records of this taxon currently. Specimens collected from MarC6 and Reference site MACREF2 (also located on Marillana Creek) in the Wet 2023, represented the same OTU which was more than 19.95% divergent from *Hanseniella* `sp. Biologic-SYMP055`. This OTU fell within the *Hanseniella* genus, but did not match any previous sequences and was therefore assigned a new OTU; *Hanseniella* `sp. Biologic-SYMP069`. Based on current information, this OTU is known only from Marillana Creek and has a linear distance of 3.7 km, All taxa within the *Hanseniella* genus are considered troglobites and have small ranges of less than 50 km (Bennelongia, 2013, 2015, 2016). As such, both *Hanseniella* `sp. Biologic-SYMP055` and *Hanseniella* `sp. Biologic-SYMP069` are considered likely to represent Potential SREs (Data Deficient).

4.5.4 Characterisation of Baseline Hyporheos Fauna

4.5.4.1 Richness

A total of 69 hyporheos fauna taxa (stygobites, permanent hyporheos stygophiles and occasional hyporheos stygophiles) was recorded from the Survey Area across all sampling events undertaken between the Dry 2020 and Wet 2023 (Table 4.5). A slightly higher number of taxa was recorded (76 taxa) from 28 Reference samples collected over the same period. This is despite the fact that a higher number of Survey Area samples (31) was collected over time. The highest number of hyporheos fauna recorded during an individual sampling event was from Reference sites in the Dry 2020 (38 taxa; Table 4.5). Generally, greater richness of hyporheos fauna was recorded from the Survey Area in the wet season, with the exception of the Wet 2023, when the creek was notably dry and pools heavily receded.

Table 4.5: Total hyporheos fauna taxa richness recorded from each site type in each event

Sampling event	Survey Area		Reference Sites	
	n	**Total**	**n**	**Total**
Dry 2020	5	19	5	38
Wet 2021	6	32	5	29
Dry 2021	4	17	4	26
Wet 2022	6	32	5	28
Dry 2022	5	33	4	17
Wet 2023	5	17	5	33
Total – all events	**31**	**69**	**28**	**76**

Hyporheos fauna taxa richness was quite variable over time, ranging from 1 to 16 taxa in the Survey Area, and 2 to 20 at Reference sites (Figure 4.26). Median hyporheos fauna taxa richness in the Survey Area (7) was similar to that recorded from Reference sites (8 taxa). The variability and general summary statistics for richness of groundwater dependent taxa recorded within hyporheic zones was comparable between Survey Area and Reference sites, with a minimum of 0, a maximum of 5, and a median of 1 taxa recorded from both site types over time (Figure 4.26).

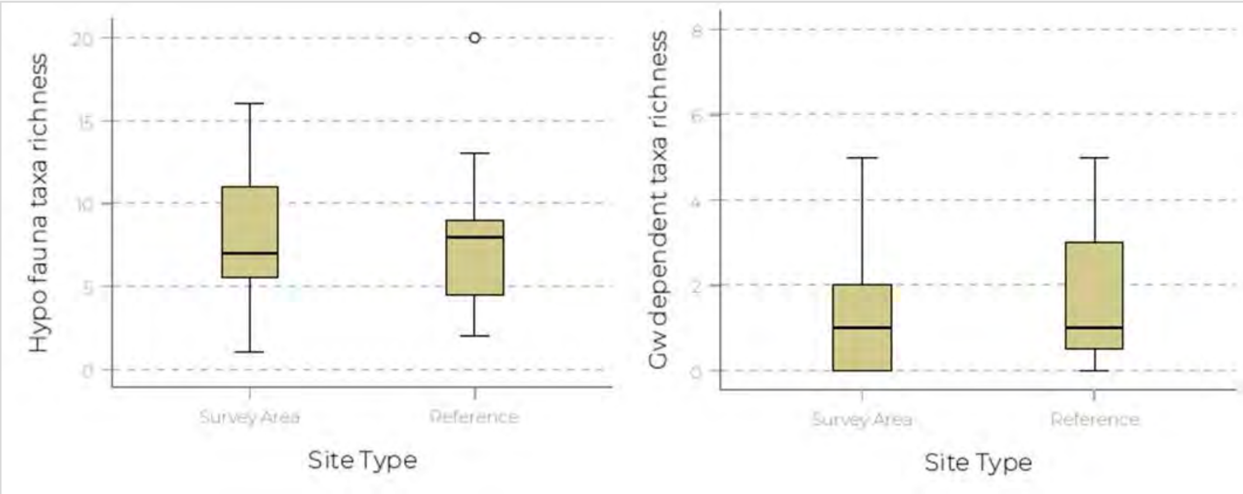


Figure 4.26: Box and whisker plot showing variation in hyporheos fauna taxa richness (left) and groundwater dependent taxa richness (right) across all sampling events

Where, the bottom of the box = 25th percentile, middle line = median, top of the box = 75th percentile, and the bottom and top whiskers represent the minimum and maximum richness, respectively.

Average richness of hyporheos fauna has generally shown a decline over time at both Survey Area and Reference sites, although this decline has been more pronounced in the Survey Area since the Wet 2021 (Figure 4.27). Overall, there was no significant difference in hyporheos fauna taxa richness between site types (Two-way ANOVA; df = 1, p = 0.629), but there was between sampling events (df = 5, p = 0.024). Richness recorded in the Wet 2023 was significantly lower than all other events, while that recorded in the Wet 2021 was significantly greatest. There was also a significant interaction between site types and sampling events (df = 5, p = 0.018), indicating that the pattern of change over time was not the same in the Survey Area as Reference sites.

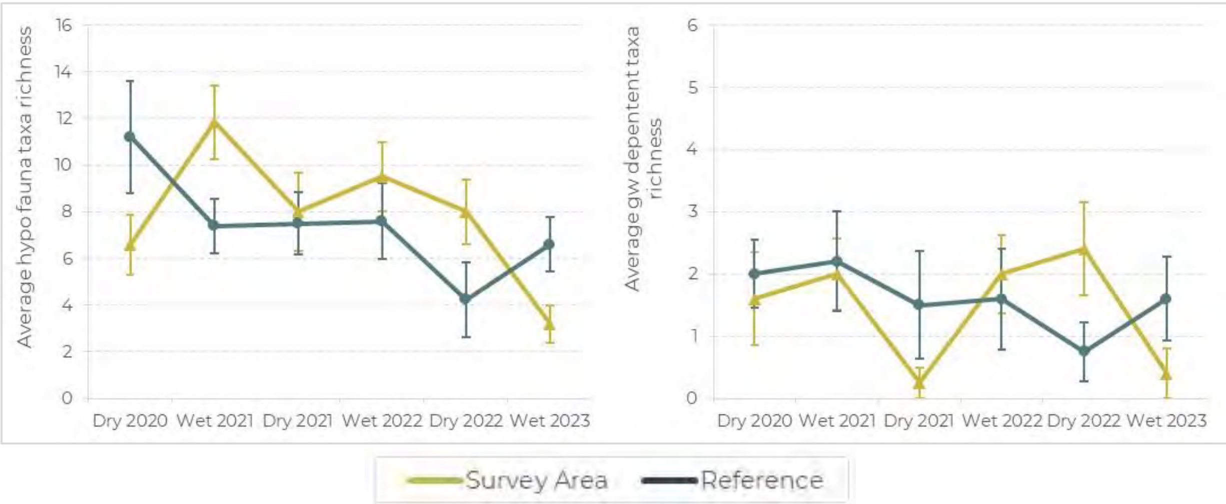


Figure 4.27: Average hyporheos fauna taxa richness (± se), and groundwater dependent taxa richness recorded in each event

Average richness of groundwater dependent taxa (stygobites and permanent hyporheos stygophiles) has varied over time in both the Survey Area and Reference sites (Figure 4.27). In the Survey Area, there was a decline between the Dry 2020 and Dry 2021, followed by an increase to the Dry 2020, and a decrease to the Wet 2023. Reference sites have shown a slight decline over time, but with a marginal increase in the Wet 2023. Overall, there was no significant difference in groundwater dependent taxa richness between site types (df = 1, p = 0.668) or sampling events (df = 5, p = 0.402).

4.6 Macroinvertebrates

4.6.1 Macroinvertebrate Composition and Richness

A total of 191 aquatic macroinvertebrate taxa was recorded from surface waters across the Survey Area, with 151 recorded in the Dry 2022 and 115 in the Wet 2023. Macroinvertebrate fauna of the Survey Area comprised Cnidaria (freshwater hydra; 1 taxon), Platyhelminthes (flat worm; 1 taxon), Nematoda (round worm; 1 taxon), Molluscs (freshwater snails; 3 taxa), Oligochaeta (aquatic segmented worms; 8 taxa), Acarina (water mites; 20 taxa), Branchiopoda (clam shrimp; 2 taxa), Collembolla (spring tails; 3 taxa), Coleoptera (beetles; 56 taxa), Diptera (two-winged flies; 43 taxa), Ephemeroptera (mayflies; 6 taxa), Hemiptera (aquatic true bugs; 22 taxa), Anisoptera (dragonflies and damselflies; 15 taxa), and Trichoptera (caddisfly larvae; 10 taxa; see Appendix H for the full taxa list). In the Dry 2022, a terrestrial pseudoscorpion Chthoniidae sp. was also recorded from MarC4.

Taxonomic composition within the Survey Area was dominated by slow flow and relatively tolerant taxa, such as Diptera (average of 29% of the overall taxa composition per site) and Coleoptera (average of 21% of the taxonomic composition; Figure 4.28). Dominance of Diptera within aquatic macroinvertebrate assemblages of the Pilbara is common (Pinder *et al.*, 2010). Odonata generally accounted for the next greatest richness (average of 9%). In the Dry 2020, richness of odonate taxa in the Survey Area was high, with the greatest number recorded from MarC2 (11 taxa), followed by MarC4 and Reference site MACREF1 (10 taxa at each site). Odonate richness in the Survey Area, was much lower in the dry season (average of 4%). At this time, the greatest richness of odonate taxa was recorded from Reference site MUNJS (9 taxa), followed by Reference sites BENS and WWS (7 taxa each). No odonates were recorded from MarC3 in the Wet 2023, despite as many as 7 taxa being recorded from this site in the previous dry (Figure 4.28).

Macroinvertebrate richness varied between sites and sampling events (Figure 4.28). Richness ranged from 45 (BENS) to 83 taxa (MUNJS) in the Dry 2022, and 21 (MarC6) to 85 taxa (MUNJS) in the Wet 2023. At sites that were sampled in both seasons, richness was generally higher in the Dry 2022. Exceptions were Reference sites BENS and SS, which both recorded greater richness in the Wet 2023, and MUNJS which recorded similar richness between seasons. At Survey Area site MarC4 a reduction of 41 taxa was recorded between seasons, and at MarC5 a reduction of 46 taxa (Figure 4.28).

4.6.2 Significant Macroinvertebrates

Most aquatic macroinvertebrates recorded from the Survey Area were common species with wide distributions. Excluding taxa which could not be assigned a distribution status due to insufficient information or taxonomy (juveniles or damaged specimens), most remaining taxa had distributions extending across Australia (42%), the world (cosmopolitan taxa; 16%), the Australasian region (11%), or northern Australia (12%). A total of 6% were WA endemics, while 1% were north WA species, and 12% were restricted to the Pilbara region.

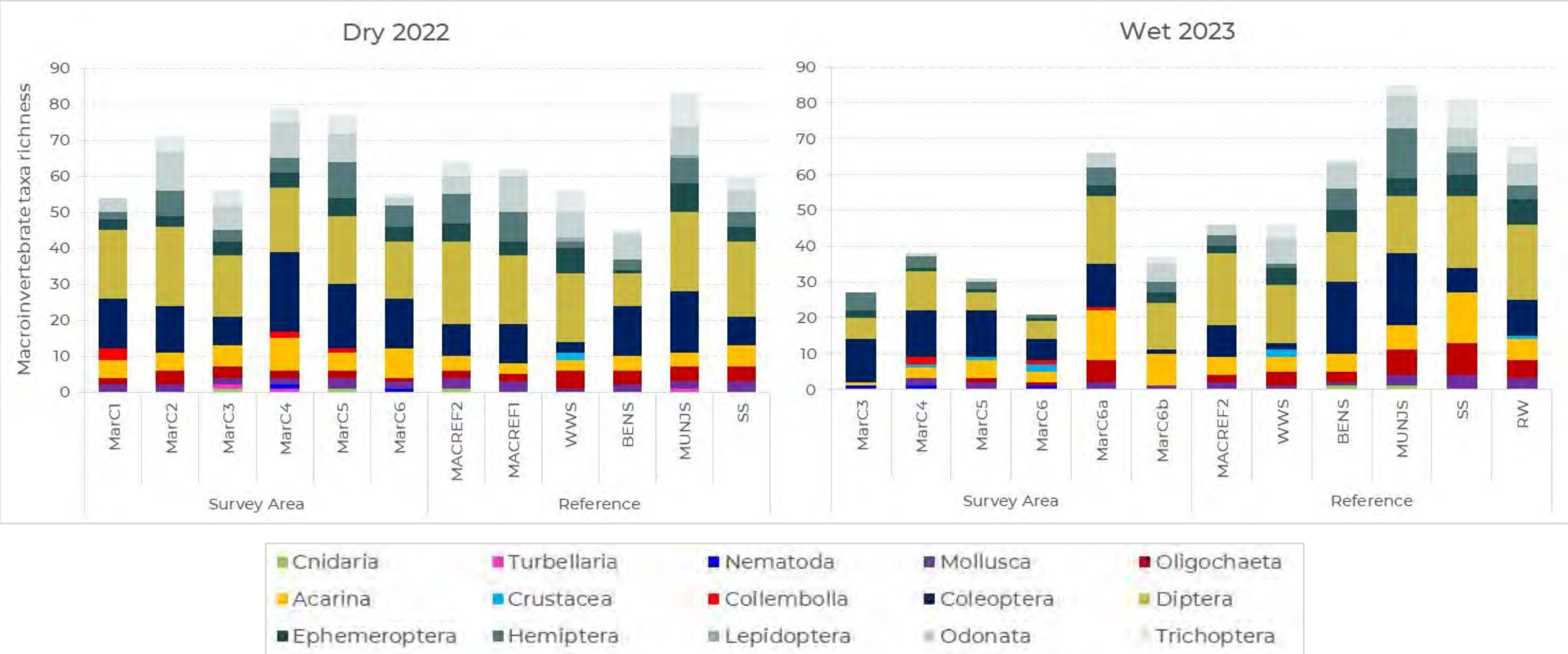


Figure 4.28: Macroinvertebrate composition and taxa richness in the Dry 2022 and Wet 2023

A total of 16 taxa are restricted to the Pilbara, with 12 of these occurring within the Survey Area. All sites recorded at least one Pilbara endemic taxon (Figure 4.29). The greatest number of Pilbara endemic taxa was recorded from the Survey Area, at MarC5 (five taxa), closely followed by MarC2 and Reference sites WWS and RW (all with four taxa; Figure 4.29).

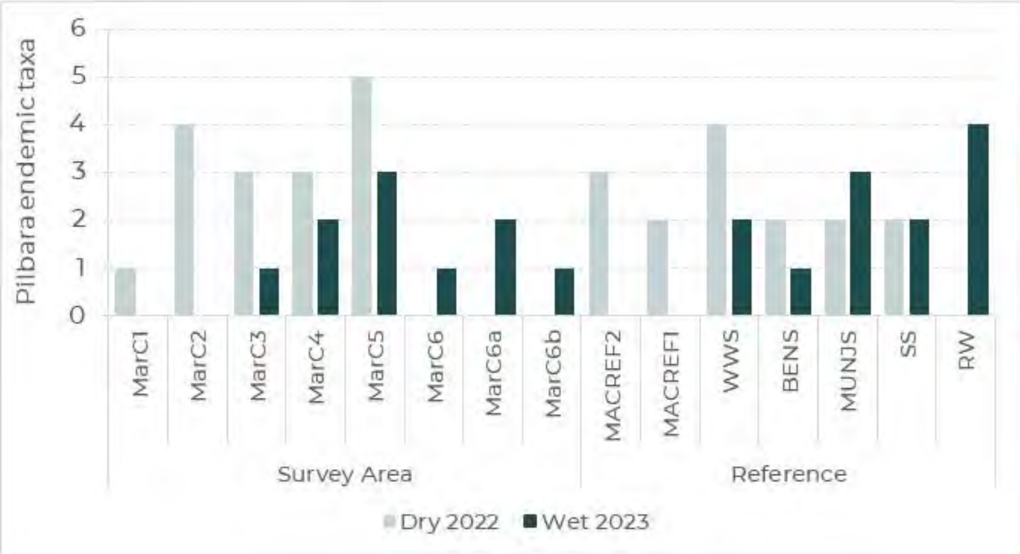
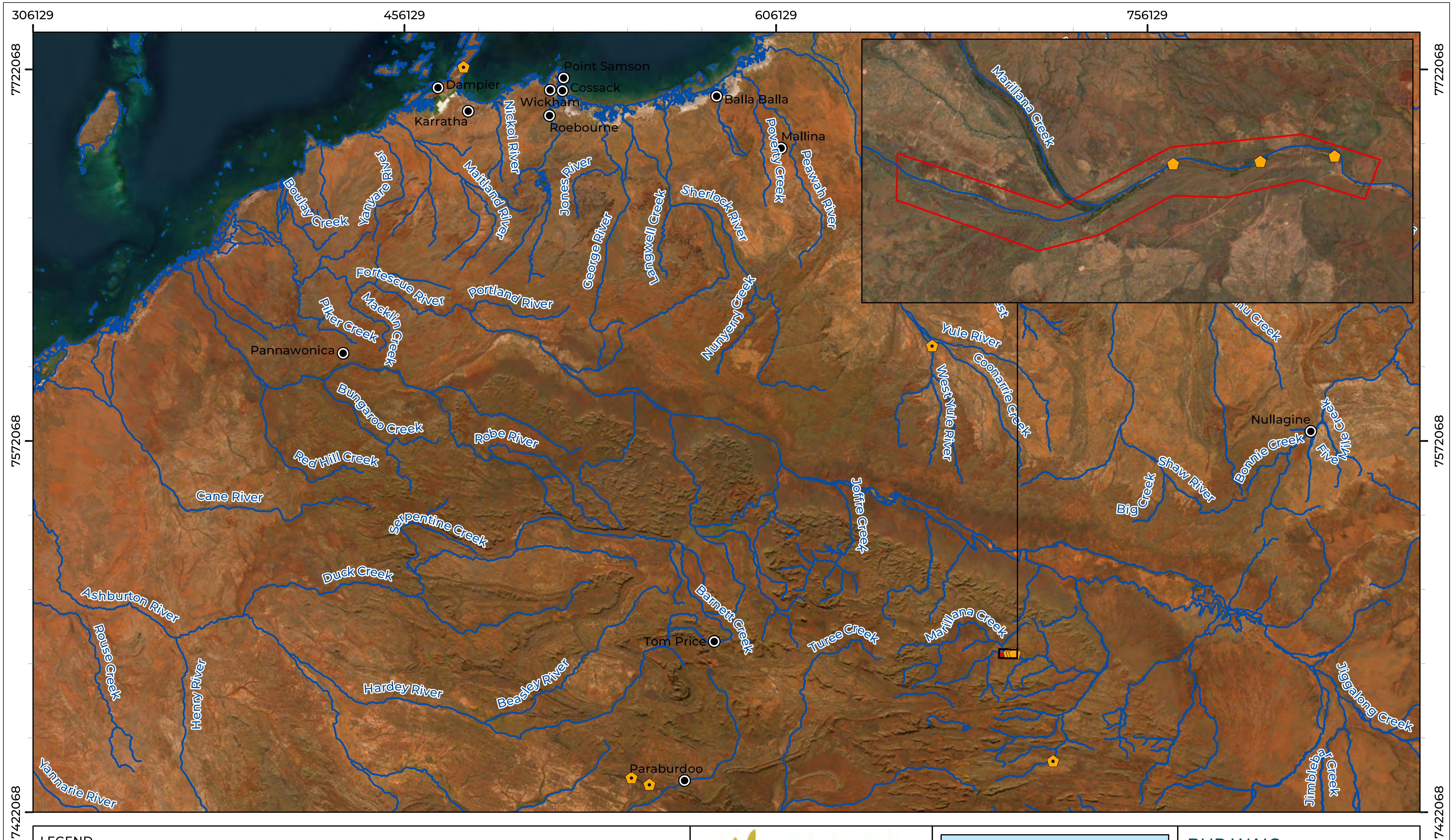


Figure 4.29: Number of Pilbara endemic taxa recorded from each site

None of the macroinvertebrate species recorded from the Survey Area are listed as significant under the BC Act, EPBC Act, or are recognised as Priority Fauna. However, three taxa recorded from the Survey Area were of further interest, either due to being potentially restricted, or because they are listed internationally under the IUCN Red List of Threatened Species.

4.6.2.1 Clam shrimp

The clam shrimp, *Limnadopsis pilbarensis*, was recorded from surface waters in the Survey Area in the Wet 2023 (MarC4, MarC5 and MarC6). This species is endemic to the Pilbara, but is relatively uncommon, being recorded from temporary pools only. During the PBS, it was only recorded from one site, Burrup Rockhole northeast of Dampier (Pinder *et al.*, 2010). It has also been recorded from Beabea Creek, Ratty Spring (Pirraburdu Creek) and Glen Ross Creek (Timms, 2009), as well as an ephemeral rock pool west of Paraburdoo (Biologic, unpub. data) (Figure 4.30).



LEGEND

Survey Area

Major Surface Hydrology

Significant Fauna

Current Survey

Limnadopsis pilbarensis

Other Survey

Limnadopsis pilbarensis

Biologic

Scale 1:1,400,000

0 30 60 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 21/12/2023

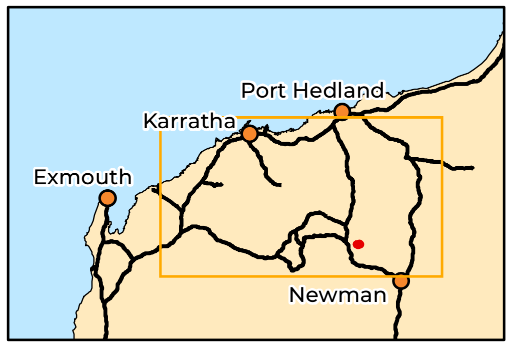


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Figure 4.30: Records of the clam shrimp *Limnadopsis pilbarensis*

4.6.2.2 Odonates

Two odonates recorded from the Survey Area during the current survey are listed on the IUCN Red List of Threatened Species. The Pilbara billabongfly, *Austroagrion pindrina*, was recorded from Survey Area sites MarC2 and MarC4 in Dry 2022, as well as Reference site MUNJS. This species is currently listed as Vulnerable based on its fragmented population and continuing decline of mature individuals (IUCN, 2023). Although it has been recorded from close to 20 locations across the Pilbara (Figure 4.31), *A. pindrina* is generally known only from springs, permanent pools, or sites of high ecological condition, with good water quality and high in-stream habitat diversity and heterogeneity.

The Pilbara tiger *Ictinogomphus dobsoni* is currently listed on the IUCN Red List as Near Threatened (IUCN, 2023). During the current study, it was recorded from the Survey Area at MarC3 in the Dry 2022, and from Reference site MUNJS in the Wet 2023. The listing for *I. dobsoni* cited its fragmented population and relatively low number of records (IUCN, 2023). Including grey literature and the PBS, *I. dobsoni* is currently known from at least 15 locations (Figure 4.31). Where present, the Pilbara tiger can occur in high local abundances (Dow, 2017). Threats to both of these odonate species include lowering of groundwater tables and loss of habitat (IUCN, 2023), impacts that would be exacerbated by climate change (Bush *et al.*, 2014).

4.6.3 Characterisation of Baseline Macroinvertebrates

4.6.3.1 Richness

A total of 309 aquatic macroinvertebrate taxa have been recorded from the Survey Area across all baseline sampling events (Table 4.6). Reference sites recorded a higher richness over the same period (340 taxa), although a great number of replicate sites was also sampled (36 compared to 32 in the Survey Area). The total number of macroinvertebrate taxa recorded in a single sampling event ranged from 104 (recorded from the Survey Area in the Dry 2021 when only two sites held water) to 192 (recorded from Reference sites in the Wet 2023).

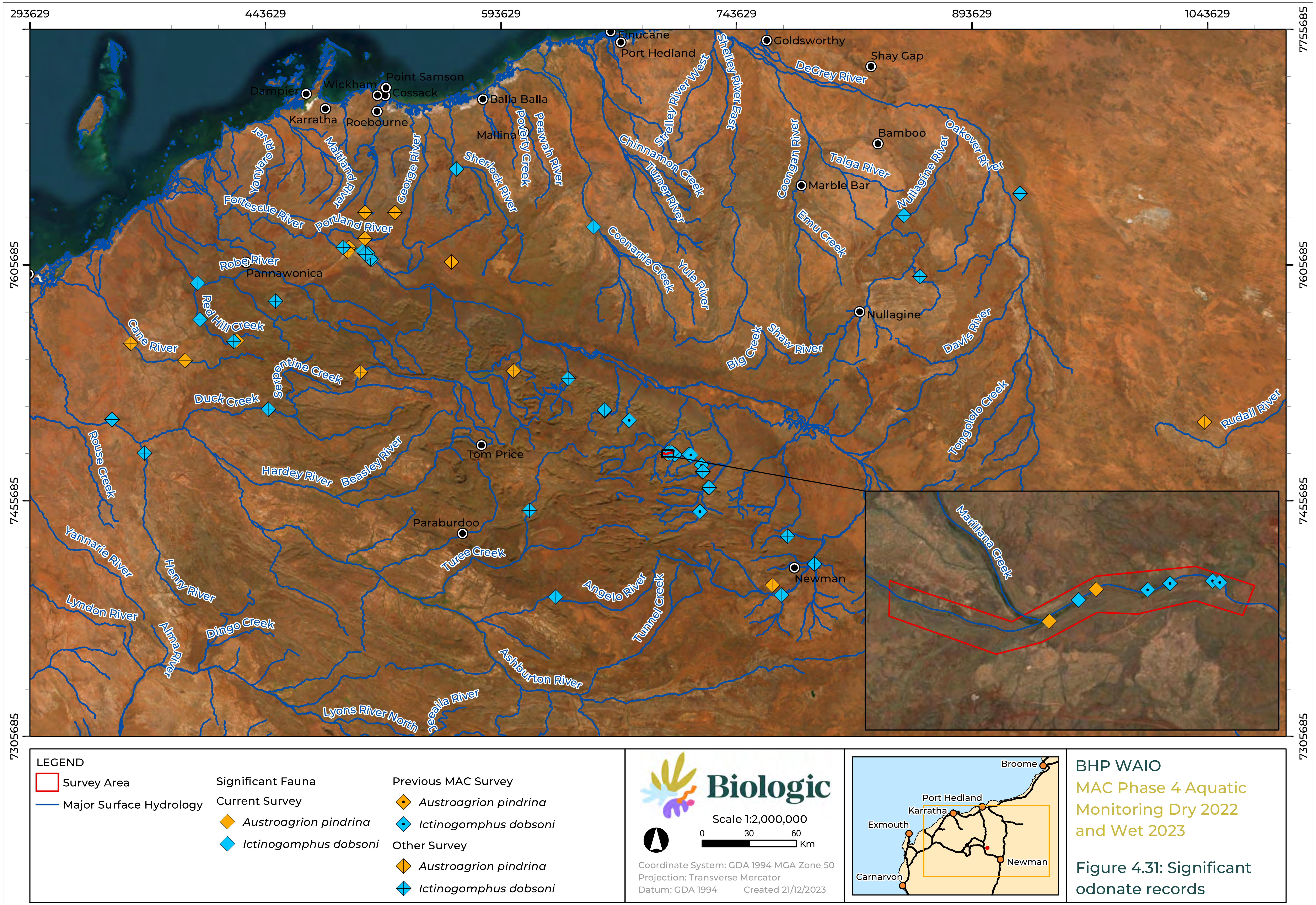

Figure 4.31: Significant odonate records

Table 4.6: Total macroinvertebrate richness recorded from each site type in each event

Sampling event	Survey Area		Reference Sites	
	n	Total	n	Total
Dry 2020	6	142	6	162
Wet 2021	6	150	6	172
Dry 2021	2	104	6	182
Wet 2022	6	180	6	169
Dry 2022	6	152	6	163
Wet 2023	6	115	6	192
Total – all events	**32**	**307**	**36**	**340**

Macroinvertebrate richness in the Survey Area was highly variable across the baseline sampling period, ranging from just 21 (at MarC6 in the Wet 2023) to 88 taxa (at MarC2 in the Wet 2022). Richness at Reference sites ranged from 35 (at MACREF1 in the Wet 2022) to 86 taxa (also at MACREF1 in the Dry 2021). Median richness was slightly higher at Reference sites (62) compared to the Survey Area (57 taxa; Figure 4.32).

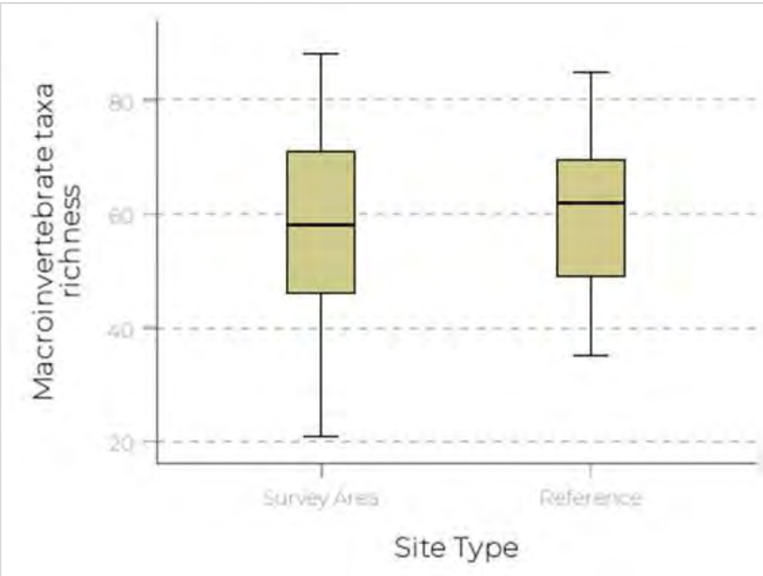

Figure 4.32: Box and whisker plot showing variation in macroinvertebrate taxa richness across all sampling events

Where, the bottom of the box = 25th percentile, middle line = median, top of the box = 75th percentile, and the bottom and top whiskers represent the minimum and maximum richness, respectively.

Taking sample size into account, average macroinvertebrate taxa richness has shown a strong and continual decline since the Dry 2021 (r = 0.89l Figure 4.33). This pattern of change was not mirrored at Reference sites, with generally consistent taxa richness recorded between the Dry 2020 and the Wet 2022, and with a slight increase to the Wet 2023.

Although average macroinvertebrate richness in the Survey Area was similar to that recorded from Reference sites in the initial sampling event (Dry 2020), richness was much lower in the Survey Area in the Wet 2023 sampling event (Figure 4.33). Given the comparable richness in earlier sampling events, overall, there was no significant difference in richness between site types (Two-way ANOVA; df = 1, p = 0.072). A significant difference in richness was detected between sampling events (df = 5, p = 0.009), with significantly lowest richness recorded in the Wet 2023, and highest in the Dry 2021. A significant interaction was also recorded, which provides further support that the pattern of change over time was different in the Survey Area to that experienced at Reference sites (Figure 4.33).

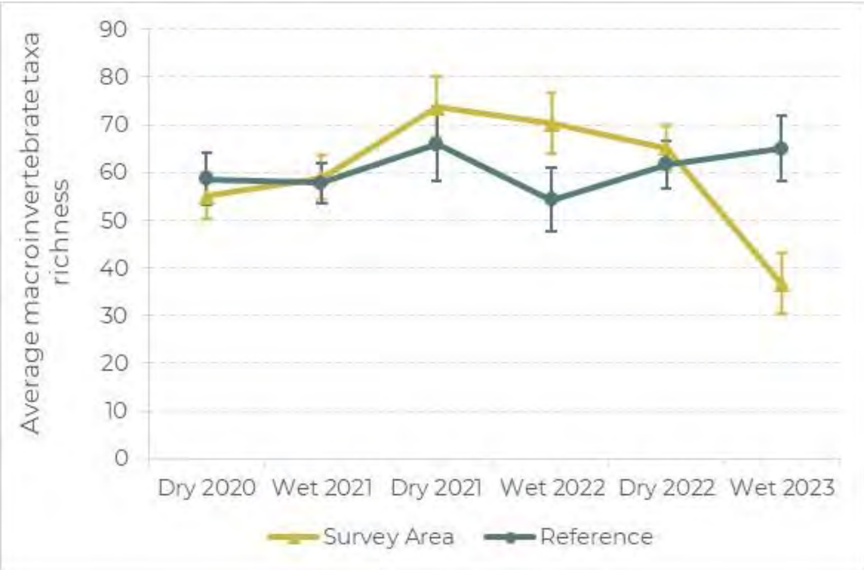

Figure 4.33: Average macroinvertebrate taxa richness (± se) recorded in each event

4.6.3.2 Assemblage

Macroinvertebrate assemblages of the Survey Area generally separated from Reference site assemblages in ordination space, with some minor overlap (Figure 4.34). However, Survey Area samples from the Wet 2023 separated from all other samples, likely based on the reduced richness recorded from the creek at this time. This separation was represented as a significant SIMPROF cluster which included all Survey Area sites sampled in the Wet 2023, except MarC6a and MarC6b (Figure 4.34). Weeli Wolli Spring macroinvertebrate samples also formed a significant SIMPROF cluster grouping, along with the RW sample from the Wet 2021 and the MACREF2 sample from the Wet 2022. Pairwise post-hoc comparison of creek differences, indicated that macroinvertebrate assemblages of the Survey Area were barely separable from the tributary of Yandicoogina Creek, but significantly different to the Marillana Creek Reference, Davis River, Weeli Wolli Creek and Munjina Spring assemblages (Figure 4.35).

Temporal variation was evident amongst macroinvertebrate samples, with a similar transition over time as reported for water quality and zooplankton assemblages (Figure 4.36). Macroinvertebrate assemblages recorded in the Wet 2023 were most different to those recorded in the initial baseline sampling event of the Dry 2020 (Figure 4.36).

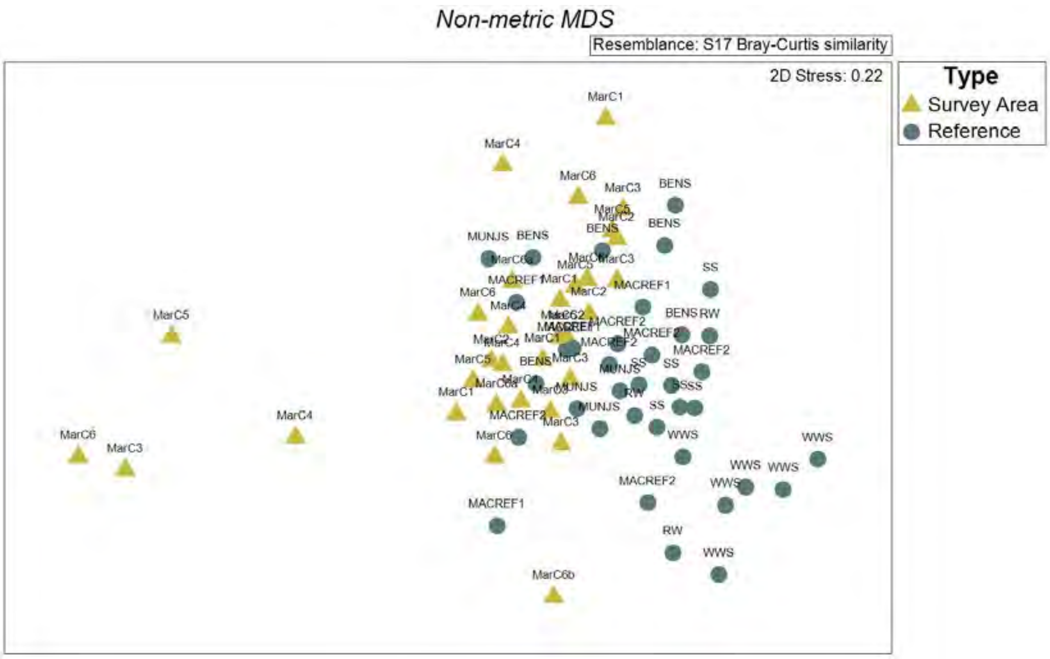

Figure 4.34: nMDS of all macroinvertebrate assemblages, with samples identified by site type

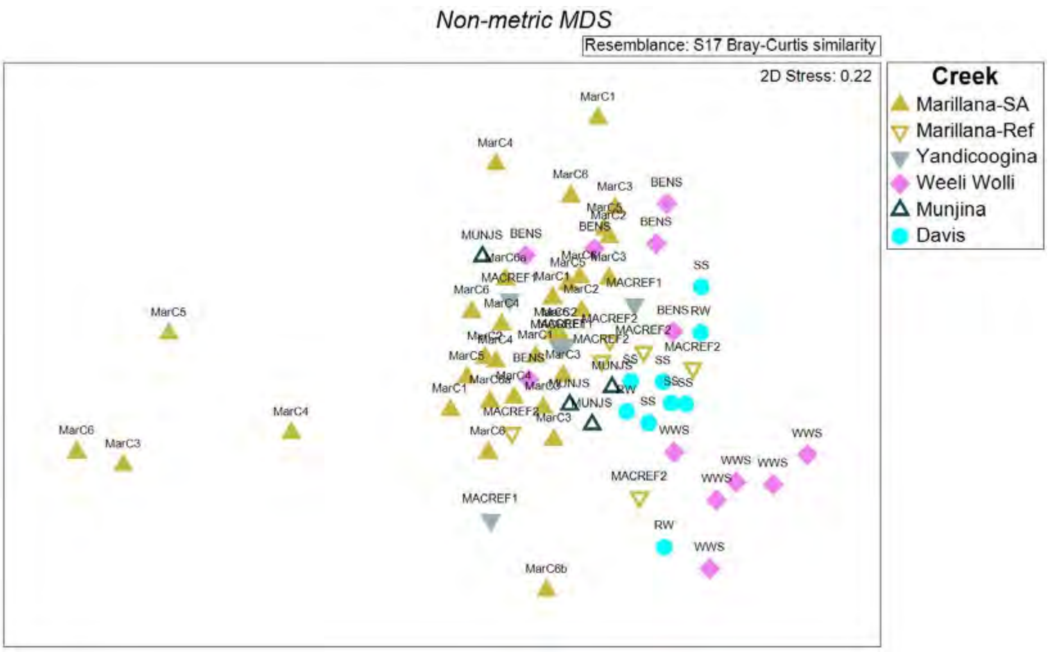

Figure 4.35: nMDS of all macroinvertebrate assemblages, with samples identified by creek

Overall, there was a significant difference in macroinvertebrate assemblages between site types (Two factor PERMANOVA; df = 1, pseudo-F = 4.29, $p < 0.001$) and between sampling events (df = 5, pseudo-F = 2.80, $p < 0.001$). There was also a significant interaction term (df = 5, pseudo-F = 1.61, $p < 0.001$), indicating that pattern of assemblage change over time was not the same in the Survey Area as that in Reference sites.

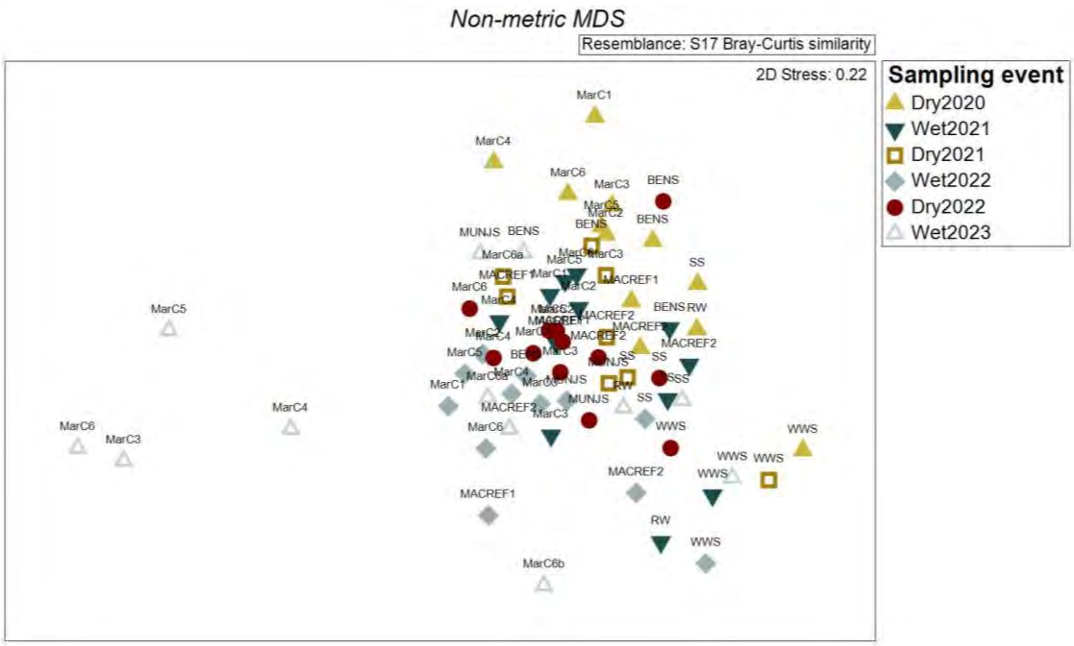

Figure 4.36: nMDS of all macroinvertebrate assemblages, with samples identified by sampling event

4.6.3.3 Correlations with environmental data

Including data from the Survey Area only (excluding Reference sites) collected across all baseline sampling events, correlations between macroinvertebrate assemblages and environmental characteristics (water quality and habitat data) were investigated using DistLM. A model with a strong correlation (r = 0.95) between macroinvertebrate assemblages and four significant predictor variables was produced (Table 4.7). These environmental variables were EC, pH, turbidity and concentration of dAs. Together, these environmental variables explained less than one third of the variation amongst the macroinvertebrate assemblages of the Survey Area (26.43%). This suggests that other factors not included in the analysis also had a strong influence on macroinvertebrate assemblages of the Survey Area, perhaps including hydrological gradients such as level of pool persistence and length of time between drying events.

Table 4.7: DistLM results examining correlations between Survey Area macroinvertebrate assemblages and environmental data (water quality and habitat).

Variable	r	Pseudo-F	*p*-value	% variance explained
EC	0.29	2.74	0.002	8.36
pH	0.38	2.022	0.007	5.97
Turbidity	0.50	2.50	<0.0001	6.91
dAs	062	2.01	0.004	5.18
		Total % variation explained		**26.43%**

4.6.4 Introduced Macroinvertebrate Taxa

No introduced macroinvertebrate species were recorded from the Survey Area. A Reference site, WWS, however, did record one introduced species. This was the freshwater crayfish, *Cherax quadricarinatus*, commonly known as redclaw. Abundances, size classes and sex ratios of the population of redclaw at Weeli Wolli Spring is being monitored as part of the Weeli Wolli Spring Aquatic Monitoring surveys for BHP (Biologic, 2023e, 2023f).

4.7 Rehydration Trials

4.7.1 Water Quality

Water quality in the rehydrate tanks was generally comparable to field conditions within inundated pools, and conducive to emergence of fauna and germination of flora. pH was slightly acidic to basic, ranging from 6.7 (MACREF1) to 8.1 (MarC1) (Table 4.8). The majority of pH values from the three sites were within ANZG (2018) DGVs and respective surface water ranges for Survey Area and Reference sites (Table 4.8). Water temperatures were comparable to those recorded from surface waters in the Dry 2022 and Wet 2023, with all values falling within the surface water ranges (Table 4.8). Similarly, DO was within those recorded in surface waters, however, minimum values at all three sites fell below the lower ANZG (2018) DGV (Table 4.8).

All EC values exceeded the conservative ANZG (2018) DGV, which is typical for Pilbara surface waters. EC from the MarC1 rehydrate tank was generally higher than that recorded in Survey Area surface waters, with the mean (2,228.8 µs/cm) and maximum (3,764.0 µs/cm) exceeding the Dry 2022 and Wet 2023 surface water range (Table 4.8). Maximum EC from the MACREF1 tank (2,235.0 µs/cm) exceeded the maximum EC recorded in Reference site surface waters (1,827 µs/cm), although mean EC (1,622.6 µs/cm) was within the surface water range (Table 4.8).

Table 4.8: Summary of water quality (minimum, maximum, mean and se) recorded during the Wet 2023 rehydration trials

Site	Analyte	ANZG DGV	SW Range	min	max	mean	se
MarC1	pH	6 - 8	7.2 - 8.4	7.3	8.0	7.7	0.1
	Temp (°C)	-	19.0 - 30.1	20.1	22.9	21.0	0.2
	EC (µs/cm)	250	148 - 2068	1180.0	**3764.0**	**2228.8**	222.2
	DO %	85 - 120	37.3 - 116.4	61.9	101.9	88.9	3.4
MarC2	pH	6 - 8	7.2 - 8.4	7.2	8.1	7.8	0.1
	Temp (°C)	-	19.0 - 30.1	20.1	23.4	21.8	0.2
	EC (µs/cm)	250	148 - 2068	755.0	1024.0	960.3	17.1
	DO %	85 - 120	37.3 - 116.4	61.4	101.9	90.4	3.6
MACREF1	pH	6 - 8	6.9 - 8.7	**6.7**	7.8	7.3	0.1
	Temp (°C)	-	16.0 - 27.6	20.1	22.7	20.9	0.2
	EC (µs/cm)	250	642 - 1827	1155.0	**2235.0**	1622.6	93.0
	DO %	85 - 120	47.4 - 112.0	56.5	93.8	78.2	3.3

Gold highlight indicates value outside of ANZG DGVs.

Bold text indicates value outside of surface water ranges for Survey Area and Reference sites recorded in the Dry 2022 and Wet 2023.

4.7.2 Rehydrate Taxa Composition and Richness

The rehydration trials yielded over 2,000 invertebrate specimens from 25 taxa, as well as several aquatic macrophytes. Most taxa emerged from the sediments of Reference site MACREF1 (22 taxa), with only four taxa emerging from the sediments of MarC1, and three from MarC2 (Figure 4.37). Taxa which emerged from Survey Area sites included Acari sp., the cladoceran *Ceriodaphnia* sp., the ostracods *Stenocypris major* and *Limnocythere dorsosicula* (along with indeterminate juvenile ostracods), and Nematoda sp. In contrast, MACREF1 sediments yielded several representatives from Cladocera (5 taxa), Insecta (including two Diptera taxa and two Odonata), Copepoda (3 taxa), Ostracoda (6 taxa), Polychaeata (1 taxa), Turbellaria (1 taxa), Nematoda (1 taxa) and Rotifera (1 taxa) (Figure 4.37).

Submerged macrophytes germinated in all three rehydrate tanks (Figure 4.37), however only those from MarC2 reached sufficient maturity for identification. These were *Chara* sp. from the multicellular algal family Characeae; a common macrophyte taxa to the Survey Area (Biologic, 2023b).

Overall, the crustacean groups Ostracoda and Cladocera were the most specious groups within the three rehydrate tanks, with eight and five taxa, respectively (Figure 4.37). 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).

The emergence trials did not result in any additional taxa recorded from the Survey Area of Reference sites (i.e., all taxa present were also recorded from the zooplankton, hyporheic zone or macroinvertebrate samples).

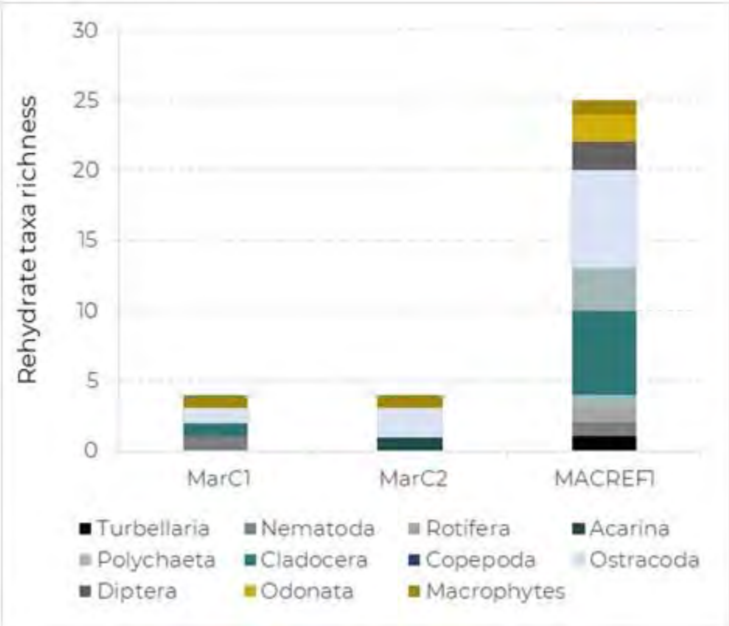

Figure 4.37: Rehydration trial composition and richness recorded from each site in the Wet 2023

4.7.3 Significant Emergent Taxa

All taxa which emerged from the rehydration tanks were common and widespread species, with none from either the Survey Area or reference sites listed as significant.

4.7.4 Characterisation of Baseline Egg and Seed Bank

Of the six sampling events undertaken over the baseline, rehydration trials were required during the Dry 2021 and Wet 2023, as all sites were inundated during all other events. Rehydration trials have included a total of seven samples from the Survey Area (five in the Dry 2021 and two in the Wet 2023), and one from Reference sites (MACREF1 in the Wet 2023).

A total of 45 taxa have emerged or germinated during rehydration trials from the eight sediment samples collected across the baseline. Survey Area sites yielded 27 taxa, including 22 taxa in the Dry 2021, and eight in the Wet 2023 (Table 4.9). Twenty-three taxa emerged from one Reference site sample (MACREF1) collected in the Wet 2023 (Table 4.9). Richness from individual Survey Area sites was typically low, ranging from four (MarC1 and MarC2; Wet 2023) to nine taxa (MarC5; Dry 2021), with an average of 5.7 taxa per trial (Figure 4.38).

Table 4.9: Total emergent taxa richness recorded from each site type in each event.

Sampling event	Dry 2021		Wet 2023		Overall	
Site Type	**n**	**Total**	**n**	**Total**	**n**	**Total**
Survey Area	5	22	2	8	7	27
Reference	-	-	1	23	1	23

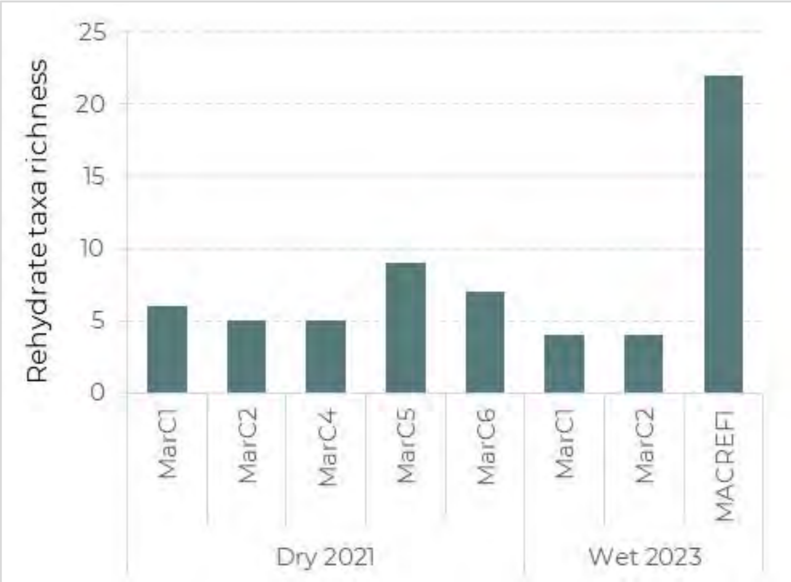

Figure 4.38: Taxa richness of emergences from sediments collected across the baseline

4.8 Fish

4.8.1 Fish Species Composition and Richness

During the current survey, one freshwater fish species was recorded from the Survey Area, the spangled perch (*Leiopotherapon unicolor*). Four additional species were recorded from Reference sites, including western rainbowfish (*Melanotaenia australis*), blue catfish (*Neoarius graeffei*), Pilbara tandan (*Neosilurus* sp.[9]) and bony bream (*Nematalosa* sp.[9]).

4.8.2 Abundance

A total of 1,283 individual fish was recorded during the current survey. In the Dry 2022, 713 fish were recorded, with 199 from the Survey Area and 514 from Reference sites (Table 4.10). Fewer

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

fish were recorded during the Wet 2023, with a total of 570 individuals; 51 from the Survey Area (all from one site; MarC6a) and 519 from Reference sites (Table 4.10). Within the Survey Area, the greatest abundance of fish was 177 individuals recorded from MarC3 (in the Dry 2022). This compares to 224 individuals recorded from References site SS (Wet 2023). Where fish were present, the lowest abundance was four individuals (at MarC6) and three individuals at Reference site BENS, both recorded in the dry season (Table 4.10). No fish have been recorded from Reference site MUNJS, in any baseline sampling event.

4.8.3 Length-Frequency Analysis

Detailed length-frequency analysis was undertaken for spangled perch only, as no other species were recorded from the Survey Area in the current survey. At Reference sites, rainbowfish populations primarily comprised new recruits in the Dry 2022, and juveniles in the Wet 2023. Pilbara tandan at Reference sites were almost exclusively adults, and the majority of bony bream recorded in the wet were juveniles.

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[10] for males and 78 mm TL for females. To allow for determination of age-classes (without knowing sex), size at maturity was estimated at 70 mm SL for the purposes of this study.

Juveniles comprised the greatest proportion of spangled perch in the Survey Area during the Dry 2022 (66%), while subadults and adults were dominant during the Wet 2023 (46% and 54% respectively), with no new recruits or juveniles recorded (Figure 4.39). Similarly, juveniles were the most abundant at Reference sites during the Dry 2022 (41%; Figure 4.39). In the Wet 2023, juveniles and subadults were the most abundant at Reference sites (38% and 44% respectively; Figure 4.39).

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

Table 4.10: Abundance of each freshwater fish species recorded from each inundated site

Type	Site	*Leiopotherapon unicolor*		*Melanotaenia australis*		*Neosilurus* sp.		*Nematalosa* sp.		*Neoarius graeffei*		*Megalops cyprinoides*		Abundance		Diversity	
		Spangled perch		Western rainbowfish		Pilbara tandan		Pilbara bony bream		Blue catfish		Oxeye herring					
		D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W
Survey Area	MarC1	0	-	0	-	0	-	0	-	0	-	0	-	0	0	0	0
	MarC2	0	-	0	-	0	-	0	-	0	-	0	-	0	0	0	0
	MarC3	177	0	0	0	0	0	0	0	0	0	0	0	177	0	1	0
	MarC4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	MarC5	18	0	0	0	0	0	0	0	0	0	0	0	18	0	1	0
	MarC6	4	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0
	MarC6a	0	51	0	0	0	0	0	0	0	0	0	0	0	51	0	1
Reference	MACREF2	41	5	0	0	0	0	0	0	0	0	0	0	41	5	1	1
	MACREF1	0	0	129	0	0	0	0	0	0	0	0	0	129	0	1	0
	WWS	6	0	142	109	14	5	0	0	0	0	0	0	162	114	3	2
	BENS	3	21	69	90	0	11	0	0	0	0	0	0	72	122	2	3
	SS	97	31	6	139	7	9	0	45	0	0	0	0	110	224	3	4
	RW	NS	4	NS	0	NS	4	NS	40	NS	5	NS	1	-	54	-	5
	Abundance	**346**	**112**	**346**	**338**	**21**	**29**	**0**	**85**	**0**	**5**	**0**	**1**	**713**	**570**	**3**	**6**
														1,283			

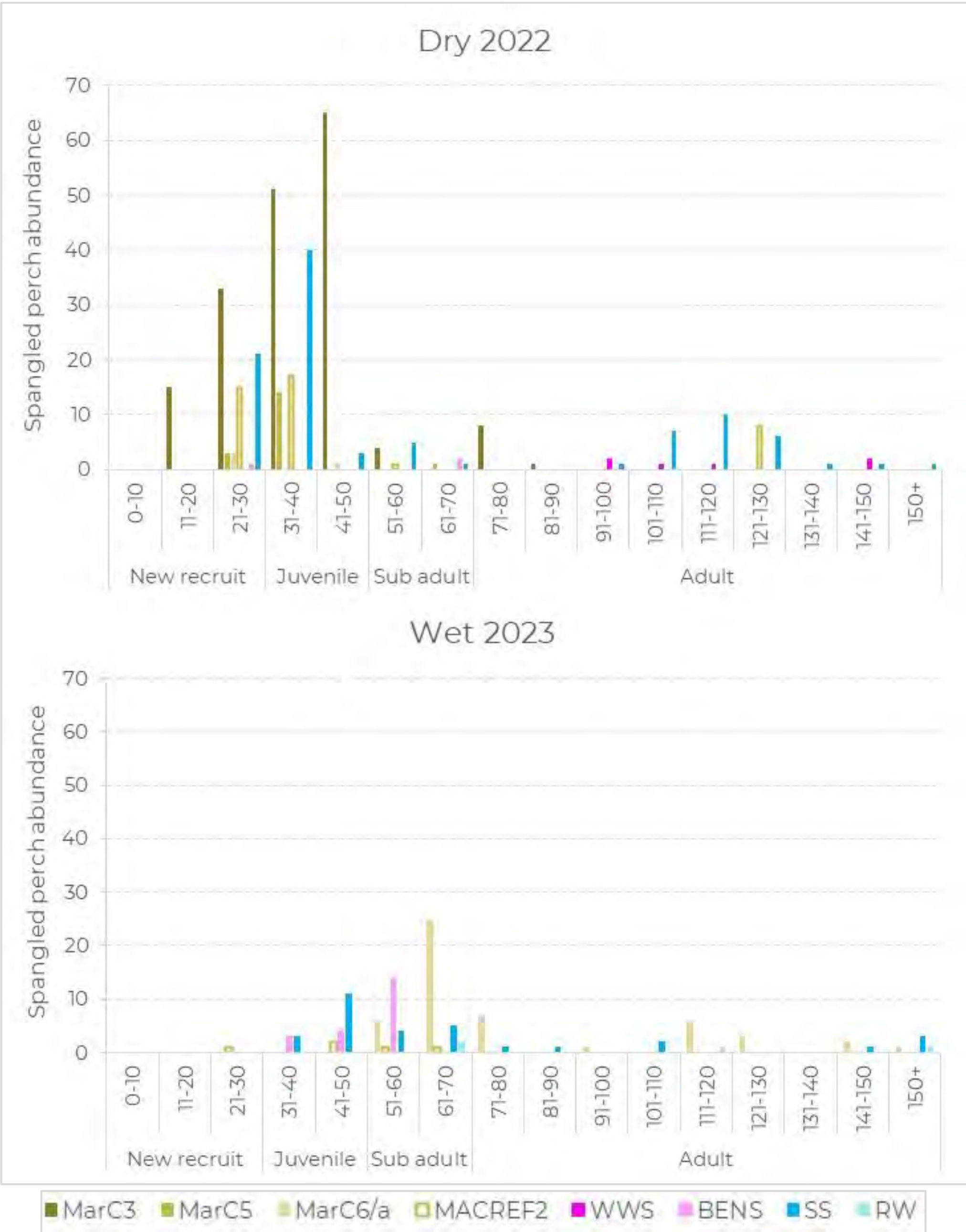

Figure 4.39: Length frequency analysis for spangled perch

4.8.4 Characterisation of Baseline Fish Populations

4.8.4.1 Richness

Two species of freshwater fish have been recorded from the Survey Area across all baseline sampling events, including spangled perch and Pilbara tandan. While spangled perch have been recorded from all sites on at least one occasion, Pilbara tandan were not recorded from MarC2 or MarC6. In addition, Pilbara tandan have not been recorded from the Survey Area since the Dry 2021 (Table 4.11).

Table 4.11: Total spangled perch and Pilbara tandan abundance recorded during the baseline

		Dry 2020		Wet 2021		Dry 2021		Wet 2022		Dry 2022		Wet 2023		Total - all events	
Site Type	**Fish species**	**n**	**Total**	**n**	**Total**	**n**	**Total**	**n**	**Total**	**n**	**Total**	**n**	**Total**	**n**	**Total**
Survey Area	Spangled perch	6	332	6	152	2	302	6	70	6	199	5	51	**31**	**1,106**
	Pilbara tandan	6	2	6	1	2	3	6	0	6	0	5	0	**31**	**6**
Reference	Spangled perch	5	118	5	263	5	190	5	129	5	147	5	61	**30**	**908**
	Pilbara tandan	5	12	5	83	5	30	5	60	5	21	5	29	**30**	**235**

n = number of sites sampled

4.8.4.2 Abundance

Spangled perch

Over all baseline sampling events, a total of 1,106 spangled perch have been recorded from the Survey Area, and 908 from Reference sites (Table 4.11). Within a sampling event, the greatest abundance of spangled perch was recorded from the Survey Area (332 individuals recorded in Dry 2020), as was the lowest abundance (51 individuals in the Wet 2023). A seasonal pattern was evident in spangled perch abundances, with lower numbers recorded in the wet season and greater in the dry (Table 4.11). In all dry season sampling events, spangled perch abundance was greater in the Survey Area compared to Reference sites, while the opposite was true in the wet.

Spangled perch abundance declined over time, in both the Survey Area and at Reference sites, although the linear trend was stronger in the Survey Area (r= 0.71, Reference r = 0.54; Figure 4.40). Total fish abundance (inclusive of all species) has only declined over time in the Survey Area (r = 0.65), while numbers at Reference sites have remained stable over the baseline period (r = 0.13; Figure 4.40).

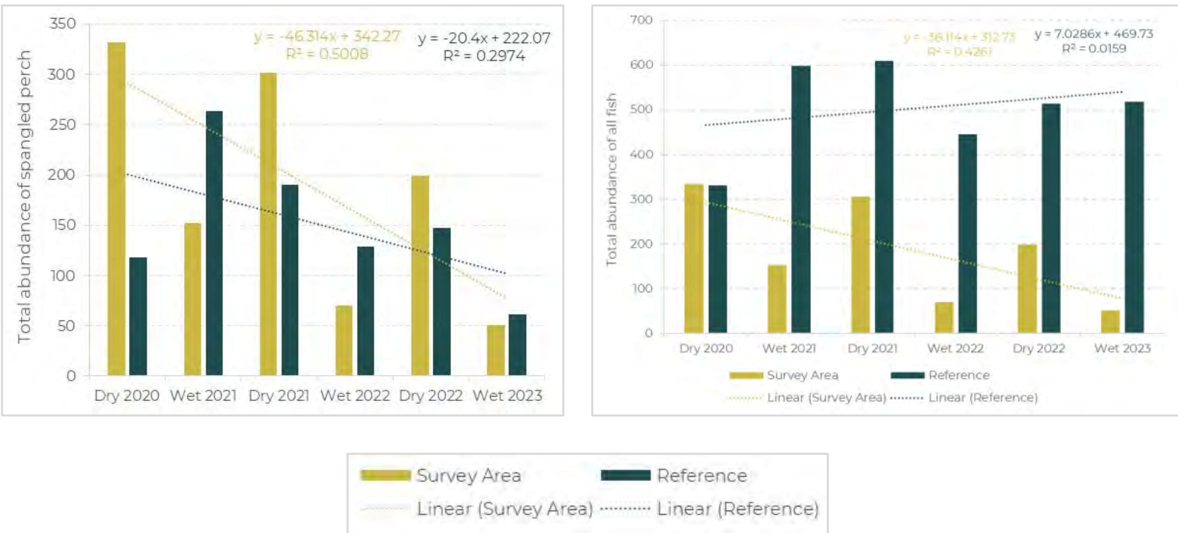

Figure 4.40: Total fish abundance of spangled perch only (left) and all fish (right) from the Survey Area and Reference sites in each sampling event

The variability in spangled perch abundance was high in both the Survey Area and at Reference sites (Figure 4.41). Median abundances were also similar between site types (Figure 4.41).

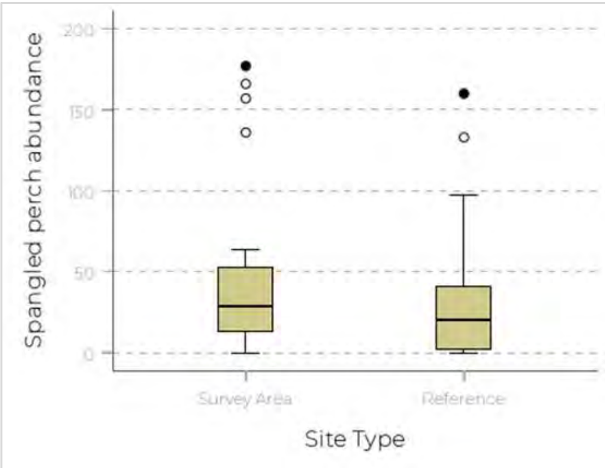

Figure 4.41: Box and whisker plot showing variation in spangled perch abundance across all sampling events

Where, the bottom of the box = 25th percentile, middle line = median, top of the box = 75th percentile, and the bottom and top whiskers represent the minimum and maximum richness, respectively.

The total abundance of spangled perch recorded was influenced by the number of sites sampled in each event. Taking this into account, the Survey Area recorded a slightly higher average number of spangled perch (36), compared to Reference sites (30; Figure 4.42). This difference, however, was not significant (Two-way ANOVA; df = 1, p = 0.128). There was, however a significant difference in spangled perch abundance between sampling events (df = 5, p = 0.013), with significantly lowest abundance recorded in the Wet 2023, and highest in the Dry 2021. There was also a significant interaction (df = 5, p = 0.044), suggesting that change in abundance over time was different in the Survey Area to that recorded from Reference sites. The baseline population of spangled perch in the Survey Area was dominated by juveniles, while at Reference sites, adults were more prevalent (Figure 4.42).

Pilbara tandan

Pilbara tandan abundance in the Survey Area was low, with a total of six individuals recorded across the entire baseline sampling period (Table 4.11). The maximum number recorded was three, from MarC3 in the Dry 2021. Most individuals were recorded during dry seasons surveys, with only one individual recorded in the wet, from MarC4 in Wet 2021. Comparatively, Reference sites recorded a high abundance of Pilbara tandan, with a total of 235 individuals recorded over the baseline (Table 4.11), and a maximum of 76 individuals recorded from one site (WWS in the Wet 2021). Given the low numbers from the Survey Area, variability over time was much greater at Reference sites (Figure 4.43).

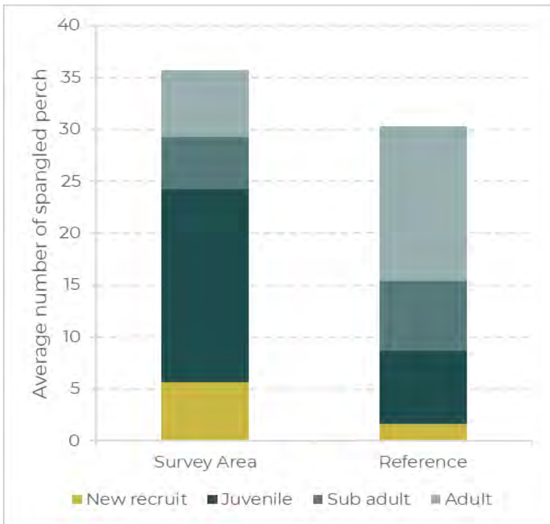

Figure 4.42: Average spangled perch abundance from the baseline for each age class

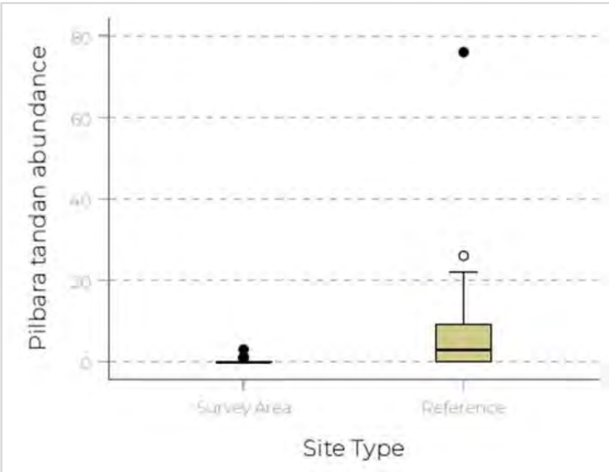

Figure 4.43: Box and whisker plot showing variation in Pilbara tandan abundance across all sampling events

Where, the bottom of the box = 25th percentile, middle line = median, top of the box = 75th percentile, and the bottom and top whiskers represent the minimum and maximum richness, respectively.

Allowing for differences in the number of sites successfully sampled, the average number of tandan recorded from the Survey Area was <1, while at Reference sites it was 8. This difference was significant (Two-way ANOVA; df =1, p = 0.011). The majority of individuals recorded from both the Survey Area and Reference sites were adults (Figure 4.44). While all size classes have been recorded from the Survey Area, no new recruits were recorded from Reference sites across the baseline sampling period (Figure 4.44). Overall, there was no significant difference in Pilbara tandan abundance between sampling events (df = 5, p = 0.649).

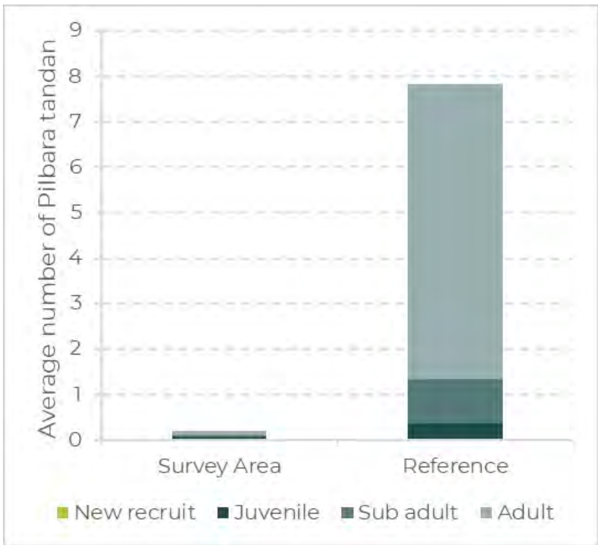

Figure 4.44. Average Pilbara tandan abundance from the baseline for each age class

All fish

Overall, a significantly greater abundance of fish was recorded from Reference sites than the Survey Area (Two-way ANOVA; df = 1, p = 0.004), but there was no significant difference between sampling events (df = 5, p = 0.187). Median abundance was notably higher at Reference sites, as was the variability in abundance recorded over the baseline sampling period (Figure 4.45).

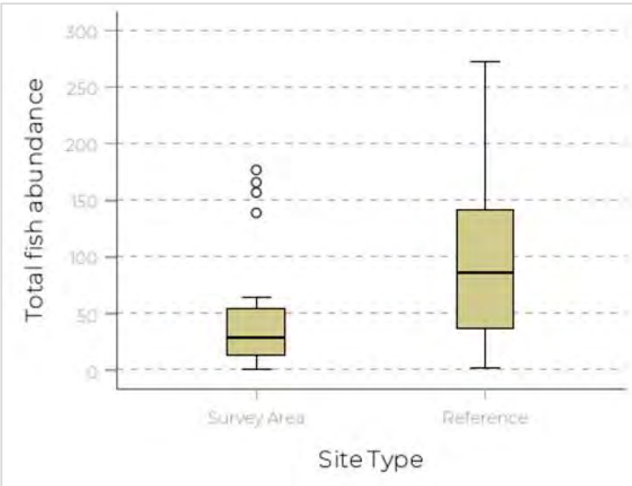

Figure 4.45: Box and whisker plot showing variation in total fish (all species) abundance across all sampling events

Where, the bottom of the box = 25th percentile, middle line = median, top of the box = 75th percentile, and the bottom and top whiskers represent the minimum and maximum richness, respectively.

4.9 Other Aquatic Fauna

4.9.1 Frogs

The desert tree frog (*Litoria rubella*; Plate 4.2) was commonly recorded in the current survey, with adults and tadpoles recorded from all Survey Area sites, except MarC1, and Reference site MACREF1. This species has also been recorded from the Survey Area previously. One additional species of frog was recorded during previous sampling, from MarC1 during the Wet 2022. The individual was not caught, and therefore identification was unable to be made. The Pilbara toadlet (*Uperoleia saxatilis*) and Main's frog (*Cyclorana mainii*) are both known from the area, and the unknown record likely represents one of these species.

Plate 4.2: The desert tree frog (*Litoria rubella*), common across the Survey Area

4.9.2 Other vertebrate fauna

No turtles or Pilbara olive python were recorded from the Survey Area during any of the baseline sampling events.

5 Discussion

5.1 Habitat Assessment

In the Dry 2022, all previously established sampling locations held water and were successfully sampled. However, in the Wet 2023, two Survey Area sites (MarC1 and MarC2) were dry. Prior to the Dry 2022 survey, the area received above average rainfall for September, while the Wet 2023 survey was preceded by below average rainfall for the wet season. Although the low rainfall prior to the Wet 2023 may explain the lack of water in the upstream pools, at least in part, this area was previously identified as a high-level GDE (Biologic, 2022b, 2023b), with vegetation indicating that perennial water is present just below the surface, if not above the surface. The dry conditions led to this GDV flora being in poor condition across the Survey Area by the time of the Wet 2023 survey, with much of the emergent macrophytes either dead or dying. Although the Survey Area is located upstream of current mining, and the current survey was undertaken to characterise baseline aquatic ecosystem conditions, several sites within the downstream end of the Survey Area may be currently experiencing some impact from drawdown. It has been suggested previously that MarC6, also known as Flat Rocks, was affected by dewatering from BHP WAIO Yandi operations (WRM, 2018). This does not explain the lowering surface water levels in the upper areas of the Survey Area, however, and the groundwater and surface water levels should be investigated.

The reduction in persistent surface water has led to a decline in aquatic habitat availability. In the Wet 2023, the absence or reduction in cover of submerged macrophytes, algae and roots was noted at many sites, for the first time since the commencement of baseline aquatic surveys. Emergent macrophyte also appears to be declining, which was evident in the numerous dead *Typha* stands throughout the Survey Area. This was drastically noticeable in the Dry 2021, due to the dry conditions of Marillana Creek at the time. Recovery of emergent macrophytes was recorded in the Wet 2022, but average cover has declined over the surveys since.

Further to this, submerged macrophyte cover has declined over time, from an average of 22.17% in the Dry 2020 to 0% in the Wet 2023 ($r = 0.77$). Macrophyte cover (submerged and emergent) was particularly low in the Dry 2021, partially recovering in 2022, before declining again in the Wet 2023, due to sites drying. This decline was also seen at Reference sites and is likely due to impacts at these sites, including algal blooms due to cattle access, and calcification of in-stream habitats.

5.2 Water Quality

Surface waters across the Survey Area were typical of Pilbara pools, ranging from fresh to brackish, with circum-neutral to slightly basic pH, low DO, and generally low concentrations of nutrients and dissolved metals. EC was highly variable across the Survey Area, reflecting the evapoconcentration of ions as pools receded. Pilbara waters are known to experience wide-ranging EC, with large temporal and seasonal variability due to flushing in the wet season and waters receding in the drier months. All Survey Area sites sampled in the Dry 2022 exceeded the ANZG (2018) DGV for EC, and although the DGV for EC is known to be conservative, and not necessarily applicable to Pilbara systems, some EC values were also greater than the transition to brackish waters (~1,500 µS/cm). EC above this threshold is known to result in a considerable shift in fauna assemblages (Hart *et al.*, 1991; Horrigan *et al.*, 2005). Across all baseline sampling events, the variability in EC (and alkalinity and ionic concentrations) was greater in the Survey Area, than at Reference sites. This likely reflects the receding water levels and drying within the Survey Area in some sampling events, which did not occur at Reference sites. Including all baseline data in the analysis, EC was significantly higher in the Survey Area than Reference sites, as was the concentration of major ions including Na, Mg, K, Cl, and S_SO_4.

DO concentrations within the Survey Area were low, with most sites recording DO below the lower ANZG (2018) DGV. Additionally, MarC5 (18.6%) and MarC4 (31.2%) recorded notably low DO in the Wet 2023, likely due to the low water levels present at the time of sampling. Although oxygen needs of aquatic biota differ between species and life history stage, Butler and Burrows (2007) reported acute toxicity between 25% and 30% for six tropical, northern Australian freshwater species. Low DO has been recorded from the Survey Area previously (Wet 2021 and Wet 2022). Incorporating all baseline data in the analysis, there was no significant difference in average DO between site types, but significantly lower DO was recorded in the Wet 2023, and highest DO in the Dry 2020.

pH in the Survey Area was circum-neutral to basic, and varied slightly across the Survey Area and between sampling events. The average pH recorded from the Survey Area was significantly higher than that recorded from Reference sites across the baseline sampling period.

Nutrient concentrations in the Survey Area were generally low and below toxicity DGVs. There were exceedances of eutrophication DGVs, however, including N_NOx, total N and total P, at both Survey Area and Reference sites. Eutrophication DGVs are 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 limiting factor for algal growth in freshwaters has been challenged as too simplistic (Beck & Hall, 2018; Elser *et al.*, 2007; Muhid & Burford, 2012), the fact that N_NOx, total N and total P concentrations were relatively high within the Survey Area currently suggests that any additional nutrient inputs (such as from cattle or inputs from groundwater discharge) would increase the risk of eutrophication. Nutrient concentrations were generally higher in the Wet 2023 than the Dry 2022.

Overall, there was relatively minor temporal variation in N_NO_3 and N_NOx concentrations across the baseline, in both the Survey Area and at Reference sites. In contrast, N_NH_3, total N and total P all recorded significant differences in average concentration between sampling events. Concentrations were comparable between site types for most nutrients, however, total N was significantly higher in the Survey Area.

Dissolved metal concentrations were low across both Survey Area and Reference sites, with the exception of some exceedances of ANZG (2018) toxicity DGVs, including:

- dB, which was elevated in comparison to the 99% toxicity DGV at most Survey Area and Reference sites, and the 95% toxicity DGV at MarC2, MarC3, MarC4 and MACREF2
- dAs, which exceeded the 99% toxicity DGV at MarC3 and MarC4, as well as Reference site MUNJS
- dAl, which exceeded the 99% DGV at MarC6 (Dry 2022), and the 95% DGV at MarC5, MarC6, MarC6A and MarC6B (Wet 2023)
- dCu, which exceeded the 95% DGV at MarC6 in the Dry 2022, and MarC3, MarC4, MarC5 and MarC6 in the Wet 2023.

It is important to note that concentrations of several dissolved metals were naturally significantly greater in the Survey Area than at Reference sites. Such metals included dAl, dAs, dB, dCo, dCu, dFe, dMo, dU, and dV.

Spot exceedances such as this are relatively common in Pilbara waterbodies, especially for dAl, dB, and dCu. Short-term, intermittent spikes in dissolved metal concentrations are unlikely to have adverse impacts on aquatic biota, in contrast to sustained and/or significantly increasing concentrations. (IV). It must be noted that these exceedances are based on spot measurements, and do not represent metal loads, or show ongoing trends. Although the values represent dissolved concentrations, this does not necessarily translate to labile concentrations and/or the portion that is bioavailable for aquatic biota. The bioavailability of metals depends on their speciation in the aquatic environment (Campbell, 1995). Metals can be present in various forms, including the hydrated free ion, inorganic complexes, organic complexes, colloids, or suspensions (Zhao *et al.*, 2016).

Analysis of baseline data indicated that water quality of the Survey Area was significantly different to Reference sites, with the Survey Area separating from Reference sites based on the higher EC, and concentrations of Ca, HCO_3, dB and dU recorded in comparison to Reference sites. Water quality of the Reference site MACREF2, located on Marillana Creek, was statistically similar to the Survey Area.

5.3 Macrophytes

The Survey Area is known to support several GDEs, including a high significance GDE extending across a 2.7 km section of Marillana Creek, that runs from upstream of the confluence with the tributary (and includes MACREF2) down to MarC4. This reach supports numerous GDV species, 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*, *E. victrix*, *Acacia ampliceps, Melaleuca bracteata*, *Ammannia baccifera* (where abundant) and *Vallisneria nana* were recorded from this area, as well as the moderate-level indicator species *Acacia coriacea* subsp. *pendens*, *Melaleuca glomerata*, *Cyperus vaginatus* (where abundant), *Echinochloa colona* (a weed species), *Schoenoplectus subulatus* and *Typha domingensis* (where abundant). (Rio Tinto, 2022). In places, the groundwater-dependent vegetation was dense. In addition to these GDVs, numerous submerged macrophytes were recorded from this reach of Marillana Creek during the baseline, including *Chara fibrosa*, *Chara globularis*, *Nitella* cf. *furcata*, *Vallisneria nana*, *Potamogeton tepperi* and *Najas tenuifolia*, all of which are considered to be moderate to high hydrophytic indicators.

Downstream of this significant GDE, a GDE of moderate significance (Biologic, 2022a) occurs over an approximate distance of 1.45 km. This section of Marillana Creek contained sparser stands of *M. argentea*, but still supported many other mesophytic species including *Eucalyptus camaldulensis*, *Melaleuca bracteata*, *Acacia ampliceps*, *Myoporum montanum*, *Vallisneria nana*, *Potamogeton tepperi* and *Diplachne fusca* subsp. *fusca*.

Large mature *M. argentea* were present at MarC5, near the lower extent of the GDE, but trees at MarC3 and MarC4 were dying in the Wet 2023.

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 which were found to occur included *Melaleuca argentea*, *Eucalyptus camaldulensis*, *Acacia ampliceps*, *Adriana tomentosa* var. *tomentosa*, *Melaleuca bracteata*, *Eleocharis geniculata* and *Diplachne fusca* subsp. *fusca*.

Across the Survey Area, 13 Moderate-High to Very High GDE indicator taxa were recorded, with an additional 16 lower-level indicator taxa. The number of indicator taxa was similar across the Survey Area, with most sites recording 9 taxa, though the abundance and maturity of very high-level indicator taxa such as *Melaleuca argentea* differed. In comparison, MACREF1 and MUNJS recorded a total of 12 GDE indicator taxa, both of which are also known GDEs. The flora and vegetation supports the notion that pools within the Survey Area were permanent, or at least highly persistent, given the high richness and density of mesophytic and hydrophytic indicator flora and macrophyte species. The recent drying of the creek since the Dry 2021 is therefore of concern.

The condition of various macrophytes and GDV taxa has declined over the course of the baseline period. During the current survey, all *Melaleuca argentea* had died at MarC3 and MarC4 (located within the high significant GDE). A decline in crown and foliage cover was also observed by Biologic's flora team during tree health monitoring between the Dry 2020 and Wet 2023, with cover significantly lower in 2023 compared to the Dry 2020 (Biologic, 2022d). This was particularly evident att tree-health monitoring Site 2 (located 194 m downstream of MarC2) and Site 1 (located 132 m upstream of MarC5). *Melaleuca argentea*, in particular, are highly susceptible to changes in groundwater level, especially declines occurring at a rapid rate. Detrimental impacts to the tree health of *Melaleuca argentea* trees can persist where the water table is up to 5.5 m from the surface and detrimental impacts to tree health have been recorded to occur with as little as a 0.5 m decrease in groundwater levels.

Additional species have also been lost, including moderate indicator species *Schoenoplectus subulatus* and *Typha domingensis* (when abundant), which had died at MarC1, and showed signs of senescence at MarC2, MarC5 and MarC6a. The macrophyte *Eleocharis geniculata* has also disappeared from MarC3, and the submerged macrophytes *Potamogeton tepperi* and *Najas tenuifolia* have not been recorded from the high significance GDE since the Wet 2022 and Wet 2021 respectively.

Macrophyte (submerged and emergent macrophyte) richness in the Survey Area was high, particularly at MarC4 and MarC6, although as discussed above, has shown declines over time. The significant flora species, *Ipomoea racemigera*, was recorded from the Survey Area for the first time during the current survey, at MarC6a and MarC6b. This species is listed by the DBCA as Priority 2 and known from only a small number of populations. Also of note was the record of the high GDE indicator *Myoporum montanum* in the present survey, which is sub-regionally rare (Biologic, 2022a).

Few weed species have been recorded from the Survey Area, with none recorded at MarC1 during the baseline.

5.4 Zooplankton

A total of 92 zooplankton taxa was recorded from the Survey Area, with 51 recorded from six sites in the Dry 2022 and 58 from six sites in Wet 2023. Greatest zooplankton taxa richness was recorded from the Survey Area in both seasons (MarC1 in the dry and MarC6a in the dry). At sites successfully sampled in both seasons, richness was generally higher in the dry season in comparison to the wet. Overall, zooplankton composition with the Survey Area was broadly similar to that reported for tropical and sub-tropical rivers elsewhere, being dominated by Branchionidae and Lecanidae rotifers and chydorid cladocerans (Dussart *et al.*, 1984; Phan *et al.*, 2021; Segers *et al.*, 2004; Tait & Shiel, 1984). All zooplankton taxa recorded from the Survey Area in the current survey were common, widespread species and known from across Australia or the broader Australasian region. None are listed as being of significance.

Across all baseline sampling events, a total of 127 zooplankton taxa have been recorded from the Survey Area. Notably low total zooplankton richness was recorded from the Survey Area in the Dry 2021. This was due to the dry conditions along Marillana Creek at the time, with only two sites holding water and able to be sampled for zooplankton. Overall, however, the Survey Area recorded significantly greater average zooplankton richness than Reference sites.

Zooplankton richness within the Survey Area was highly variable over time, with a high number of singleton taxa recorded and high species turnover between sampling events. This was also the case at Reference sites and is a common finding, as zooplankton are known to be patchily distributed, with notably high temporal variability (Klais *et al.*, 2016; Tait & Shiel, 1984; Zhang *et al.*, 2019).

This temporal variability was also evident within the zooplankton assemblages, with a significant difference between sampling events recorded, and a transition of assemblage change over time, with the earliest events separating more strongly from recent events. High temporal variability within zooplankton assemblages is well reported in the literature (Shiel *et al.*, 2006; Zhang *et al.*, 2019), with one study indicating that temporal variation over four sampling events across two years exceeded spatial variability across a 200 km stretch of an arid zone creek in Australia (Shiel *et al.*, 2006). Factors found to influence high temporal variation in zooplankton assemblages include season, flow events, disconnection during periods of no flow, predation and salinity (Shiel *et al.*, 2006).

Spatial variation was also recorded, with a significant difference in zooplankton assemblages between site types. Post-hoc analysis examining differences between creeks, found that assemblages of the Survey Area were statistically similar to the Reference site on Marillana Creek (MACREF2), as well as Yandicoogina and the Davis River, but significantly different to Weeli Wolli Creek and Munjina Spring assemblages.

5.5 Hyporheos Fauna

A total of 92 invertebrate taxa were recorded from hyporheic zones in the Survey Area, with 80 recorded from five sites in the Dry 2022 and 33 from five sites in the Wet 2023. Of all invertebrates recorded from Survey Area hyporheic zones, 12% are dependent on groundwater for their persistence (4% stygobite and 8% permanent hyporheos stygophiles). Another 8% are occasional hyporheos stygophiles, utilising the hyporheic zone opportunistically. The percentage of stygobitic fauna recorded from the Survey Area is comparable to that of other Pilbara springs, with a previous study indicating 5% of taxa from the hyporheic zone of springs were stygal (Halse *et al.*, 2002). The greatest richness of groundwater dependent taxa was recorded from MarC2 and MarC4 in the Dry 2022, and Reference site WWS in the Wet 2023. The high proportion of groundwater dependent taxa reflects the strong groundwater connection within this reach of Marillana Creek, despite the recent lowering surface water levels.

Hyporheos fauna of significance and/or scientific interest recorded from the Survey Area during the current survey included:

- Water mite *Rutacarus* \`sp. Biologic-ACAR007\` - recorded from the hyporheos at MarC4 and MarC5, with a current known linear range of 42.5 km
- Water mite *Rutacarus* \`sp. Biologic-ACAR022\` - recorded from the hyporheos at MarC4 and constitutes the first record of this OTU
- Harpacticoid nr *Phyllognathopus* \`sp. Biologic-HARP058\` - recorded from the hyporheos at MarC2 and constitutes the first record of this OTU

- Harpacticoid Canthocamptidae `sp. Biologic-HARP059` - recorded from the hyporheos at MarC2 and MarC4, with these two records being the only known records of this OTU (linear distribution of 1 km)
- Syncarid *Atopobathynella* `sp. Biologic-PBAT019`- recorded from MarC4 and MACREF2, Potential SRE, may be part of a species complex, and appears to have a disjunct distribution based on current knowledge and information.

Across all baseline sampling events, a total of 69 hyporheos fauna taxa (not including stygoxenes) have been recorded from hyporheic zones within the Survey Area, compared to a total of 76 taxa from Reference sites. While average richness has generally shown a decline over time at both Survey Area and Reference sites, this decline has been more pronounced in the Survey Area since the Wet 2021. Overall, hyporheos fauna taxa richness was significantly lower in the Wet 2023 than all other events.

The relatively high richness of hyporheos fauna in the Dry 2022, including groundwater dependent taxa at MarC2 and MarC4, indicates the presence of sub-surface flow in these areas. The hyporheic zone is an ecotone between the surface and groundwater, and provides a number of ecosystem services to both habitats, including mediating exchange processes, regulating water flows and transfer of nutrients, carbon, oxygen and nitrates, as well as the maintenance of biodiversity (Boulton, 2001; Dole-Olivier & Marmonier, 1992a; Edwards, 1998). Fauna utilising this habitat are also an ecotone between surface and groundwater, with representatives of both benthic epigean species and stygofauna. Benthic macroinvertebrates migrate vertically to exploit hyporheic habitats as a nursery to protect juveniles from predation (Bruno *et al.*, 2012; Jacobi & Cary, 1996), and during times of floods (Dole-Olivier & Marmonier, 1992b; Edwards, 1998; Palmer *et al.*, 1992), drought (Coe, 2001; Cooling & Boulton, 1993; Hose *et al.*, 2005), and disturbance in food supplies (Edwards, 1998). The hyporheic zone serves to enhance the resilience of the benthic community to disturbance and influence river recovery following perturbations. Hyporheos fauna have been used worldwide as an indicator of ecosystem health, with reported responses to disturbances such as metal pollution and eutrophication (Boulton, 2014; Leigh *et al.*, 2013; Moldovan *et al.*, 2013; Pacioglu & Moldovan, 2016).

5.6 Macroinvertebrates

A total of 191 macroinvertebrate taxa was recorded from surface waters across the Survey Area, with 151 recorded from six sites in the Dry 2022 and 115 from six sites in the Wet 2023. The composition of macroinvertebrates from Survey Area pools was dominated by slow flow and relatively tolerant taxa, and was broadly similar to other Pilbara waterbodies which are known to be primarily comprised of Diptera and Coleoptera (Pinder *et al.*, 2010). Taxa richness across the Survey Area was higher in the Dry 2022 compared to the following wet, while richness at Reference sites were more variable.

While most aquatic macroinvertebrates recorded from the Survey Area during the current survey were common, widespread species, three were of note and/or were of significance, including:

- The clam shrimp, *Limnadopsis pilbarensis*, - recorded from MarC4, MarC5 and MarC6 in the Wet 2023. This taxon is a Pilbara endemic, known from few records within temporary pools
- Pilbara billabongfly, *Austroagrion pindrina* – recorded from MarC2 and MarC4 in the Dry 2022. The species is listed as Vulnerable on the IUCN Red List of Threatened Species, and is generally known only from springs, permanent pools, or sites of high ecological condition
- Pilbara tiger *Ictinogomphus dobsoni* – recorded from MarC3 in the Dry 2022 and is currently listed on the IUCN Red List as Near Threatened (IUCN, 2023).

Macroinvertebrate taxa richness recorded from the Survey Area has generally been comparable to Reference sites over time, except in the Wet 2023, when notably lower richness was recorded from the Survey Area. Interestingly, macroinvertebrate richness in the Dry 2021 was comparable to Reference sites, despite only two surface pools in the Survey Area at the time. It is likely these remaining pools were acting as refuges for aquatic fauna at this time, when the creek was largely dry and biota would have been under stress. 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). Since the Dry 2021, the continued drying of the creek within the Survey Area has led to reductions in macroinvertebrate richness over time, with notably low richness recorded in the Wet 2023, despite six sites being successfully sampled at this time. The increase in time between inundation and reduced time of inundation appears to be affecting the fauna currently, with macroinvertebrates unable to recover between drying events. Hydrological processes, including the timing, frequency and extent of flows, and persistence of surface water are known to be important natural drivers for aquatic ecosystems in arid zones (Boulton, 1999; Walker *et al.*, 1995). In their study of over 100 Pilbara pools, Pinder *et al.* (2010) found that flow and hydrological persistence were two of the environmental variables most strongly correlated with macroinvertebrate assemblages and patterns of occurrence, along with turbidity, salinity, sediment and macrophytes, all of which are related to flows and pool persistence.

The continued drying of Marillana Creek within the Survey Area also appears to be affecting the more sensitive odonate fauna. A consistently high richness of odonates was recorded from the Survey Area previously, with as many as 14 taxa recorded from one site (Biologic, 2022b). In the current survey, 11 odonate taxa was recorded at MarC2 in the Dry 2022, and 10 from MarC4. During the PBS, only 15% of samples (98 sites, most of which were sampled on two occasions) recorded nine or more odonate species (Pinder *et al.*, 2010), suggesting the richness recorded from the Survey Area is high. However, in the Wet 2023, odonate richness reduced dramatically, with only two of the long-term established sampling sites recording a single odonate species, and odonates being entirely absent from the remaining two sites. 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 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). It is therefore likely that the high richness of odonates recorded from the Survey Area was due to the reasonably extensive riparian vegetation and high abundance and diversity of submerged and macrophytes, and the reduction in richness over time is due to the decline in condition of GDV taxa, and reduction in submerged macrophyte cover.

5.7 Rehydration Trials

While few rehydration studies are publicly available for Pilbara systems, and reported results are highly variable, the Survey Area recorded lower taxa richness than has been recorded from creeklines in the region previously (Table 5.1). Across the Pilbara, the highest richness recorded from an individual site was 17 taxa, from sediments collected from ephemeral sites near Paraburdoo, this was followed by 16 from ephemeral sites at Western Ridge (Table 5.1). In contrast, generally four taxa emerged from Survey Area sediments, with the greatest emergences being from MarC5 in the Dry 2021 (8 taxa), and an average of 5.7 taxa per trial.

The low richness of emergences recorded from Survey Area sediments is likely associated with the semi-permanent to permanent nature of the pools present, which are not likely to favour temporary wetland specialist taxa that produce desiccation-resistant eggs and resting stages. Aquatic fauna of more persistent pools, such as those which exist in the Survey Area, would not historically be adapted to seasonal drying. Strategies such as diapause or having dormant life history stages (typically eggs) are adaptations typically found in aquatic invertebrates which inhabit harsh or unstable environments, such as ephemeral creek pools (Radzikowski, 2013). Predictable and persistent drying in isolated temporary waterbodies exerts pressure on species which inhabit these environments to produce desiccation-tolerant and thermally resistant diapausing forms in order to survive (Radzikowski, 2013; Strachan *et al.*, 2015). Given it is an adaptive response, resistance abilities would differ between organisms inhabiting permanent aquatic habitats in comparison to temporary ones. The resistance of dormant forms originating from permanent habitats has been shown to be lower than that of their relatives from more variable, ephemeral habitats (Caprioli & Ricci, 2001; Radzikowski, 2013; Ricci, 1998).

Survival of invertebrates utilising one of the drought resisting strategies depends not only on the length of time between inundation events (Radzikowski, 2013; Stubbington *et al.*, 2016), but also the rate of initial pool drying (Strachan *et al.*, 2015). The highest rates of survival in the invertebrate egg bank following desiccation have been reported following slow drying, which allows sufficient time for individuals to adjust their metabolism and/or enact a strategy to survive the drought (Strachan *et al.*, 2015). This has implications for systems undergoing artificial drying due to groundwater drawdown from mining operations, with invertebrates potentially not able to respond quickly enough to pool drying, even in ephemeral systems.

Table 5.1: Taxa richness recorded during rehydration studies in the Pilbara

			Individual site richness	
Area	Study	No. of sites sampled	Min	Max
Paraburdoo	Biologic (unpub. data)	3	7	17
Western Ridge (2022)	Biologic (2023g)	9	9	16
Western Ridge (2023)	Biologic in prep.	15	2	14
Ministers North	Biologic (2023c)	4	5	11
MAC (Dry 2021)	Biologic (2023b)	5	4	8
MAC (Wet 2023)	This study	3	4	4 (22 from a Reference site

All richness values are excluding Rotifera species-level identifications to allow comparison to the current study.

5.8 Fish

Two species of freshwater fish were recorded from the Survey Area across all baseline sampling events; the spangled perch (*Leiopotherapon unicolor*) and the Pilbara tandan (*Neosilurus* sp.). Western rainbowfish (*Melanotaenia australis*) were not recorded from the

Survey Area, despite this species being present downstream, including in locations as close as 800 m from the Survey Area (WRM, 2015, 2018). This may be due to the reduced connectivity between the permanent pools within the Survey Area, with rainbowfish unable to make their way through the culvert system associated with the mine access road during flood events. Comparatively, spangled perch are able to move in minimal water depth, and are known to be hardy and tolerant of broad ranges in pH and salinity (Morgan *et al.*, 2014). Though the fish diversity appears low within the Survey Area, this is expected given the low diversity of fish across the Pilbara generally, likely due to the region's aridity (Allen *et al.*, 2002; Masini, 1988; Morgan *et al.*, 2014). Although the Pilbara tandan is endemic to the region, both it and the spangled perch are common and ubiquitous across the Pilbara. Neither are listed or are of significance. No introduced fish species were recorded within the Survey Area.

The distribution of spangled perch within the Survey Area has reduced over the course of the baseline sampling period. Spangled perch have not been recorded from MarC2 since the Dry 2020, or from MarC1 and MarC4 since the Wet 2021 (Table 5.2). The Dry 2021 survey occurred during a notable drying event. While the population persisted in additional pools sampled at that time (MarC3a and MarC6a), spangled perch have been lost from the upper reaches of Marillana Creek since the Dry 2021 and have not dispersed back into this area since. In the Wet 2023, spangled perch were only recorded from MarC6a, located downstream of MarC6. If conditions throughout the remainder of the Survey Area continue to experience prolonged dry periods, spangled perch may not be able to move upstream to recolonise the upper reaches.

Table 5.2: Presence/absence of spangled perch in the Survey Area across the baseline

Survey	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6
Dry 2020	✓	✓	✓	✓	✓	✓
Wet 2021	✓	X	✓	✓	✓	✓
Dry 2021						
Wet 2022	X	X	✓	X	✓	✓
Dry 2022	X	X	✓	X	✓	✓
Wet 2023			X	X	X	X

Grey shading indicates site was dry at the time of sampling

In addition to a reduction in range, spangled perch abundance in the Survey Area has declined over time. Although a negative linear correlation was also recorded from Reference sites, the trend was considerably stronger at Reference sites. Total fish abundances (including other species recorded) have also reduced over time, and in this case, the trend was not observed at Reference sites. Spangled perch abundance dropped from 332 individuals in the Dry 2020 to 51 individuals in the Wet 2023. The decline in abundance was evident at all Survey Area sites, with the exception of MarC3 in the Dry 2022, which recorded 177 individuals, the highest abundance recorded from a single site during the baseline. The population at this site was dominated by new recruits and juveniles, but with no fish persisting by the time of the Wet 2023 survey. This trend of greater abundances of juvenile in the dry season was evident throughout the baseline, demonstrating that where fish continue to occur, recruitment events were successful in the breeding season prior. However, there appears be poor survivorship to the wet season of the following year, likely due to the drying and contracting of aquatic habitat.

5.9 Other Aquatic Fauna

The presence of other aquatic vertebrate fauna within the Survey Area was low. Only one species, the desert tree frog (*Litoria rubella*), was confirmed. It was present in high abundance, and was common throughout the Survey Area. Listed vertebrate fauna were identified previously as potentially occurring within the Survey Area including the MNES Pilbara olive python and various migratory shorebirds (Biologic, 2022b). Given the dispersal capabilities of these animals, records of their presence are inherently sporadic. While they were not recorded during baseline surveys, their absence cannot be assumed.

6 Conclusion

6.1 Main Findings

Results from this and the previous sampling events for the MAC Phase 4 project provide an assessment of the baseline ecological values and health of aquatic systems in the Survey Area. To-date, bi-annual sampling has been undertaken over three consecutive years. A summary of the ecological values and condition of the Survey Area recorded over this baseline period is provided in Table 6.1. Within the extent of creek surveyed, Marillana Creek supports a series of pools which were characterised by generally brackish waters, with neutral-basic pH and low concentrations of nutrients and dissolved metals. The Survey Area supports a number of GDEs of varying level of significance, including:

- Marillana Creek – High significance GDE extending 1.2 km upstream of the confluence of the tributary and Marillana Creek downstream to MarC4 (encompassing MACREF2, MarC1, MarC2, MarC3 and MarC4).
- Marillana Creek – Lower significance GDE extending from just below MarC4 downstream 1.45 km to just below MarC5.
- Tributary – A small, isolated lower significance GDE extending approximately 250 m and encompassing sampling site MarC1.

These GDEs are showing signs of water stress, with drying of the creek impacting vegetation health and condition. In recent sampling events, several dead *Melaleuca argentea* trees have been noted, along with dying emergent macrophytes and a reduction in submerged macrophytes in-stream. Although other Reference sites also displayed low water levels or dry conditions in the Wet 2023, the effect on the Survey Area was more pronounced, indicating that perhaps there are some drawdown impacts influencing ground- and surface-water levels, especially in the lower end of the Survey Area.

Despite the drying conditions the Survey Area was found to support diverse flora and fauna assemblages, including 79 riparian flora taxa, 488 native aquatic invertebrate taxa (across zooplankton, hyporheic, rehydrate and macroinvertebrate lists), two freshwater fish species, and two frog species. Several high-level mesophytic indicators were recorded from the Survey Area, with riparian vegetation characterised by an open forest of *Eucalyptus camaldulensis*, with scattered mature *Melaleuca argentea* and other indicator taxa such as *Acacia ampliceps*, *Vallisneria* sp. and *Melaleuca bracteate*, along with a high richness of submerged and emergent macrophytes (Table 6.1). Overall, the Survey Area supported a significantly high zooplankton richness compared to Reference sites, as well as relatively high hyporheic and macroinvertebrate taxa richness. Odonate richness was notably high at some sites over most sampling events, except the Wet 2023.

Table 6.1: Summary of ecological values and condition of Marillana Creek recorded during the baseline

Habitat	Water Quality	Flora	Invertebrate Fauna	Vertebrate Fauna	Disturbances Noted
A series of pools, including at least one permanent pool. High in-stream habitat diversity comprising complex, heterogenous substrates with which to support aquatic fauna. Bedrock and clay more dominant downstream. Habitat diversity and condition has declined over time.	Generally brackish with neutral-basic pH and low concentrations of nutrients and dissolved metals. Higher variability in water quality within Survey Area compared to Reference sites, likely due to evapococentration effects of receding pools.	The high-level mesophytic indicators *Melaleuca argentea*, *Eucalyptus camaldulensis, Acacia ampliceps, Vallisnera* sp. and *Melaleuca bracteata* were present throughout the Survey Area. Other GDV taxa were present more sparsely throughout the Survey Area. High richness of submerged and emergent macrophytes. Macrophyte and GDV taxa have declined in richness and cover over time. Significant flora species *Ipomoea racemigera* (P2), present at MarC6a and MarC6b.	Zooplankton richness significantly higher than Reference sites, with strong seasonal and temporal variability. Relatively high hyporheic and macroinvertebrate fauna richness, comparable to Permanent Reference sites. 25 significant species recorded (listed, locally restricted or rarely collected species) including 7 stygal mites, 2 ostracods, 5 harpacticoids, 1 stygal amphipods, 2 syncarids, 1 clam shrimp, 2 troglobitic symphyla, 2 damselflies, 2 dragonflies and 1 aquatic beetle (see Table 6.2).	Supports two native species of fish, spangled perch and Pilbara tandan. Provides breeding grounds and nursery habitat for spangled perch. Pilbara tandan occur in low abundance, while spangled perch abundance has declined over time. Desert tree frog abundant and widespread throughout the Survey Area. One other species of frog and waterbird recorded, but species not identified.	Impacts from reduction in groundwater resulting in sites drying. Cattle impacts at some sites. Weeds present.

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Table 6.2: Significant taxa recorded from the Survey Arearecorded during the baseline, including species of scientific interest

Type	Species	Survey Area	Reference	Significance (includes locally restricted taxa and those known from few records)
Riparian flora	*Ipomoea racemigera*	MarC6a, MarC6b	SS	DBCA Priority 2
Stygal mites	*Aspidiobates pilbara*	MarC2, MarC3 (surface waters)		Pilbara endemic known only from springs and permanent pools in good ecological condition
	Guineaxonopsis `sp. Biologic-ACAR013`	MarC2 and MarC4 (hyporheos)		Currently known only from Marillana Creek and Yandicoogina Creek. Further work may find it to be more widespread.
	Guineaxonopsis sp.	MarC1, MarC2, (hyporheos), MarC4 (hyporheos and surface waters)		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-ACAR007`	MarC4, MarC5 (hyporheos)	BENS	Currently known only from Marillana Creek with a linear distance of 42.5 km.
	Rutacarus `sp. Biologic-ACAR022`	MarC4 (hyporheos)		This is the first record of this taxon.
	Rutacarus sp.	MarC2, MarC4, MarC5 (hyporheos)	BENS (hyporheos)	Species identification unknown, may be uncommon, with a disjunct or restricted distribution in the Pilbara
	Wandesia sp.	MarC1, MarC5 (hyporheos), MarC2 (surface waters)	MACREF2, WWS (hyporheos)	Species identification unknown, may be uncommon, with a disjunct or restricted distribution in the Pilbara
Ostracoda	*Gomphodella alexanderi*	MarC2 (hyporheos)		SRE known only from the hyporheos of Marillana Creek, Yandicoogina Creek, lower Weeli Wolli Creek, and groundwater bores at Yandi.
	Bennelongia `sp. Biologic-OSTR026`	MarC1 (surface water)		Known only from Marillana Creek and Gingianna Pool.

Type	Species	Survey Area	Reference	Significance (includes locally restricted taxa and those known from few records)
Harpacticoida	Canthocamptidae `sp. Biologic-HARP059	MarC2, MarC4 (hyporheos)		This is the first record of this taxon. Known linear distribution of 1 km.
	Elaphoidella sp.	MarC4 (hyporheos)	SS (hyporheos)	Undescribed and may be new to science
	Kinnecaris `sp. Biologic-HARP037`	MarC2 (hyporheos)		Currently known from only the Survey Area and Yandicoogina Creek.
	Parastenocaris sp.	MarC2, MarC5 (hyporheos)	SS (hyporheos)	Represents either a specimen new to science or additional records for known fauna
	nr *Phyllognathopus* `sp. Biologic-HARP058`	MarC2 (hyporheos)		This is the first record of this taxon.
Stygal amphipods	*Chydaekata* sp. MJ1-UM1	MarC4 (hyporheos)		Known to have a restricted range, recorded from upper Marillana Creek only
Syncarids	*Atopobathynella* `sp. Biologic-PBAT019`	MarC4 (hyporheos)	MACREF2 (hyporheos)	Previously recorded as *Atopobathynella* `sp. Biologic-PBAT042` and *Atopobathynella* `sp. Biologic-PBAT044`. Previously recorded from Turee Creek East sub catchment, the Weeli Wolli sub catchment and the Fortescue River catchment. Distribution is highly disjunct.
	Bathynellidae sp.	MarC2 (hyporheos)		Likely represents a new, undescribed species based on morphology
Clam shrimp	*Limnadopsis pilbarensis*	MarC4, MarC5, MarC6 (surface waters)		Pilbara endemic, relatively uncommon. Previously recorded from Burrup Rockhole, Beabea Creek, Ratty Spring (Pirraburdu Creek) and Glen Ross Creek.
Troglobitic symphyla	*Hanseniella* `sp. Biologic-SYMP055`	MarC4 (hyporheos)		Only known records of this taxon. Potential SRE.
	Hanseniella `sp. Biologic-SYMP069`	MarC6 (hyporheos)	MACREF2 (hyporheos)	Currently only known from Marillana Creek, with a linear distance of 3.7 km. Potential SRE.

Type	Species	Survey Area	Reference	Significance (includes locally restricted taxa and those known from few records)
Damselfly	*Austroagrion pindrina*	MarC2, MarC4 (surface waters)	MUNJS	Vulnerable, IUCN Red List.
	Eurysticta coolawanyah	MarC4, MarC5 (surface waters)	MACREF2, MACREF1, WWS, BENS, SS (surface waters)	Vulnerable, IUCN Red List
Dragonfly	*Hemicordulia koomina*	MarC1, MarC4, MarC5, MarC6 (surface waters)	BENS (surface waters)	Vulnerable, IUCN Red List
	Ictinogomphus dobsoni	MarC3 (surface waters)	MUNJS	Near Threatened, IUCN Red List
Beetle	*Haliplus fortescueensis*	MarC4 (surface waters)		Pilbara endemic with a restricted distribution

6.2 Final Remarks

Results from the baseline survey indicated that several water quality analytes naturally exceed ANZG (2018) DGVs within the Survey Area. To reduce the risk of compliance issues associated with changes to water quality from future developments, it is recommended that site-specific guideline values (SSGVs) be derived for major analytes such as pH, EC, DO and turbidity, as well as nutrients and dissolved metals. ANZG (2018) recommend that SSGVs should be based on at least two years of monthly monitoring data, or in the case of ephemeral systems such as those within the Survey Area, a minimum of 12 discrete sampling events from multiple sites/replicates.

Groundwater and surface water levels appear to be declining over time in the Survey Area, and the cause for the decline should be investigated further. The changes in surface water depths are not always seasonal like those that have occurred at Reference sites, and appear to indicate the influence of declining groundwater. Although some Reference sites also showed low water levels in the Wet 2023, the effects on vegetation and aquatic biota was not as pronounced. The fact that permanent pools completely dried in the Wet 2023 and negative impacts to GDVs are being observed is of concern.

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Appendix A: Default ANZG (2018) 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).

Aquatic Ecosystem	Analyte						
	TP	FRP	TN	NOx	NH_4^+	DO	pH
Units	mg/L	mg/L	mg/L	mg/L	mg/L	% saturation	
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). Exceptions are *Moderate Reliability* for freshwater Al (ph>6.5) and Mn.

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 [N_NH3] at pH 8. For changes in DV 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 B: Conservation 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 Attraction 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 C: Raw Habitat Data

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

Dry 2022

	Site	Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt	Clay
Survey Area	MarC1	4	1	4	39	42	2	8	0
	MarC2	0	0	4	34	45	12	5	0
	MarC3	60	8	4	6	11	5	5	1
	MarC4	4	0	9	20	37	10	8	12
	MarC5	0	0	3	37	43	10	5	2
	MarC6	11	4	12	4	18	11	10	30
Reference	MACREF2	87	0	0	0	3	5	0	5
	MACREF1	72	2	0	0	8	6	6	6
	WWS	5	1	9	30	28	18	9	0
	BENS	5	2	2	38	43	8	2	0
	MUNJS	83	0	1	3	2	1	4	6
	SS	1	2	8	30	37	18	3	1

Wet 2023

	Site	Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt	Clay
Survey Area	MarC1	Dry at the time of sampling							
	MarC2	Dry at the time of sampling							
	MarC3	70	0	4	5	6	12	2	1
	MarC4	6	0	6	11	20	29	8	20
	MarC5	3	2	8	30	44	10	2	1
	MarC6	9	5	6	10	20	13	7	30
	MarC6a	84	4	0	0	2	4	5	1
	MarC6b	60	1	0	5	11	12	10	1
Reference	MACREF2	90	0	0	1	3	2	1	3
	MACREF1	Dry at the time of sampling							
	WWS	5	1	9	30	28	18	9	0
	BENS	1	1	2	40	50	1	5	0
	MUNJS	95	2	0	0	0	0	3	0
	SS	1	2	8	29	34	20	5	1
	RW	3	9	12	20	26	20	5	5

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

Dry 2022

	Site	Inorganic seds.	Sub. mac.	Emerg. Mac.	Algae	LWD	Detritus	Roots	Trailing veg.
Survey Area	MarC1	34	4	40	7	3	2	2	8
	MarC2	51	1	22	8	3	3	8	4
	MarC3	29	3	11	51	2	1	2	1
	MarC4	77	3	7	2	2	7	1	1
	MarC5	36	8	18	15	5	6	9	3
	MarC6	47	16	1	0	6	25	3	2
Reference	MACREF2	6	8	22	53	3	5	2	1
	MACREF1	21	18	24	17	6	10	2	2
	WWS	77	0	2	1	3	5	10	2
	BENS	50	0	2	2	8	12	18	8
	MUNJS	65	6	11	9	4	2	2	1
	SS	18	6	4	45	5	8	12	2

Wet 2023

	Site	Inorganic seds.	Sub. mac.	Emerg. Mac.	Algae	LWD	Detritus	Roots	Trailing veg.
Survey Area	MarC1	Dry at the time of sampling							
	MarC2	Dry at the time of sampling							
	MarC3	87	0	8	0	1	3	0	1
	MarC4	82	0	5	0	1	11	0	1
	MarC5	73	0	15	0	3	5	2	2
	MarC6	80	0	1	0	4	12	2	1
	MarC6a	72	15	5	2	1	3	0	2
	MarC6b	82	3	10	0	1	3	0	1
Reference	MACREF2	9	10	18	33	2	25	2	1
	MACREF1	Dry at the time of sampling							
	WWS	86	0	1	1	3	5	3	1
	BENS	70	0	0	0	2	21	5	2
	MUNJS	71	4	1	20	3	1	0	0
	SS	28	7	4	43	5	6	5	2
	RW	59	2	1	8	6	8	15	1

Appendix D: Raw Water Quality Data

Dry 2022

Shading indicates values are in excess of: ■ > the 99% ANZG (2018) DGV, ■ > the 95% DGV, and ■ > the low reliability trigger

		ANZG (2018) Guideline		Survey Area						Reference					
Analyte	Units	99% DGV	95% DGV	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF1	MACREF2	WWS	BENS	MUNJS	SS
Temperature	°C			19	20.4	21	21.4	20.3	20.1	16	17.7	26.1	18.7	16.4	27.6
Conductivity (EC)	µS/cm		250	1463	2068	1964	2002	1843	297.3	704	1591	988	395	609	640
pH	pH units		6-8	7.24	7.72	7.89	7.96	8.12	8.39	6.92	8.03	7.64	7.76	8.03	8.30
Redox	mV			57	128.7	127.6	185.5	109.6	111	134.6	105.8	46.5	61.3	38.5	15.8
DO	%		85-120	37.3	45.4	90.7	67.8	105.6	116.4	58.3	94.5	47.2	27.4	75.2	112.0
Turbidity	NTU		15	2.7	0.4	0.6	0.2	1.4	3.6	0.7	0.2	0.2	0.4	0.6	1.4
TSS	mg/L			1	<1	3	<1	2	4	<1	<1	<1	<1	<1	6
Alkalinity	mg/L			244	498	467	460	311	88	240	423	366	200	159	246
Hardness	mg/L			379	746	665	662	692	96	262	605	364	196	196	223
Na	mg/L			63.6	170	168	175	133	23.7	72.6	146	43.3	8.2	65.9	39
Ca	mg/L			64.7	94.5	81.6	77.3	94.1	15.8	34.9	84.8	61.9	36.2	26.2	41.8
Mg	mg/L			52.8	124	112	114	111	13.8	42.4	95.6	50.8	25.7	31.8	28.8
K	mg/L			8.1	21.7	20.3	20.1	16.2	4.8	6.3	19.4	9.2	2.5	8.9	4.7
HCO_3	mg/L			244	498	467	460	311	88	240	423	366	200	159	235
Cl	mg/L			160	453	388	404	428	34	120	367	78	13	137	39
S_SO_4	mg/L			20.3	52.7	47.3	49.3	55	7.2	8.4	36	20.3	4.43	3.77	5.93
CO_3	mg/L			<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	11
S	mg/L			21.8	55.5	50.5	52.3	55.3	7.6	9.1	42.3	21	4.2	4.1	6.9
dAl	mg/L	0.027	0.055	<0.005	<0.005	<0.005	<0.005	<0.005	0.035	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
dAs	mg/L	0.001	0.024	0.0004	0.0006	0.0006	0.0009	0.0003	0.0005	0.0002	0.0004	0.0003	0.0003	<0.0002	0.0002
dB	mg/L	0.09	0.37	0.25	0.498	0.513	0.524	0.252	0.119	0.22	0.488	0.312	0.050	0.145	0.107
dBa	mg/L			0.0726	0.134	0.11	0.106	0.139	0.0273	0.0402	0.147	0.0115	0.0176	0.05	0.194
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			<0.0001	0.0003	<0.0001	<0.0001	0.0002	0.0001	0.0002	<0.0001	<0.0001	0.0002	<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	0.00037	0.00032	0.00036	0.00061	0.00031	0.00149	0.00021	0.00014	<0.00005	0.0006	0.00007	0.00014
dFe	mg/L	0.300*		0.01	0.015	0.014	0.008	0.019	0.033	0.187	0.018	<0.002	0.036	0.093	0.008
dMn	mg/L	1.2	1.9	<0.0005	0.0406	0.0067	0.0079	0.0405	0.0079	0.0259	0.0265	<0.0005	0.0933	0.0058	0.0643
dMo	mg/L			0.0002	0.0002	0.0003	0.0002	0.0002	0.0003	0.0002	0.0002	0.0001	0.0001	<0.0001	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
dSe	mg/L	0.005	0.011	<0.0002	<0.0002	0.0002	0.0003	<0.0002	0.0013	<0.0002	0.0004	<0.0002	<0.0002	<0.0002	0.0003
dU	mg/L			0.001	0.00387	0.00351	0.00388	0.00296	0.0005	0.00041	0.00191	0.00056	0.00021	<0.00005	0.0007
dV	mg/L			0.0035	0.0038	0.0061	0.0094	0.0031	0.0053	0.001	0.0023	0.0021	0.0018	0.0002	0.0018
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	0.03	0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.01	0.04	<0.01	0.02
N_NO_3	mg/L	1.00	2.40	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.02	<0.01	0.02	<0.01	<0.01	0.11
N_NOx	mg/L		0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.02	<0.01	0.02	<0.01	<0.01	0.11
Total N	mg/L		0.30	0.04	0.07	0.11	0.1	0.05	0.58	0.07	0.08	0.03	0.04	0.05	0.20
Total P	mg/L		0.010	<0.005	<0.005	<0.005	<0.005	<0.005	0.028	<0.005	<0.005	0.019	<0.005	<0.005	0.006

Wet 2023

Shading indicates values are in excess of: ■ > the 99% ANZG (2018) DGV, ■ > the 95% DGV, and ■ > the low reliability trigger

		ANZG (2018) Guideline		Survey Area						Reference					
Analyte	Units	99% DGV	95% DGV	MarC3	MarC4	MarC5	MarC6	MarC6a	MarC6b	MACREF2	WWS	BENS	MUNJS	SS	RW
Temperature	ºC			30.1	29.4	25.2	27.4	29.7	29	24.3	25.6	28.4	24.5	29.0	30.7
Conductivity (EC)	µS/cm		250	811	1595	340	147.7	184.5	185.5	1827	975	981	1482	642	1277
pH	pH units		6-8	7.56	7.57	7.54	7.53	7.67	7.44	7.64	7.25	7.64	8.71	7.66	7.16
Redox	mV			-16.8	39.9	-17.8	-5.2	-9.5	24.9	-62.7	-2.0	113.8	84.5	111.3	105.3
DO	%		85-120	44.6	31.2	18.6	50.1	85.6	65.3	48	55.2	47.4	65.8	53.3	45.3
Turbidity	NTU		15	2.8	1.5	11	21	11	9.8	4.3	<0.1	2	1.9	0.5	0.4
TSS	mg/L			2	2	5	10	3	3	35	<1	6	3	<1	<1
Alkalinity	mg/L			149	197	71	58	40	62	504	382	382	192	250	302
Hardness	mg/L			197	334	83	40	45	48	553	412	414	310	190	364
Na	mg/L			62.6	156	26.6	3.6	4.8	5.1	156	47.1	27.7	156	35.4	81.7
Ca	mg/L			28	40.3	13.6	9.4	11.6	12.1	66.6	62	62.5	23	32.7	56.1
Mg	mg/L			30.9	56.8	12	4	3.9	4.3	94	62.4	62.6	61.4	26.2	54.4
K	mg/L			12.2	17.4	6.7	3	2.9	3	21	8.4	5.5	22.6	4.6	9.9
HCO_3	mg/L			149	197	71	58	40	62	487	382	382	177	250	302
Cl	mg/L			94	295	41	4	8	8	271	94	60	386	37	139
S_SO_4	mg/L			21.7	41	8.23	1.4	2.64	2.83	34	21.7	14.2	4.07	5.33	31.1
CO_3	mg/L			<1	<1	<1	<1	<1	<1	16	<1	<1	15	<1	<1
S	mg/L			25.2	37.6	9.5	1.8	3.4	3.5	30.8	20.1	14.3	4.7	6	26.9
dAl	mg/L	0.027	0.055	0.025	<0.005	0.066	0.124	0.098	0.06	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
dAs	mg/L	0.001	0.024	0.0015	0.0016	0.0005	0.0004	0.0003	0.0003	0.0004	0.0004	0.0007	0.0012	0.0002	<0.0002
dB	mg/L	0.09	0.37	0.299	0.524	0.16	0.057	0.054	0.059	0.64	0.313	0.125	0.271	0.112	0.2
dBa	mg/L			0.0598	0.0802	0.034	0.021	0.0209	0.0237	0.15	0.0111	0.127	0.0753	0.146	0.0285
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			0.0009	0.0006	0.0008	0.0002	<0.0001	0.0001	<0.0001	0.0002	0.0006	0.0001	<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	0.0003
dCu	mg/L	0.001	0.0014	0.0019	0.00152	0.00145	0.00126	0.00064	0.00063	0.00022	0.0002	0.0004	0.00045	0.00022	0.00016
dFe	mg/L	0.300*		0.291	0.124	0.299	0.147	0.1	0.115	0.068	<0.002	0.052	0.039	0.006	0.004
dMn	mg/L	1.2	1.9	0.357	0.0783	0.222	0.0236	0.0051	0.0176	0.0131	<0.0005	0.58	0.0083	0.0338	0.0119
dMo	mg/L			0.0006	0.0006	0.0002	0.0002	<0.0001	<0.0001	0.0002	0.0002	0.0003	<0.0001	0.0002	0.0003
dNi	mg/L	0.008	0.011	0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0006	<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	0.0002	<0.0001	0.0002	<0.0001
dSe	mg/L	0.005	0.011	0.0005	0.0014	0.0003	0.0006	<0.0002	<0.0002	0.0006	<0.0002	<0.0002	<0.0002	0.0004	0.0018
dU	mg/L			0.00069	0.00064	0.00013	0.0001	0.00008	0.00008	0.00206	0.00064	0.00036	<0.00005	0.00051	0.00161
dV	mg/L			0.0086	0.0131	0.004	0.0036	0.0022	0.0019	0.0021	0.0027	0.0011	0.0002	0.0016	0.0018
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	0.02	0.12	0.02	<0.01	0.02	0.1	0.11	0.01	0.06	0.08	0.11	0.05
N_NO_3	mg/L	1.00	2.40	0.08	0.25	<0.01	0.08	0.03	0.11	0.01	0.04	0.01	<0.01	0.25	2.12
N_NOx	mg/L		0.01	0.08	0.34	<0.01	0.08	0.03	0.11	0.01	0.04	0.01	<0.01	0.25	2.12
Total N	mg/L		0.30	1.05	0.9	0.6	0.47	0.39	0.39	0.27	0.05	0.24	0.91	0.33	2.14
Total P	mg/L		0.010	0.051	0.052	0.035	0.021	0.019	0.02	0.064	0.019	0.028	0.026	0.016	0.016

Appendix E: Raw Flora Data

			Survey Area								Reference Sites						
Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6a**	**MarC6b**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**	**RW**
CHLOROPHYTA																	
CHAROPHYCEAE																	
Charales	**Characeae**	*Chara fibrosa*↓^	X	X		X	X					X				X	
		Chara globularis↓^			X										X		X
		Nitella cf. *furcata*↓^			X												
PLANTAE																	
EQUISETOPSIXA																	
Caryophyllales	**Amaranthaceae**	*Achyranthes aspera*													X		
MAGNOLIOPSIDA																	
Asterales	**Asteraceae**	**Bidens bipinnata*										X					
		**Erigeron bonariensis*		X								X					
		**Flaveria trinervia*				X											
		**Lactuca serriola*										X	X				
		Pluchea dentex^	X	X	X	X	X				X		X				
		Pluchea rubelliflora^		X	X	X	X	X	X	X	X	X	X	X			
		Pterocaulon sphacelatum					X					X					
		Rhodanthe margarethae													X		
		**Sonchus oleraceus*		X							X	X					
	Campanulaceae	*Lobelia arnhemiaca*^^										X	X				X
		Wahlenbergia tumidifructa^				X											
	Goodeniaceae	*Goodenia lamprosperma*	X		X	X	X										
	Stylidiaceae	*Stylidium fluminense*^^													X		
		Stylidium weeliwolli^^ (P3)												X			
Boraginales	**Boraginaceae**	*Euploca tenuifolia*	X		X												
		Trichodesma zeylanicum var. *zeylanicum*										X					
Brassicales	**Capparaceae**	*Capparis spinosa* subsp. *nummularia*				X				X							
	Cleomaceae	*Arivela viscoca*	X		X			X	X	X		X					
Caryophyllales	**Amaranthaceae**	*Achyranthes aspera*										X					
		Alternanthera denticulata										X					
		Amaranthus undulatus										X					
		Ptilotus exaltatus			X												
	Nyctaginaceae	*Boerhavia schomburgkiana*		X							X						

			Survey Area								Reference Sites						
Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6a**	**MarC6b**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**	**RW**
Ericales	**Primulaceae**	*Samolus* sp. Millstream (M.I.H. Brooker 2076)^^															X
Fabales	**Fabaceae**	*Acacia ampliceps*^^	X	X	X	X	X	X	X	X	X	X					X
		Acacia bivenosa											X		X		
		Acacia coriacea subsp. *pendens*^	X	X	X	X	X	X	X		X	X	X		X		X
		Acacia citrinoviridis											X				
		Acacia pyrifolia var. *pyrifolia*	X								X	X					
		Acacia trachycarpa															X
		Acacia tumida var. *pilbarensis*	X	X	X		X	X			X	X	X		X		X
		Crotalaria cunninghamii															X
		Crotalaria medicaginea var. *neglecta*	X	X	X						X	X		X			
		Glycine canescens									X		X				
		Isotropis iophyta										X					
		Petalostylis labicheoides	X	X			X			X	X	X	X	X			X
		Rhynchosia minima							X	X		X	X	X			
		Senna artemisioides subsp. × *artemisioides*					X	X		X							
		Sesbania cannabina^											X				
		Tephrosia rosea var. Fortescue creeks (M.I.H. Brooker 2186)	X	X	X		X	X		X	X						
		**Vachellia farnesiana*		X			X	X			X						
		Vigna lanceolata var. *lanceolata*^										X				X	X
	Surianaceae	*Stylobasium spathulatum*^										X					
Gentianales	**Apocynaceae**	*Cynanchum viminale subsp. australe*													X		
		Schenkia clementii^^															X
Lamiales	**Lamiaceae**	*Clerodendrum tomentosum*											X				
	Plantaginaceae	*Stemodia grossa*^	X	X	X	X	X	X	X	X		X	X	X	X		
		Stemodia viscosa^								X						X	
	Scrophulariaceae	*Myoporum montanum*^^					X					X					
Laurales	**Lauraceae**	*Cassytha capillaris*											X				
Malpighiales	**Euphorbiaceae**	*Adriana tomentosa* var. *tomentosa*^^	X														
		Euphorbia coghlanii	X		X			X			X						
		**Euphorbia hirta*											X				
		Euphorbia vaccaria var. *vaccaria*											X				
	Passifloraceae	**Passiflora foetida*															X

Class/Order	Family	Lowest taxon	Survey Area								Reference Sites						
			MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MarC6a	MarC6b	MACREF2	MACREF1	WWS	BENS	MUNJS	SS	RW
	Phyllanthaceae	*Nellica maderaspatensis*	X	X		X		X	X	X	X						X
		Notoleptopus decaisnei							X								
Malvales	**Malvaceae**	*Abutilon* sp. Dioicum (A.A. Mitchell PRP 1618)											X				
		Androcalva luteiflora									X		X				
		Corchorus crozophorifolius^	X	X	X	X	X	X			X		X			X	
		Corchorus incanus subsp. *lithophilus*															X
		Corchorus lasiocarpus subsp. *lasiocarpus*							X								
		Corchorus tridens								X							
		Gossypium robinsonii		X							X	X	X	X			X
		Gossypium sturtianum var. *sturtianum*^											X	X			
		Sida sp.									X						
Myrtales	**Lythraceae**	*Ammannia baccifera*^^		X	X			X				X				X	X
	Myrtaceae	*Eucalyptus* sp.							X								
		Eucalyptus camaldulensis^^	X	X	X	X	X	X			X	X	X	X	X		X
		Eucalyptus victrix^^			X						X		X				
		Melaleuca argentea^^	X	X	X(dead)	X(dead)	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	X	X	X					X
	Papaveraceae	**Argemone ochroleuca* subsp. *ochroleuca*														X	
Rosales	**Moraceae**	*Ficus* sp.													X		
		Ficus brachypoda										X					
Sapindales	**Sapindaceae**	*Atalaya hemiglauca*^					X	X			X		X		X		
		Dodonaea viscosa subsp. *mucronata*												X			
		Dodonaea lanceolata var. *lanceolata*^										X					
Solanales	**Convolvulaceae**	*Duperreya commixta*					X	X									
		Ipomoea plebeia												X			
		Ipomoea racemigera (P2)							X	X						X	
	Solanaceae	**Solanum nigrum*										X	X				
LILIOPSIDA																	
Alismatales	**Hydrocharitaceae**	*Najas marina*↓^^														X	
		Najas tenuifolia↓^^						X									
		Vallisneria sp.↓^^						X									

			Survey Area								Reference Sites						
Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6a**	**MarC6b**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**	**RW**
		Vallisneria annua↓^^													X	X	
		Vallisneria nana↓^^			X	X	X				X	X				X	
	Potamogetonaceae	*Potamogeton tepperi*↓^^					X	X	X		X					X	X
	Ruppiaceae	*Ruppia* sp.↓						X								X	
Poales	**Cyperaceae**	*Cladium procerum*Δ^^ (P2)											X				
		*Cyperus squarrosus*Δ^							X								
		*Cyperus vaginatus*Δ^	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		*Eleocharis geniculata*Δ^^	X								X	X	X			X	X
		?Fimbristylis sp. Δ														X	
		*Fimbristylis sieberiana*Δ^^ (P3)										X					X
		*Machaerina rubiginosa*Δ^^													X		
		*Schoenoplectus subulatus*Δ^	X		X	X					X	X	X		X	X	X
	Poaceae	*Aristida burbidgeae*													X		
		Aristida contorta							X								
		**Cenchrus ciliaris*		X													
		Chloris virgata														X	
		Chrysopogon fallax	X		X					X	X	X					
		Cymbopogon ambiguus											X		X		
		Cynodon convergens											X				
		**Cynodon dactylon*			X	X											X
		Diplachne fusca subsp. *fusca*^^	X				X		X								
		**Echinochloa colona*^				X	X	X	X	X							
		Enneapogon lindleyanus							X								
		Enteropogon ramosus^					X	X									
		Eragrostis tenellula	X						X	X		X					X
		Eriachne mucronata			X							X			X		X
		Eulalia aurea^	X		X		X		X	X	X	X					X
		Imperata cylindrica^^													X		
		Sorghum plumosum	X														
		Sorghum timorense											X				
		Themeda triandra	X	X		X			X		X	X	X		X		
		Triodia sp.			X			X	X	X							

			Survey Area								Reference Sites						
Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6a**	**MarC6b**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**	**RW**
	Typhaceae	*Typha domingensis*Δ^		X		X	X	X	X	X	X	X	X		X	X	
		Taxa richness	**30**	**26**	**29**	**22**	**29**	**28**	**25**	**22**	**34**	**45**	**36**	**13**	**23**	**19**	**28**

* Introduced species

(P2) DBCA Priority 2

(P3) DBCA Priority 3

^^ Very High to Moderate-High GDE indicator species

^ Associated with creeks and/or Moderate to Low GDE indicator species

↓ submerged macrophyte

Δ emergent macrophyte

Appendix F: Raw Zooplankton Data

Dry 2022

			Survey Area						Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
AMOEBOZOA														
Tubulinea														
Arcellinida		Testate Amoeba sp.	2	0	1	1	1	0	0	0	3	2	1	2
CILIOPHORA		Ciliate indet.	1	1	0	2	2	0	0	0	1	2	1	1
Prostomatea														
Prorodontida	**Colepidae**	*Coleps* sp.	2	0	0	0	0	0	0	0	0	0	0	0
Spirotrichea		Spirotrichea sp.	2	0	0	0	0	0	0	0	0	0	0	0
ROTIFERA		Rotifera sp.	2	0	1	1	1	0	2	0	2	2	0	1
Bdelloidea		Bdelloidea sp.	2	1	2	0	0	3	0	0	1	0	0	2
Monogononta														
Flosculariaceae	**Flosculariidae**	*Ptygura* sp.	0	0	0	0	2	0	0	0	0	0	0	0
Ploima	**Brachionidae**	*Keratella* sp.	1	0	0	1	0	0	0	0	0	0	0	0
		Keratella procurva	1	0	1	1	2	5	1	0	0	2	0	2
		Keratella quadrata	3	3	3	3	3	0	0	0	0	0	0	0
		Notholca squamula	0	0	0	0	0	0	0	0	0	0	0	1
	Dicranophoridae	*Dicranophorus* cf. *halbachi*	0	0	0	0	0	0	0	0	0	1	0	0
	Euchlanidae	*Euchlanis* sp.	0	0	0	0	0	0	0	0	0	0	0	2
	Lecanidae	*Lecane* sp.	1	1	0	1	1	0	1	0	2	0	0	0
		Lecane arcuata	2	0	0	1	0	0	1	0	0	2	0	1
		Lecane bulla	2	0	0	0	2	0	2	0	2	0	1	1
		Lecane hamata	1	0	0	0	0	0	0	0	0	0	0	0
		Lecane hastata	0	0	0	0	1	0	0	0	0	0	0	0
		Lecane cf. *luna*	0	0	0	0	0	0	0	0	0	1	0	0
		Lecane opias	2	0	2	0	0	0	0	0	0	0	0	0
		Lecane pyriformes	0	1	1	2	0	0	0	0	0	0	0	0
	Lepadellidae	*Colurella* sp.	1	1	1	0	0	0	0	0	2	0	0	1
		Colurella obtusa	0	0	0	0	1	0	0	0	0	0	0	0
		Colurella uncinata	2	0	0	0	0	0	2	0	2	0	0	2
		Lepadella sp.	0	0	2	0	0	3	0	0	0	0	0	0
		Lepadella benjamini	0	0	0	0	1	0	0	0	0	0	0	0
		Lepadella ovalis	0	0	0	0	0	0	0	0	0	0	0	2
		Lepadella patella	0	0	0	0	0	0	0	0	2	2	0	0
	Mytilinidae	*Mytilina* cf. *ventralis*	0	0	0	0	0	0	1	0	0	0	0	0
	Proalidae	*Proales* sp.	0	0	0	0	0	4	1	0	0	2	0	0
	Synchaetidae	*Polyarthra dolichoptera*	0	0	0	0	0	0	0	0	0	1	0	0
	Trichocercidae	*Trichocerca* sp.	0	0	0	0	0	0	0	0	0	0	1	0
		Trichocerca cf. *inermis*	0	0	0	0	0	0	0	0	0	0	1	0
		Trichocerca similis	0	0	0	0	0	5	0	0	0	1	2	0
	Trichotriidae	*Macrochaetus danneeli*	0	0	0	0	2	0	0	0	0	0	0	0

			Survey Area						Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
ARTHROPODA														
Branchiopoda														
Diplostraca	**Chydoridae**	*Alona* sp.	0	0	0	0	0	0	0	0	0	0	3	0
		Alona iheringi	0	0	2	2	0	0	0	0	0	0	0	0
		Chydorus sp.	0	0	0	0	0	0	0	0	0	0	0	1
		Dunhevedia crassa	0	0	0	0	0	0	0	0	3	0	0	0
		Leberis cf. *diaphanus*	0	0	0	0	0	0	0	0	2	0	0	0
	Daphniidae	*Simocephalus* sp.	0	0	0	2	1	3	0	0	0	0	0	0
	Moinidae	*Moina* sp.	0	0	0	0	0	0	0	0	0	0	1	0
	Sididae	*Latonopsis australis*	0	0	2	0	0	0	0	0	0	0	0	0
Ostracoda		Ostracoda sp. (imm./dam.)	1	0	0	0	0	0	0	0	0	0	0	0
Podocopida	**Candonidae**	*Candonopsis* cf. *tenuis* (`sp. Biologic-OSTR009`)	3	0	3	1	0	1	0	2	0	2	3	0
	Cyprididae	Cyprididae sp.	2	0	0	0	0	0	0	0	0	0	0	0
		Bennelongia strellyensis	0	0	0	0	0	0	0	0	0	0	4	0
		Candonocypris novaezelandiae	2	0	0	0	0	0	0	0	0	0	0	0
		Cypretta sp.	0	0	0	0	0	1	0	2	0	0	0	0
		Cypridopsis sp.	0	0	3	2	0	0	0	0	4	0	0	0
		Cypridopsis `sp. Biologic-OSTR011`	0	0	0	0	0	0	0	3	0	0	0	0
		Ilyodromus sp.	0	0	0	2	0	0	0	0	0	0	0	2
		Ilyodromus `sp. Biologic-OSTR014`	0	0	0	0	2	0	0	0	0	0	3	0
		Ilyodromus `sp. Biologic-OSTR036`	0	0	0	0	0	2	0	0	0	0	0	0
		Sarscypridopsis aculeata	0	0	2	0	0	0	0	0	0	0	0	0
		Stenocypris major	4	0	0	0	0	0	0	3	0	0	3	2
	Darwinulidae	*Darwinula* sp.	2	0	0	0	0	0	0	0	0	1	2	0
		Vestalenula marmonieri	0	0	0	0	0	0	0	0	0	0	3	1
	Ilyocypridae	*Ilyocypris australiensis*	2	0	0	0	0	0	0	0	0	0	0	0
	Limnocytheridae	*Limnocythere dorsosicula*	0	0	3	0	0	0	0	0	0	0	0	0
	Notodromadidae	*Newnhamia fenestrata*	0	0	0	0	0	0	0	0	0	0	3	0
Maxillopoda		Copepoda sp. indet	0	0	0	0	0	0	0	0	1	0	0	0
Cyclopoida	**Cyclopidae**	Cyclopoid copepodite	3	2	0	3	2	5	0	0	0	0	0	0
		Cyclopoid nauplii	2	0	2	2	3	5	1	0	0	0	0	0
		Apocyclops cf. *dengizicus*	3	2	0	1	1	0	0	0	0	0	0	0
		Ectocyclops phaleratus	0	0	1	0	0	0	0	0	1	0	0	0
		Eucyclops australiensis	0	0	0	0	2	0	0	0	3	0	0	2
		Mesocyclops darwini	0	2	0	2	0	0	0	2	0	0	3	2
		Mesocyclops notius	3	0	2	1	0	2	0	2	0	2	3	2
		Microcyclops varicans	3	2	2	2	2	2	0	0	2	1	3	2
		Paracyclops cf. *fimbriatus*	0	0	0	0	0	0	1	0	0	0	3	1
		Thermocyclops decipiens	0	0	0	0	0	0	0	0	0	0	0	2
		Tropocyclops prasinus	0	0	0	0	0	4	0	0	0	0	1	0
			28	**10**	**19**	**20**	**19**	**14**	**10**	**6**	**16**	**15**	**20**	**22**

Wet 2023

			Survey Area						Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC3	MarC4	MarC5	MarC6	MarC6a	MarC6b	MACREF2	WWS	BENS	MUNJS	SS	RW
AMOEBOZOA														
Tubulinea														
Arcellinida		Testate Amoeba sp.	2	2	2	2	3	2	2	0	0	1	0	0
		Sphaerothecina sp.	2	3	0	2	0	0	0	3	2	2	0	0
CILIOPHORA		Ciliate indet.	0	2	0	0	0	0	2	0	2	0	0	0
Litostomatea														
Pleurostomatida		Pleurostomatida sp.	2	3	1	0	0	0	0	0	0	0	0	0
Prostomatea		Prostomatea sp.	0	1	2	0	2	2	1	0	0	0	0	0
Spirotrichea		Spirotrichea sp.	1	0	0	0	0	0	1	0	0	0	0	0
		Oligotrichia sp.	3	4	3	0	0	0	0	0	2	1	2	1
ROTIFERA		Rotifera sp.	2	2	2	0	2	0	2	0	2	2	1	0
Bdelloidea		Bdelloidea sp.	1	1	0	0	0	0	2	0	2	1	3	0
Monogononta														
Flosculaidaceae	**Flosculariidae**	Flosculariidae sp.	1	2	0	1	0	0	0	0	0	1	1	0
		Sinantherina sp.	0	0	0	0	0	0	0	0	0	0	2	0
Ploima	**Asplanchnidae**	*Asplanchna cf. herricki*	0	0	0	1	0	0	0	0	0	0	0	0
	Dicranophoridae	Dicranophorus sp.	0	0	0	0	0	0	0	0	0	0	1	0
		Encentrum sp.	0	0	0	0	0	0	0	0	2	0	2	0
	Epiphanidae	*cf. Rhinoglena sp.*	0	0	0	0	0	0	0	0	1	0	0	0
		Epiphanes cf. cyrtonia	0	0	0	0	0	0	0	0	0	0	1	0
	Euchlanidae	*Euchlanis sp.*	0	0	0	0	0	1	0	0	0	0	0	0
		Euchclanis dilatata	0	0	0	0	2	0	1	0	0	0	0	0
		Euchlanis cf. meneta	0	0	0	0	1	0	0	0	0	0	0	0
	Notommatidae	Cephalodella sp.	0	2	0	0	0	0	0	0	0	0	0	0
		Monommata sp.	0	0	0	0	0	1	0	0	0	0	0	0
	Brachionidae	*Anuraeopsis sp.*	0	0	0	0	1	0	0	0	0	0	0	0
		Anuraeopsis cf. navicula	0	0	0	0	0	0	0	0	1	1	0	0
		Brachionus angularis	0	0	0	0	1	0	0	0	0	0	0	0
		Brachionus dichotomus	0	0	0	0	2	2	0	0	0	0	0	0
		Brachionus falcatus	0	0	0	0	2	3	0	0	0	0	0	0
		Brachionus cf. plicatilis	0	0	0	0	0	0	0	0	0	2	0	0
		Brachionus quadridentatus	0	0	0	0	2	2	0	0	0	0	0	0
		Keratella sp.	0	0	0	0	0	0	0	0	0	0	0	1
		Keratella procurva	0	0	0	2	3	3	0	0	0	0	2	0
		Notholca squamula	0	0	0	0	2	0	0	0	0	0	0	0
	Lecanidae	*Lecane* sp.	0	0	0	0	0	0	0	0	1	2	0	0
		Lecane arcuata	0	0	0	0	0	0	1	0	1	2	0	0
		Lecane bulla	0	0	0	0	2	0	0	0	0	2	2	0
		Lecane hastata	0	0	0	0	0	0	0	0	0	2	0	0
		Lecane papuana	0	0	0	0	0	0	0	0	2	0	0	0
		Lecane pyriformes	0	0	0	0	0	0	0	0	0	1	0	0

			Survey Area						Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC3	MarC4	MarC5	MarC6	MarC6a	MarC6b	MACREF2	WWS	BENS	MUNJS	SS	RW
	Lepadellidae	*Colurella* sp.	0	0	0	0	0	0	0	0	1	0	0	0
		Colurella uncinata	0	0	0	0	1	0	0	0	2	2	0	0
		Lepadella sp.	0	0	0	0	0	0	0	1	0	1	0	0
		Lepadella ovalis	0	0	0	0	0	0	3	0	0	0	0	0
		Lepadella patella	2	0	0	0	0	0	0	0	0	2	0	0
	Proalidae	*Proales* sp.	0	0	0	0	0	0	1	0	2	1	0	0
	Trochosphaeridae	Horaella brehmi	0	0	0	0	0	0	0	0	1	0	0	0
	Synchaetidae	*Polyarthra sp.*	0	0	0	0	0	0	0	0	0	1	0	0
		Polyarthra dolichoptera	0	0	0	2	2	0	0	0	3	0	0	0
		Ploesma cf. truncata	1	0	0	0	0	0	0	0	0	0	1	0
	Trichocercidae	*Trichocerca* sp.	0	0	0	0	0	0	0	0	1	0	0	0
		Trichocerca similis	0	0	0	1	0	0	0	0	0	0	0	0
	Trichotriidae	*Macrochaetus sp.*	0	0	0	0	0	1	0	0	0	0	0	0
ARTHROPODA														
Branchiopoda		Cladocera sp.	0	2	0	0	3	0	0	0	3	0	0	2
Diplostraca	Chydoridae	*Alona* sp.	0	0	0	0	2	3	0	0	0	0	0	2
		Alona rigidicaudis	0	0	0	0	3	0	0	0	0	3	0	0
		Chydorus sp.	0	0	0	0	0	2	0	0	0	0	0	0
		Dunhevedia crassa	0	0	0	0	0	0	0	3	0	0	0	0
		Ephemeroporus barroisi	0	0	0	0	0	1	0	0	0	0	0	0
		Leberis cf. *diaphanus*	0	0	0	0	0	0	0	3	0	0	0	0
	Daphniidae	*Ceriodaphnia* sp.	0	0	0	0	4	4	0	0	0	0	0	0
		Simocephalus sp.	0	0	2	2	0	0	0	0	3	3	0	0
	Ilyocryptidae	*Ilyocryptus* sp.	0	0	0	0	3	3	0	0	0	0	0	0
		Ilyocryptus spinifer	0	0	0	0	0	0	0	0	0	0	0	1
	Macrothricidae	*Macrothrix* sp.	0	0	0	0	0	2	0	0	0	0	0	0
	Moinidae	*Moina micrura*	0	4	3	4	3	0	0	0	0	0	0	0
Ostracoda		Ostracoda sp. (imm./dam.)	0	0	1	0	0	0	0	1	1	0	0	0
	Candonidae	*Candonopsis* sp.	0	0	2	0	0	0	0	0	0	0	0	0
		Candonopsis cf. *tenuis* (`sp. Biologic-OSTR009`)	3	2	3	4	2	2	0	0	0	0	2	0
		Candonopsis `sp. Biologic-OSTR044`	0	0	2	0	0	0	0	0	0	0	0	0
	Cyprididae	*Bennelongia strellyensis*	0	0	0	0	0	0	0	0	0	2	0	0
		Bennelongia tirigie	0	0	0	0	2	0	0	0	0	0	0	0
		Candonocypris novaezelandiae	0	0	1	0	0	0	0	0	0	0	0	0
		Cypretta sp.	0	0	0	1	3	0	0	0	0	0	0	3
		Cypretta `sp. Biologic-OSTR029`	0	0	0	0	0	0	0	3	0	0	3	3
		Cypricercinae sp.	0	0	0	0	3	0	0	0	0	0	0	0
		Cypridopsis `sp. Biologic-OSTR011`	0	0	0	0	0	0	0	0	0	3	0	0
		Ilyodromus sp.	0	0	0	0	0	0	0	0	0	3	0	0
		Riocypris cf. *fitzroyi*	0	1	0	0	0	0	0	0	0	0	3	2
		Stenocypris major	0	0	0	0	0	0	0	0	0	0	3	3
	Darwinulidae	*Darwinula* sp.	0	0	0	0	0	0	0	0	0	0	3	0

			Survey Area						Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC3	MarC4	MarC5	MarC6	MarC6a	MarC6b	MACREF2	WWS	BENS	MUNJS	SS	RW
		Vestalenula marmonieri	0	0	0	0	0	0	1	2	0	0	4	0
	Notodromadidae	*Newnhamia fenestrata*	0	0	0	0	0	0	0	0	0	5	0	0
Maxillopoda		Copepoda sp. indet	2	4	3	3	4	3	0	0	4	3	2	2
Cyclopoida	**Cyclopidae**	Cyclopoid copepodite	3	5	4	5	5	5	0	2	4	3	3	1
		Diacyclops cf. *sobeprolatus*	0	0	3	3	0	0	0	0	0	0	0	0
		Eucyclops australiensis	0	0	0	0	0	0	0	2	0	0	0	0
		Mesocyclops sp.	0	0	0	0	0	0	0	0	2	0	0	0
		Mesocyclops brooksi	0	0	0	0	0	0	0	0	3	0	0	0
		Mesocyclops darwini	0	0	0	0	0	0	0	0	0	0	4	4
		Mesocyclops notius	0	0	0	0	4	3	0	0	3	2	0	0
		Microcyclops varicans	2	4	3	3	4	3	0	3	4	0	4	4
		Paracyclops fimbriatus	0	0	0	0	0	0	0	2	0	0	0	0
		Pescecyclops sp.	0	0	0	2	0	0	0	0	0	0	0	0
		Pescecyclops arnaudi	0	3	0	0	0	0	0	0	0	0	0	0
		Thermocyclops sp.	0	0	2	0	0	0	0	0	4	0	0	0
		Thermocyclops decipiens	0	4	0	0	3	3	0	0	0	0	0	0
		Tropocyclops prasinus	0	0	0	0	0	0	0	0	3	3	0	0
			14	**19**	**17**	**16**	**30**	**21**	**11**	**11**	**28**	**28**	**21**	**13**

Appendix G: Raw Hyporheic Data

Dry 2022

			Survey Area					Reference			
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**WWS**	**BENS**	**MUNJS**	**SS**
ANNELIDA											
Oligochaeta											
Tubificida		Oligochaeta sp.	2	0	0	0	0	0	0	0	0
	Naididae	*Pristina aequiseta*	0	4	0	0	0	0	2	0	0
		Pristina leidyi	1	3	0	0	0	0	3	0	3
		Pristina longiseta	0	3	2	0	0	0	3	0	0
	Phreodrilidae	Phreodrilidae sp.	0	0	0	0	0	0	0	0	3
Polychaeta	**Aeolosomatidae**	Aeolosomatidae sp.	0	0	0	1	0	0	0	0	0
CNIDARIA											
Hydrozoa											
Anthoathecata	**Hydridae**	*Hydra* sp.	2	2	0	0	0	0	0	0	0
PLATYHELMINTHES		Turbellaria sp.	0	2	0	0	0	0	0	0	0
NEMATODA		Nematoda sp.	0	0	2	0	2	0	0	2	0
MOLLUSCA											
Gastropoda											
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	0	0	0	0	2	0	0	0	0
	Planorbidae	*Gyraulus* sp.	1	0	0	2	0	0	0	0	0
ARTHROPODA											
Arachnida		Acari sp.	0	0	3	0	0	0	0	0	0
		Trombidioidea sp.	0	2	1	0	0	1	0	0	0
Mesostigmata		Mesostigmata sp.	0	0	2	3	1	0	0	2	2
Sarcoptiformes		Oribatida sp.	0	1	0	0	0	0	0	0	0
Trombidiformes	**Anisitsiellidae**	*Rutacarus* sp.	1	2	0	0	0	0	0	0	0
		Rutacarus `sp. Biologic-ACAR007`	0	0	0	2	0	0	0	0	0
		Rutacarus `sp. Biologic-ACAR022`	0	0	1	0	0	0	0	0	0
	Hydryphantidae	*Wandesia* `sp. Biologic-ACAR008`	0	2	0	0	0	0	0	0	0
		Wandesia `sp. Biologic-ACAR009`	2	0	0	2	0	0	0	0	0
	Mideopsidae	*Guineaxonopsis* `sp. Biologic-ACAR011`	0	0	2	0	0	0	0	0	0
Ostracoda											
	Candonidae	*Candonopsis* cf. *tenuis* (`sp. Biologic-OSTR009`)	2	2	0	0	4	0	0	2	0
	Cyprididae	Cyprididae sp.	0	0	0	0	2	0	0	0	0
	Darwinulidae	*Vestalenula* sp.	0	0	0	0	2	0	0	0	0
Maxillopoda											
Cyclopoida	**Cyclopidae**	*Diacyclops* cf. *humphreysi*	0	0	0	0	0	0	1	0	0
		Ectocyclops phaleratus	2	2	0	0	0	0	0	0	0

			Survey Area					Reference			
Phylum/Class/Order	Family	Lowest taxon	MarC2	MarC3	MarC4	MarC5	MarC6	WWS	BENS	MUNJS	SS
		Mesocyclops darwini	0	0	2	0	0	0	0	0	0
		Mesocyclops notius	2	0	0	0	0	0	0	0	0
		Microcyclops varicans	3	4	3	3	4	0	2	2	2
		Paracyclops cf. *affinis*	0	0	0	0	0	0	1	0	0
Harpacticoida		nr *Phyllognathopus* `sp. Biologic-HARP058`	1	0	0	0	0	0	0	0	0
	Canthocamptidae	Canthocamptidae `sp. Biologic-HARP059`	2	0	0	0	0	0	0	0	0
		Elaphoidella sp.	0	0	2	0	0	0	0	0	0
Malacostraca											
Amphipoda	**Paramelitidae**	Paramelitidae `sp. Biologic-AMPH024`	0	0	0	0	0	1	0	0	0
		Chydaekata sp. E TLF-2008	0	0	0	0	0	0	3	0	0
Bathynellacea	**Parabathynellidae**	*Atopobathynella* `sp. Biologic-PBAT019`	0	0	3	0	0	0	0	0	0
Collembola											
Poduromorpha		Poduroidea sp.	0	0	2	0	0	0	0	0	1
Symphypleona		Symphypleona sp.	0	0	3	0	0	0	2	0	2
Entomobryomorpha		Entomobryoidea sp.	1	2	3	2	0	0	0	0	0
Insecta											
Coleoptera	**Carabidae**	Carabidae sp. (L)	0	0	0	0	2	0	0	0	0
		Carabidae sp.	0	0	0	0	0	0	0	0	1
	Dytiscidae	Bidessini sp. (L)	0	1	0	0	0	0	0	0	0
		Allodessus bistrigatus	2	0	0	0	0	0	0	0	0
		Hydroglyphus grammopterus	2	0	0	0	2	0	0	0	0
	Georissidae	*Georissus* sp.	0	0	0	0	0	1	0	0	0
	Hydraenidae	Hydraenidae sp. (L)	2	3	0	0	1	0	0	0	2
		Hydraena sp.	3	2	0	3	0	0	0	0	0
		Limnebius sp.	3	3	0	1	2	0	0	0	1
		Ochthebius sp.	3	0	0	0	1	0	0	0	0
	Hydrochidae	*Hydrochus interioris*	0	0	0	1	1	0	0	0	0
	Hydrophilidae	Hydrophilidae sp. (L)	3	3	2	2	0	1	2	0	3
		Agraphydrus coomani	0	1	0	0	0	0	0	0	0
		Anacaena horni	1	0	0	0	0	0	0	0	0
		Chaetarthria nigerrima (L)	0	0	0	0	0	0	0	0	3
		Helochares sp. (L)	2	1	0	1	0	0	0	0	1
		Laccobius sp. (L)	0	0	0	0	0	0	0	0	2
		Paracymus sp. (L)	0	0	0	0	1	0	0	0	0
		Paracymus spenceri	2	0	0	0	0	0	0	0	0
	Ptiliidae	Ptiliidae sp.	0	1	0	2	0	0	0	0	0
	Scirtidae	Scirtidae sp. (L)	3	4	0	2	0	0	2	0	0
		Scirtidae sp. (A)	0	0	0	0	0	0	0	0	2
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	1	0	0	0	0	0	0	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	2	2	2	2	4	0	0	0	0
		Ceratopogoninae sp.	3	3	3	1	2	2	2	2	3

			Survey Area					Reference			
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**WWS**	**BENS**	**MUNJS**	**SS**
		Dasyhelea sp.	2	3	0	0	0	0	0	0	0
		Forcipomyiinae sp.	3	1	0	0	0	0	0	0	0
	Chironomidae	Chironomidae sp. (P)	0	1	0	0	0	0	0	0	2
	Chironominae	*Cryptochironomus griseidorsum*	1	0	0	0	0	0	0	0	0
		Dicrotendipes sp. `CA1`	0	0	1	0	0	0	0	0	0
		Cladotanytarsus sp.	0	0	0	0	0	0	0	0	2
		Tanytarsus sp.	3	2	2	0	2	0	0	0	3
	Orthocladiinae	nr. *Gymnometriocnemus* sp.	2	0	0	0	0	0	0	3	1
	Tanypodinae	?*Australopelopia* sp.	1	0	0	0	0	0	1	0	0
		Larsia ?albiceps	2	0	0	2	0	0	2	0	2
		Paramerina sp. 1	2	0	0	0	0	0	0	0	1
		Paramerina sp. 2	3	0	0	3	0	0	2	0	2
		Procladius sp.	2	3	1	1	0	0	0	0	0
	Culicidae	*Anopheles* sp.	2	0	0	0	0	0	0	0	0
	Ephydridae	Ephydridae sp.	2	0	0	0	0	0	0	0	0
	Psychodidae	Psychodidae sp.	2	0	0	0	0	0	0	0	0
	Sciaridae	Sciaridae sp.	0	1	0	1	0	0	0	0	0
	Stratiomyidae	Stratiomyidae sp.	2	0	0	0	0	0	0	0	0
	Tipulidae	Tipulidae sp.	2	0	0	0	0	0	0	0	4
Ephemeroptera	**Baetidae**	Baetidae sp.	2	0	0	0	0	0	0	0	0
		Offadens G1 sp. WA2	0	0	0	0	0	1	0	0	0
	Caenidae	Caenidae sp.	3	0	0	0	0	0	0	0	2
		Tasmanocoenis sp. P/arcuata	1	0	0	0	0	0	0	0	0
Hemiptera	**Hebridae**	*Hebrus axillaris*	2	0	0	0	0	0	0	0	0
	Veliidae	Veliidae sp.	1	1	0	0	0	0	0	0	0
Odonata	**Libellulidae**	*Diplacodes haematodes*	1	0	0	0	0	0	0	0	0
Trichoptera	**Hydroptilidae**	*Orthotrichia* sp.	2	0	0	0	0	0	0	0	0
Symphyla											
Cephalostigmata	**Scutigerellidae**	*Hanseniella* `sp. Biologic-SYMP055`	0	0	2	0	0	0	0	0	0
		Taxa richness	**49**	**31**	**21**	**20**	**17**	**6**	**14**	**6**	**24**

Wet 2023

			Survey Area					Reference				
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6b**	**MACREF2**	**WWS**	**BENS**	**SS**	**RW**
ANNELIDA												
Oligochaeta												
Tubificida	**Enchytraeidae**	Enchytraeidae sp.	3	0	0	0	0	2	0	0	0	0
	Naididae	Naidinae sp.	0	0	0	0	1	0	0	0	0	3
		Dero sp.	0	0	0	0	0	0	0	3	0	3
		Dero nivea	0	0	0	0	0	0	0	2	0	3
		Pristina aequiseta	0	0	0	0	0	0	0	0	3	0
		Pristina leidyi	0	0	0	0	0	0	2	0	0	0
		Pristina longiseta	0	1	3	0	0	0	2	0	0	4
	Phreodrilidae	Phreodrilidae sp.	0	0	0	0	0	0	1	0	3	0
NEMATODA		Nematoda sp.	0	4	0	2	2	3	0	0	0	0
ARTHROPODA												
Arachnida		Acari sp.	0	0	0	1	2	2	2	2	0	0
		Trombidioidea sp.	0	0	0	0	1	0	0	0	0	0
Mesostigmata		Mesostigmata sp.	1	4	0	0	1	2	0	2	0	0
Sarcoptiformes		Oribatida sp.	0	4	2	0	0	1	0	0	3	1
Trombidiformes	**Anisitsiellidae**	*Rutacarus* `sp. Biologic-ACAR005`	0	0	0	0	0	0	1	0	0	0
	Halacaridae	Halacaridae sp.	0	0	0	0	0	0	2	0	2	0
	Pezidae	Pezidae sp.	1	3	0	0	0	0	0	0	0	0
	Unionicolidae	Unionicolidae sp.	0	3	2	0	0	0	0	0	0	2
Branchiopoda												
Diplostraca	**Chydoridae**	*Alona rigidicaudis*	0	0	0	0	0	0	0	0	0	1
	Ilyocryptidae	*Ilyocryptus spinifer*	0	0	0	0	0	0	0	0	0	1
Ostracoda												
Podocopida	**Candonidae**	*Candonopsis* cf. tenuis (`sp. Biologic-OSTR009`)	0	0	3	3	0	0	0	2	0	0
		Notacandona boultoni	0	0	0	0	0	0	3	0	0	0
		Notacandona modesta	0	0	0	0	0	0	2	0	0	0
	Cyprididae	*Cypretta* sp.	0	0	0	0	0	0	3	0	0	0
		Cypretta `sp. Biologic-OSTR029`	0	0	0	0	0	0	0	0	0	3
		Cyprinotus cingalensis	0	0	0	0	0	0	0	0	0	2
		Stenocypris major	0	0	0	0	0	0	0	0	2	3
	Darwinulidae	*Penthesilenula brasiliensis*	0	2	0	0	0	0	0	0	0	0
		Vestalenula marmonieri	0	2	0	0	0	0	0	0	3	0
	Limnocytheridae	*Limnocythere* cf. *porphyretica*	0	0	0	0	0	0	0	0	0	4
Maxillopoda												
Calanoida		Calanoida sp.	0	2	0	0	0	0	0	0	0	0
Cyclopoida	**Cyclopidae**	*Ectocyclops phaleratus*	0	0	0	0	0	0	2	3	0	0

			Survey Area					Reference				
Phylum/Class/Order	Family	Lowest taxon	MarC3	MarC4	MarC5	MarC6	MarC6b	MACREF2	WWS	BENS	SS	RW
		Microcyclops varicans	0	4	3	3	2	0	2	3	0	2
		Paracyclops fimbriatus	0	0	0	0	0	0	0	0	1	0
Harpacticoida	**Canthocamptidae**	Canthocamptidae `sp. Biologic-HARP059`	0	4	0	0	0	0	0	0	0	0
	Parastenocarididae	*Parastenocaris* `sp. Biologic-HARP022`	0	0	0	0	0	1	0	0	0	0
Malacostraca												
Amphipoda	**Paramelitidae**	Paramelitidae `sp. Biologic-AMPH045`	0	0	0	0	0	0	2	0	0	0
Bathynellacea	**Parabathynellidae**	*Atopobathynella* `sp. Biologic-PBAT019`	0	0	0	0	0	2	0	0	0	0
Collembola												
Entomobryomorpha		Entomobryoidea sp.	2	4	3	2	2	2	2	2	0	0
Symphypleona		Symphypleona sp.	0	4	2	0	1	0	0	0	0	0
Insecta												
Coleoptera	**Carabidae**	Carabidae sp. (L)	0	0	0	0	0	0	1	0	0	0
	Dytiscidae	Bidessini sp. (L)	0	0	3	2	0	0	0	0	0	2
		Hydroglyphus grammopterus	0	0	0	0	0	0	0	2	0	1
		Hydroglyphus orthogrammus	0	0	0	0	0	0	0	1	0	0
		Limbodessus compactus	0	0	0	0	0	0	0	0	0	1
	Elmidae	*Austrolimnius* sp. (L)	0	0	0	0	0	0	0	0	2	0
	Georissidae	*Georissus* sp.	0	0	0	0	0	0	0	1	0	0
	Hydraenidae	Hydraenidae sp. (L)	0	0	0	0	1	0	0	0	0	0
		Hydraena sp.	0	0	0	0	0	1	0	3	0	0
		Limnebius sp.	0	0	2	0	0	0	0	0	0	2
		Ochthebius sp.	0	0	0	0	0	1	0	0	0	0
	Hydrochidae	*Hydrochus* sp. (L)	0	0	0	0	0	0	0	0	0	2
	Hydrophilidae	Hydrophilidae sp. (L)	0	0	0	0	0	0	2	2	0	0
		Agraphydrus coomani	0	0	0	0	0	0	0	1	0	0
		Anacaena horni	0	0	0	0	0	0	0	1	0	0
		Berosus sp. (L)	0	0	0	0	0	0	0	0	0	1
		Chaetarthria nigerrima (L)	0	0	0	0	0	0	1	0	0	0
		Enochrus sp. (L)	0	0	0	1	0	0	0	0	0	0
		Helochares sp. (L)	0	0	0	0	0	0	0	1	0	0
		Helochares tatei	0	0	0	0	0	0	0	2	0	0
		nr. *Anacaena* sp.	0	0	0	0	0	1	0	0	0	0
		Sternolophus sp. (L)	0	0	0	0	0	0	0	1	0	0
	Scirtidae	Scirtidae sp. (L)	0	0	0	0	1	0	1	3	2	0
Diptera		Diptera sp. (L)	0	0	0	0	0	2	0	0	0	0
	Cecidomyiidae	Cecidomyiidae sp.	0	0	0	0	0	2	0	0	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	0	0	0	0	1	0	0	2	0	1
		Ceratopogoninae sp.	0	2	2	1	1	2	2	3	3	4
		Dasyhelea sp.	0	0	2	0	0	2	2	0	0	0
	Chironomidae	Chironomidae sp. (P)	0	0	0	0	0	0	0	1	0	0
	Chironominae	*Cladotanytarsus* sp.	0	0	0	0	0	0	0	0	0	3

			Survey Area					Reference				
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6b**	**MACREF2**	**WWS**	**BENS**	**SS**	**RW**
		Paratanytarsus sp.	0	0	0	0	0	0	0	0	0	4
		Cryptochironomus griseidorsum	0	0	0	0	0	0	0	0	1	0
		Dicrotendipes sp. `CA1`	0	1	0	0	0	2	0	2	0	3
		Polypedilum (*Pentapedilum*) *leei*	0	0	0	0	0	1	0	0	0	3
		Skusella sp.	0	0	0	0	0	0	0	0	1	0
	Orthocladiinae	Orthocladiinae sp. BES12662	0	0	0	0	0	0	0	1	0	0
	Tanytarsus	*Tanytarsus* sp.	0	0	3	0	2	0	0	3	0	4
		Larsia ?albiceps	0	0	0	0	0	0	0	0	2	2
		Paramerina sp. 1	0	0	0	0	0	0	0	0	2	0
		Paramerina sp. 2	0	0	0	0	0	0	0	3	0	0
		Procladius sp.	0	0	0	2	0	0	0	0	0	2
	Ephydridae	Ephydridae sp.	0	0	0	0	0	0	0	2	0	0
	Muscidae	Muscidae sp.	0	0	0	0	0	2	0	0	0	0
	Tabanidae	Tabanidae sp.	0	0	0	0	0	0	0	0	0	1
	Tipulidae	Tipulidae sp.	0	0	0	0	2	0	1	2	0	0
Ephemeroptera	**Baetidae**	Baetidae sp.	0	0	0	0	0	0	0	1	0	0
	Caenidae	Caenidae sp.	0	0	0	0	0	0	0	2	1	0
Odonata		Anisoptera sp.	1	0	0	0	0	0	0	0	0	1
Trichoptera	**Leptoceridae**	*Oecetis* sp.	0	0	0	0	0	0	0	0	0	1
Symphyla												
Cephalostigmata	**Scutigerellidae**	*Hanseniella* `sp. Biologic-SYMP069`	0	0	0	2	0	1	0	0	0	0
		Taxa richness	**5**	**15**	**12**	**10**	**14**	**19**	**20**	**30**	**15**	**31**

Appendix H: Raw Macroinvertebrate Data

Dry 2022

Phylum/Class/Order	Family	Lowest taxon	Survey Area						Reference					
			MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
ANNELIDA														
Oligochaeta														
Tubificida	**Naididae**	Naidinae sp.	0	0	0	0	0	0	0	0	0	0	3	0
		Allonais paraguayensis	0	0	0	0	0	0	0	0	3	0	0	0
		Allonais pectinata	0	3	1	1	0	0	1	0	3	0	3	2
		Dero sp.	0	0	0	0	0	0	0	0	0	2	0	0
		Dero nivea	0	0	0	0	0	0	0	0	3	2	0	0
		Nais variabilis	0	0	0	0	2	0	0	0	0	0	0	0
		Pristina aequiseta	2	2	0	0	0	0	0	0	0	0	4	0
		Pristina leidyi	0	4	3	3	2	0	2	3	3	1	3	2
		Pristina longiseta	3	3	2	0	0	1	0	0	3	2	0	2
		Pristina nr. *osborni*	0	0	0	0	0	0	0	2	0	0	0	0
	Phreodrilidae	Phreodrilidae sp.	0	0	0	0	0	0	0	0	0	0	0	2
CNIDARIA														
Hydrozoa														
Anthoathecata	**Hydridae**	*Hydra* sp.	0	0	2	0	1	0	2	0	0	0	0	0
PLATYHELMINTHES		Turbellaria sp.	0	0	2	2	0	0	0	0	0	0	1	0
NEMATODA		Nematoda sp.	0	0	0	3	0	2	0	0	0	0	0	0
MOLLUSCA														
Gastropoda														
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	5	3	3	5	4	4	3	3	0	0	2	3
	Planorbidae	*Ferrissia petterdi*	0	0	0	0	3	0	1	2	4	2	0	2
		Gyraulus sp.	5	3	3	5	4	3	2	3	0	2	4	2
ARTHROPODA														
Arachnida														
		Acari sp.	1	1	2	2	3	3	0	3	0	2	2	2
Mesostigmata		Mesostigmata sp.	2	0	0	0	0	0	0	0	2	1	2	0
Sarcoptiformes		Oribatida sp.	0	2	2	1	0	0	2	0	4	0	0	0
Trombidiformes		Trombidioidea sp.	1	0	0	2	0	2	0	0	0	2	0	0
	Arrenuridae	*Arrenurus* sp.	1	0	0	0	0	3	0	0	0	0	0	0
		Arrenurus (*Arrenurus*) sp.	1	0	0	0	3	0	0	0	0	0	0	0
		Arrenurus (*Megaluracarus*) sp.	0	0	1	0	0	0	0	0	0	0	0	0
	Aturidae	*Albia* sp.	0	1	0	1	0	0	0	0	0	0	0	0
	Hydrodromidae	*Hydrodroma* sp.	0	0	1	0	0	0	1	0	0	0	0	0
	Hygrobatidae	*Australiobates* sp.	0	0	0	0	0	0	0	0	2	0	0	0
		Coaustraliobates minor	0	1	2	0	3	3	1	1	0	0	0	0
		Procorticacarus sp.	0	0	0	0	0	0	0	0	0	0	0	1

			Survey Area						Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
	Limnesiidae	*Limnesia parasolida*	0	0	0	0	0	3	0	0	0	2	2	2
		Limnesia sp. `solida group`	0	3	2	2	4	4	3	2	0	0	3	2
	Limnocharidae	*Limnochares* sp.	0	0	0	1	0	2	0	0	0	0	0	0
	Oxidae	*Oxus* sp.	0	0	0	0	3	0	0	0	0	0	0	0
		Oxus spinosa	0	0	0	0	0	0	0	0	0	0	0	1
	Pionidae	*Piona* nr. *australica*	0	0	0	0	0	2	0	0	0	0	0	0
	Unionicolidae	*Neumania* sp.	0	0	0	1	0	0	0	0	0	0	0	2
		Recifella sp.	0	0	0	1	0	0	0	0	0	0	0	0
Pseudoscorpiones	**Chthoniidae**	Chthoniidae sp.	0	0	0	1	0	0	0	0	0	0	0	0
Malacostraca														
Amphipoda	**Paramelitidae**	*Chydaekata* sp. E TLF-2008	0	0	0	0	0	0	0	0	3	0	0	0
Decapoda	**Parastacidae**	*Cherax quadricarinatus*	0	0	0	0	0	0	0	0	1	0	0	0
Collembolla														
Entomobryomorpha		Entomobryoidea sp.	1	0	0	2	1	0	0	0	0	0	0	0
Poduromorpha		Poduroidea sp.	1	0	0	0	0	0	0	0	0	0	0	0
Symphypleona		Symphypleona sp.	1	0	0	1	0	0	0	0	0	0	0	0
Insecta														
Coleoptera		Coleoptera sp. (L)	0	0	0	2	0	0	0	0	0	0	0	0
	Carabidae	Carabidae sp.	0	0	0	0	0	0	0	0	1	0	0	0
	Dytiscidae	*Allodessus bistrigatus*	0	0	0	1	0	0	0	0	1	0	1	0
		Bidessini sp. (L)	2	0	0	2	0	0	0	0	0	0	2	0
		Cybister sp. (L)	0	1	0	0	0	0	0	0	0	0	0	0
		Cybister tripunctatus	0	0	0	0	0	0	0	1	0	1	0	0
		Hydroglyphus grammopterus	0	0	1	2	4	2	0	0	0	0	0	0
		Hydroglyphus orthogrammus	1	0	0	0	4	3	0	1	0	3	0	2
		Hydrovatus sp. (L)	0	0	2	0	1	0	0	0	0	0	1	0
		Hydrovatus opacus	0	0	0	0	0	0	0	0	0	1	0	0
		Hyphydrus sp. (L)	0	0	0	0	1	0	0	0	0	0	0	1
		Hyphydrus elegans	0	1	0	0	3	0	0	2	0	2	0	0
		Hyphydrus lyratus	0	0	2	0	3	1	0	3	0	2	2	0
		Laccophilus sharpi	0	0	0	1	0	0	0	0	0	0	1	0
		Limbodessus compactus	2	2	0	1	0	2	0	1	0	0	1	0
		Necterosoma sp. (L)	0	0	0	1	0	1	1	0	0	0	0	0
		Necterosoma regulare	0	0	0	0	0	0	0	0	0	1	0	0
		Neobidessodes denticulatus	0	0	0	1	4	0	0	0	0	0	0	0
		Platynectes sp. (L)	0	0	0	2	0	0	0	0	0	0	2	0
		Platynectes decempunctatus var. *decempunctatus*	0	0	0	0	0	0	0	0	0	0	1	0
		Rhantus sp. (L)	0	0	0	2	0	0	0	0	0	0	0	0
		Rhantaticus congestus	0	0	0	0	0	0	0	2	0	0	1	0
		Sternopriscus multimaculatus	0	0	0	1	0	0	0	0	0	0	0	0
		Tiporus tambreyi	0	0	0	0	0	0	0	0	0	1	0	0

			Survey Area						Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
	Elmidae	Austrolimnius sp. (L)	0	0	1	0	0	0	0	0	0	0	0	2
		Austrolimnius sp.	0	0	0	0	0	0	0	0	0	0	0	1
	Gyrinidae	Gyrinidae sp.	1	0	0	3	0	0	0	2	0	0	0	0
		Macrogyrus sp. (L)	0	0	0	0	0	0	0	0	0	0	3	0
		Dineutus australis	0	0	0	2	0	0	0	2	0	0	3	0
	Hydraenidae	Hydraenidae sp. (L)	1	0	0	2	0	0	0	0	0	0	0	0
		Hydraena sp.	1	3	0	3	3	2	2	2	0	2	1	0
		Limnebius sp.	1	0	0	0	2	2	0	0	0	0	0	0
		Ochthebius sp.	0	2	0	2	2	3	0	0	0	0	0	0
	Hydrochidae	*Hydrochus interioris*	0	2	0	1	2	2	0	0	0	2	0	0
		Hydrochus obscuroaeneus	0	2	0	0	2	0	2	0	0	2	0	0
		Hydrochus sp. P1	0	0	0	0	1	0	0	0	0	0	0	0
	Hydrophilidae	Hydrophilidae sp. (L)	0	0	0	0	2	0	0	0	0	0	0	0
		Anacaena horni	1	3	0	0	2	0	0	0	0	1	1	0
		Berosus sp. (L)	2	2	2	0	0	0	0	0	0	0	0	0
		Berosus australiae	0	0	0	0	0	1	0	0	0	0	0	0
		Berosus dallasi	0	1	2	0	0	2	0	0	0	0	0	1
		Chaetarthria nigerrima (L)	0	0	0	0	0	0	0	0	0	1	0	0
		Enochrus deserticola	0	0	0	0	0	1	2	0	0	0	0	0
		Helochares sp. (L)	2	2	2	2	2	0	2	0	0	0	2	0
		Helochares tatei	0	0	0	0	2	0	1	0	0	0	0	0
		Laccobius sp. (L)	2	0	0	0	0	0	0	0	0	0	0	0
		Paracymus sp. (L)	2	0	0	0	0	0	0	0	0	0	0	0
		Paracymus pygmaeus	0	0	0	3	0	0	0	0	0	0	0	0
		Paracymus spenceri	0	0	2	1	0	2	1	0	0	0	1	0
		Regimbartia attenuata	1	2	0	1	0	0	1	2	0	1	1	0
		Sternolophus sp. (L)	0	0	0	0	0	0	0	0	0	0	0	1
		Sternolophus marginicollis	0	0	0	0	0	1	0	0	0	0	0	1
	Scirtidae	Scirtidae sp. (L)	3	3	0	4	2	0	2	2	3	2	3	2
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	0	0	0	2	0	0	1	0	0	0	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	4	3	2	2	2	2	3	2	2	0	2	3
		Ceratopogoninae sp.	4	3	3	3	2	4	3	3	3	3	4	3
		Dasyhelea sp.	4	3	3	4	3	0	3	3	3	0	4	2
		Forcipomyiinae sp.	2	0	0	1	1	1	0	1	2	0	0	0
	Chironomidae	Chironomidae sp. (P)	2	3	3	3	3	2	2	2	2	2	3	0
	Chironominae													
	Chironomini	*Chironomus* aff. *alternans*	0	2	0	4	2	0	0	3	3	4	4	2
		Cryptochironomus griseidorsum	0	1	0	0	0	0	0	0	0	0	0	2
		Dicrotendipes sp. `CA1`	0	1	3	3	2	3	1	2	0	4	4	0
		Dicrotendipes sp. P4	0	0	0	0	1	0	0	0	0	0	0	0
		Paracladopelma sp.	0	0	0	0	0	2	0	0	0	0	0	0
		Parakiefferiella sp.	0	0	0	0	0	0	0	0	0	0	3	0
		Polypedilum (*Pentapedilum*) *leei*	0	0	0	3	0	0	0	0	0	0	0	0
		Polypedilum nubifer	0	0	0	0	0	2	0	0	0	0	0	0

			Survey Area						Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
		Polypedilum sp. K1	3	2	0	0	0	0	2	0	0	0	0	2
		Polypedilum watsoni	0	1	3	0	0	0	0	0	0	0	0	0
		Skusella subvittata	3	1	0	0	0	0	0	0	0	0	0	0
		Stenochironomus watsoni	0	0	3	0	2	0	1	2	2	0	0	1
	Tanytarsini	*Cladotanytarsus* sp.	0	0	0	0	0	0	1	0	0	0	0	0
		Paratanytarsus sp.	0	0	0	0	0	4	0	0	0	0	0	0
		Pentaneurini sp.	0	0	0	0	0	0	0	0	0	0	4	0
		Stempellinella sp.	0	0	0	0	1	0	0	0	0	0	0	0
		Tanytarsus sp.	4	3	4	4	3	3	3	3	4	4	4	3
	Orthocladiinae	*Corynoneura* sp.	0	0	0	0	0	0	0	0	4	0	3	0
		Cricotopus albitarsis	0	0	3	0	0	0	0	0	0	0	0	0
		Cricotopus sp. 2	0	0	0	0	0	0	0	0	3	0	0	2
		Nanocladius sp.	0	0	0	0	0	2	0	0	0	0	0	0
		nr. *Parametriocnemus* sp.	0	0	0	0	0	0	2	0	0	0	4	3
		Rheocricotopus sp.	0	0	0	0	0	0	0	0	3	0	4	3
		Thienemanniella sp.	0	0	0	0	0	0	1	0	4	0	4	2
	Tanypodinae	*Ablabesmyia hilli*	3	0	3	3	0	0	1	1	2	0	4	3
		Larsia ?albiceps	4	0	4	3	3	4	3	3	3	0	4	3
		Paramerina sp. 1	4	2	3	3	3	0	2	2	4	0	0	3
		Paramerina sp. 2	0	0	0	0	0	0	0	1	0	0	0	2
		Procladius sp.	3	2	4	0	2	4	2	2	0	3	4	3
	Culicidae	Culicidae sp. (P)	1	2	2	3	2	0	1	1	0	0	0	0
		Anopheles sp.	2	3	3	4	4	2	3	2	2	0	2	0
		Culex sp.	3	1	3	3	2	0	0	0	2	0	1	0
	Dolichopodidae	Dolichopodidae sp.	2	1	0	0	0	0	1	0	2	2	1	2
	Ephydridae	Ephydridae sp.	0	2	0	0	0	0	0	0	0	0	0	0
	Muscidae	Muscidae sp.	0	2	0	2	0	3	2	0	0	0	0	1
	Psychodidae	Psychodidae sp.	2	2	0	0	1	2	0	2	0	1	0	0
	Sciomyzidae	Sciomyzidae sp.	0	0	0	0	0	0	0	0	0	0	1	0
	Simuliidae	Simuliidae sp.	0	0	5	0	0	0	2	0	0	0	5	3
	Stratiomyidae	Stratiomyidae sp.	2	3	0	2	2	0	3	2	1	0	2	2
	Tabanidae	Tabanidae sp.	0	0	0	0	0	0	1	2	0	1	0	0
	Tipulidae	Tipulidae sp.	2	2	0	0	0	1	0	0	0	0	0	0
Ephemeroptera	**Baetidae**	Baetidae sp.	2	0	4	5	4	4	3	3	3	0	5	2
		Cloeon fluviatile	0	0	0	0	2	0	2	0	3	0	3	2
		Cloeon sp. Red Stripe	0	3	4	5	4	3	2	2	3	0	4	0
		Offadens G1 sp. WA2	0	0	0	0	0	0	0	0	5	0	3	0
		Pseudocloeon hypodelum	0	0	0	0	0	0	0	0	3	0	0	0
	Caenidae	Caenidae sp.	2	3	3	3	4	3	3	1	3	0	5	3
		Tasmanocoenis sp.	0	0	0	0	0	0	0	0	0	2	0	0
		Tasmanocoenis sp. M	0	0	0	0	0	0	0	0	0	0	3	0
		Tasmanocoenis sp. P/*arcuata*	1	3	2	3	4	2	2	1	1	0	4	3
	Leptophlebiidae	*Atalophlebia* sp. AV17	0	0	0	0	0	0	0	0	0	0	4	0
Hemiptera	**Belostomatidae**	*Diplonychus eques*	0	0	0	0	0	0	0	1	0	0	0	1

			Survey Area						Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
	Corixoidea	Corixoidea sp.	0	0	0	2	2	3	0	0	0	0	0	0
	Gerridae	Gerridae sp.	0	2	3	0	0	0	2	0	2	0	2	0
		Limnogonus fossarum gilguy	0	0	1	0	0	0	2	0	0	0	0	0
		Limnogonus luctuosus	0	0	0	0	0	0	2	0	0	3	0	3
	Hebridae	Hebridae sp.	0	0	0	0	0	0	0	0	0	0	1	0
		Hebrus axillaris	0	0	0	0	0	0	1	0	0	0	1	0
	Micronectidae	*Micronecta* sp.	0	0	0	0	2	3	0	0	0	0	0	0
		Micronecta annae	0	0	0	0	0	3	0	1	0	0	0	0
	Notonectidae	Notonectidae sp.	0	3	0	3	3	1	0	2	0	0	2	0
		Anisops sp.	0	0	0	0	1	0	0	1	0	0	0	0
		Anisops elstoni	0	0	0	0	0	0	0	0	0	0	3	0
		Anisops hackeri	0	1	0	0	1	0	0	1	0	0	0	0
		Enithares woodwardi	0	0	0	0	1	0	0	0	0	0	0	0
	Pleidae	*Paraplea* sp.	0	0	0	0	0	0	0	0	0	0	0	1
		Paraplea brunni	0	2	2	2	2	0	1	2	0	1	1	0
	Veliidae	Veliidae sp.	2	3	0	2	3	2	3	2	2	0	1	0
		Microvelia oceanica	2	0	0	0	0	0	0	0	0	0	0	0
		Nesidovelia peramoena	0	3	0	0	3	1	2	0	0	0	0	0
		Nesidovelia sp.	0	3	0	0	2	0	2	1	0	1	0	2
Lepidoptera	**Crambidae**	Acentropinae sp.	0	0	0	0	0	0	0	0	1	0	0	0
		Margarosticha sp. 3	0	0	0	0	0	0	0	0	0	0	2	0
Odonata														
Zygoptera		Zygoptera sp.	0	2	2	3	2	0	0	1	3	1	3	1
	Coenagrionidae	*Argiocnemis rubescens*	0	3	0	0	0	0	1	1	0	1	0	1
		Austroagrion pindrina	0	2	0	4	0	0	0	0	0	0	2	0
		Ischnura aurora	2	3	2	4	2	0	0	2	0	0	0	0
		Ischnura heterosticta	0	2	0	4	0	0	0	2	0	0	0	0
		Pseudagrion aureofrons	0	0	0	3	0	0	0	0	2	0	0	1
	Isostictidae	*Eurysticta coolawanyah*	0	0	0	0	0	0	0	0	0	1	0	0
	Platycnemididae	*Nososticta pilbara*	0	0	0	0	0	0	0	0	2	0	0	0
Anisoptera		Anisoptera sp.	2	2	3	0	2	0	1	2	3	2	3	2
	Aeshnidae	Aeshnidae sp.	0	0	0	0	0	0	1	2	0	0	0	0
		Adversaeschna brevistyla	0	0	0	0	0	0	0	0	0	0	2	0
		Hemianax papuensis	0	3	0	3	2	0	1	2	0	0	2	0
	Corduliidae	*Hemicordulia tau*	0	2	0	0	2	0	0	0	0	0	0	0
	Gomphidae	*Austrogomphus gordoni*	0	0	2	2	0	0	0	0	0	1	0	1
	Libellulidae	*Diplacodes bipunctata*	0	2	0	3	2	0	0	0	0	0	0	0
		Diplacodes haematodes	3	3	3	3	2	2	2	2	2	1	2	0
		Nannophlebia injibandi	0	0	0	0	0	0	0	0	2	0	0	2
		Orthetrum caledonicum	1	2	2	2	2	2	0	1	0	0	0	0
		Orthetrum migratum	0	0	0	0	0	0	0	0	0	0	1	0
		Tramea sp.	0	0	0	0	0	0	0	2	0	0	2	0
		Zyxomma elgneri	0	0	0	0	0	0	0	0	2	2	0	0
	Lindeniidae	*Ictinogomphus dobsoni*	0	0	1	0	0	0	0	0	0	0	0	0

			Survey Area						Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
Trichoptera	**Ecnomidae**	Ecnomidae sp.	0	0	0	0	0	0	1	0	1	0	0	0
		Ecnomina sp. F group	0	0	0	0	0	0	0	0	0	0	4	0
		Ecnomus pilbarensis	0	1	2	2	2	0	3	2	1	0	0	0
	Hydropsychidae	*Cheumatopsyche wellsae*	0	0	0	0	0	0	0	0	3	0	2	3
	Hydroptilidae	*Hellyethira* sp.	0	0	1	1	2	0	0	0	0	0	3	0
		Orthotrichia sp.	0	0	0	0	0	0	0	0	2	0	0	0
	Leptoceridae	Leptoceridae sp.	0	0	0	2	0	1	0	0	1	0	2	0
		Oecetis sp.	0	2	0	0	0	0	0	0	0	1	0	2
		Oecetis sp. Pilbara 1	0	0	0	0	2	0	0	0	0	0	0	0
		Oecetis sp. Pilbara 4	0	3	1	2	3	0	2	1	0	0	2	0
		Triaenodes sp.	0	0	0	0	1	0	0	0	0	0	1	0
		Triplectides australis	0	2	0	0	0	0	0	0	0	0	0	0
		Triplectides ciuskus seductus	0	0	1	0	0	0	3	0	0	0	1	2
		Triplectides sp.	0	0	0	0	0	0	0	0	0	0	1	0
	Philopotamidae	Philopotamidae sp.	0	0	0	0	0	0	0	0	2	0	0	0
		Chimarra sp. AV17	0	0	0	0	0	0	0	0	0	0	0	4
	Polycentropodidae	Polycentropodidae sp.	0	0	0	0	0	0	0	0	0	0	1	0
		Taxa richness	**54**	**71**	**56**	**79**	**77**	**55**	**64**	**62**	**56**	**45**	**83**	**60**

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			Survey Area						Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6a**	**MarC6b**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**	**RW**
ANNELIDA														
Oligochaeta														
Tubificida	**Naididae**	Naidinae sp.	0	0	0	0	0	0	0	0	4	4	4	3
		Allonais paraguayensis	0	0	0	0	0	0	0	1	0	0	0	0
		Allonais pectinata	0	0	0	2	1	0	0	1	0	4	3	0
		Allonais ranauana	0	0	0	0	0	0	1	0	0	3	0	0
		Dero sp.	0	0	0	0	0	0	0	0	0	3	3	0
		Dero digitata	0	0	0	0	2	0	0	0	0	3	0	0
		Dero furcata	0	0	0	0	0	0	0	0	3	0	3	2
		Dero nivea	0	0	2	0	1	0	0	0	4	3	3	1
		Nais variabilis	0	0	0	0	0	0	0	0	0	0	3	0
		Pristina aequiseta	0	0	0	0	2	0	2	0	0	0	3	2
		Pristina longiseta	0	0	0	0	2	0	0	2	0	3	3	2
		Pristina nr. *osborni*	0	0	0	0	2	0	0	0	0	0	0	0
	Phreodrilidae	Phreodrilidae sp.	0	0	0	0	0	0	0	2	0	0	3	0
CNIDARIA														
Hydrozoa														
Anthoathecata	**Hydridae**	*Hydra* sp.	0	0	0	0	0	0	0	0	1	2	0	0
NEMATODA		Nematoda sp.	2	4	0	2	0	0	0	0	0	0	0	0
MOLLUSCA														
Bivalvia														
Cardiida	**Cyrenidae**	*Corbicula* sp.	0	0	0	0	0	0	0	0	0	0	0	2
Gastropoda														
Cerithimorpha	**Thiaridae**	*Plotiopsis balonnensis*	0	0	0	0	0	0	0	0	0	0	2	0
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	0	1	2	0	2	1	2	0	0	4	2	0
	Planorbidae	*Ferrissia petterdi*	0	0	0	0	0	0	0	2	0	2	2	4
		Gyraulus sp.	0	2	2	0	3	0	2	0	4	3	3	1
ARTHROPODA														
Arachnida		Acari sp.	0	0	3	3	3	1	0	2	0	3	3	0
Mesostigmata		Mesostigmata sp.	0	0	0	0	3	0	0	0	0	0	0	0
Sarcoptiformes		Oribatida sp.	0	3	0	0	3	0	2	0	0	3	3	0
Trombidiformes		Trombidioidea sp.	0	0	0	0	3	0	0	0	3	0	0	0
	Anisitsiellidae	Anisitsiellidae sp.	0	0	0	0	0	0	0	2	0	0	0	0
	Arrenuridae	*Arrenurus* sp.	0	3	2	0	3	0	0	0	0	0	3	0
		Arrenurus (*Arrenurus*) sp.	0	0	2	0	0	0	0	0	0	0	0	0
		Arrenurus (*Brevicadaturus*) sp.	0	0	0	0	0	0	0	0	0	4	0	0
		Arrenurus (*Dividuracarus*) sp.	0	0	0	0	3	2	0	0	0	0	0	0

			Survey Area						Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6a**	**MarC6b**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**	**RW**
		Arrenurus (*Megaluracarus*) sp.	0	0	0	0	0	2	0	0	0	0	0	0
	Aturidae	*Albia* sp.	0	0	0	0	3	0	0	0	0	0	3	0
	Eylaidae	*Eylais* sp.	0	0	0	0	0	0	0	0	0	0	3	0
	Hydrachnidae	*Hydrachna* sp.	0	0	0	0	0	0	0	0	0	3	0	0
	Hydrodromidae	*Hydrodroma* sp.	0	0	0	0	4	2	1	0	0	3	0	0
	Hydryphantidae	*Pseudohydryphantes* sp.	0	0	0	0	3	2	0	2	0	1	0	0
	Hygrobatidae	*Australiobates* sp.	0	0	0	0	0	0	0	1	0	0	3	3
		Coaustraliobates minor	0	0	0	0	3	1	1	0	0	0	3	2
		Procorticacarus sp.	0	0	0	0	0	0	0	0	0	0	3	0
	Limnesiidae	*Limnesia parasolida*	0	0	0	0	0	0	0	0	0	0	4	3
		Limnesia sp. `solida group`	0	0	0	0	4	2	2	0	3	4	3	3
	Limnocharidae	*Limnochares* sp.	2	0	2	3	3	2	2	0	0	0	0	0
	Oxidae	*Oxus* sp.	0	0	0	0	3	0	0	0	3	0	3	0
	Piersigiidae	*Stygolimnochares* `sp. Biologic-ACAR026`	0	0	0	0	0	0	0	0	0	0	2	0
	Pionidae	*Piona cumberlandensis*	0	0	0	0	0	2	0	0	0	0	0	0
	Unionicolidae	Unionicolidae sp.	0	0	0	0	0	0	0	0	3	0	0	2
		Neumania sp.	0	4	2	4	0	0	0	0	4	0	3	0
		Recifella sp.	0	0	0	0	3	0	0	0	0	0	3	2
Branchiopoda														
Diplostraca	**Cyzicidae**	*Ozestheria packardi*	0	0	0	3	0	0	0	0	0	0	0	0
	Daphniidae	*Limnadopsis pilbarensis*	0	2	2	2	0	0	0	0	0	0	0	0
Malacostraca														
Amphipoda	**Paramelitidae**	*Chydaekata* sp. E TLF-2008	0	0	0	0	0	0	0	3	0	0	0	0
Decapoda	**Parastacidae**	*Cherax quadricarinatus*	0	0	0	0	0	0	0	1	0	0	0	1
Collembola														
Entomobryomorpha		Entomobryoidea sp.	0	1	0	2	2	0	0	0	0	0	0	0
Symphypleona		Symphypleona sp.	0	2	0	0	0	0	0	0	0	0	0	0
Insecta														
Coleoptera	**Dytiscidae**	*Allodessus bistrigatus*	2	0	0	0	0	0	0	0	1	2	0	0
		Bidessini sp. (L)	4	3	2	4	3	0	0	0	0	0	1	2
		Copelatus nigrolineatus	0	0	0	0	2	0	0	0	0	0	0	0
		Cybister tripunctatus	0	0	0	0	0	0	0	0	2	0	0	0
		Eretes australis (L)	3	1	2	3	0	0	0	0	0	0	0	0
		Eretes australis	2	3	0	0	0	0	0	0	0	0	0	0
		Hydaticus daemeli	0	0	0	0	0	0	0	0	0	2	0	0
		Hydroglyphus grammopterus	2	2	2	2	2	0	1	0	2	2	1	3
		Hydroglyphus leai	0	0	0	0	3	0	0	0	0	0	0	0
		Hydroglyphus orthogrammus	0	0	2	2	0	0	0	0	2	2	0	2
		Hydrovatus sp. (L)	0	0	0	0	0	0	0	0	3	3	1	0
		Hydrovatus opacus	0	0	0	0	0	0	0	0	2	0	0	0

			Survey Area						Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6a**	**MarC6b**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**	**RW**
		Hyphydrus elegans	0	0	0	0	0	0	1	0	0	0	0	0
		Hyphydrus lyratus	2	1	0	0	0	0	0	0	1	0	0	0
		Laccophilus sharpi	0	0	1	0	2	0	0	0	0	0	0	0
		Limbodessus compactus	0	0	0	0	2	0	0	0	0	1	1	0
		Necterosoma regulare	0	1	0	0	0	0	2	0	2	0	0	0
		Necterosoma undecimlineatum	0	0	0	0	0	0	0	0	2	0	0	0
		Neobidessodes denticulatus	0	0	0	0	0	0	2	0	0	0	0	3
		Onychohydrus sp. (L)	0	0	0	0	0	0	0	0	0	1	0	0
		Platynectes sp. (L)	2	0	0	0	0	0	0	0	0	0	0	0
		Platynectes decempunctatus var. *decempunctatus*	0	0	0	0	2	0	0	0	0	2	0	0
		Rhantaticus congestus	0	0	0	0	0	0	0	0	0	2	0	0
		Tiporus centralis	0	0	0	0	0	0	1	0	0	0	0	0
		Tiporus tambreyi	0	0	0	0	2	0	0	0	2	0	0	0
	Elmidae	*Austrolimnius* sp. (L)	0	0	0	0	0	0	0	0	0	0	4	3
	Gyrinidae	Gyrinidae sp.	0	3	0	0	0	0	0	0	0	0	0	0
		Dineutus australis (L)	2	0	0	0	0	0	0	0	0	0	0	0
		Dineutus australis	2	1	0	0	0	0	0	0	0	2	0	0
		Macrogyrus gibbosus	0	0	0	0	0	0	0	0	0	2	0	0
		Macrogyrus paradoxus	0	0	0	0	0	0	0	2	0	0	0	0
	Haliplidae	*Haliplus pilbaraensis*	1	1	1	0	0	0	0	0	0	0	0	0
		Haliplus pinderi	0	0	2	0	0	0	0	0	0	0	0	0
	Hydraenidae	*Hydraena* sp.	0	0	0	0	2	0	0	0	1	2	0	1
		Limnebius sp.	0	0	0	0	0	0	0	0	0	0	0	3
	Hydrochidae	*Hydrochus eurypleuron*	0	0	0	0	0	0	0	0	2	1	0	0
		Hydrochus interioris	0	0	1	0	1	0	2	0	1	0	0	0
		Hydrochus obscuroaeneus	0	0	0	0	0	0	1	0	2	1	0	0
	Hydrophilidae	*Anacaena horni*	0	0	0	0	0	0	0	0	2	2	0	0
		Berosus sp. (L)	0	0	0	0	0	0	0	0	1	0	0	0
		Berosus approximans	2	1	3	1	0	0	0	0	0	0	0	0
		Berosus dallasi	0	2	0	0	0	0	1	0	2	0	0	0
		Berosus pulchellus	0	0	2	2	0	0	0	0	0	0	0	0
		Helochares sp. (L)	1	0	0	0	2	0	1	0	2	2	0	1
		Hydrochus macroaquilonius	0	0	0	0	0	0	0	0	1	1	0	0
		Hydrophilus brevispina	0	0	1	0	0	0	0	0	0	0	0	0
		Paracymus spenceri	0	1	0	0	0	0	0	0	0	2	1	0
		Regimbartia attenuata	0	0	2	0	0	1	0	0	0	2	0	0
		Sternolophus sp. (L)	0	0	2	0	0	0	0	0	0	1	0	0
		Sternolophus marginicollis	0	0	0	0	0	0	0	0	0	0	2	2
	Scirtidae	Scirtidae sp. (L)	0	3	0	0	2	0	0	3	2	0	0	1
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	0	0	0	0	1	0	0	0	0	0	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	0	0	0	0	2	0	2	0	3	2	1	1
		Ceratopogoninae sp.	2	1	0	2	3	1	3	1	2	4	3	2
		Dasyhelea sp.	0	0	0	0	2	1	3	2	0	3	2	0
		Forcipomyiinae sp.	0	0	0	0	0	0	0	0	0	0	0	1

			Survey Area						Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6a**	**MarC6b**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**	**RW**
	Chaoboridae	Chaoboridae sp.	0	0	0	0	1	0	0	0	0	0	0	0
	Chironomidae	Chironomidae sp. (P)	0	2	0	0	2	2	1	1	0	3	3	3
	Chironominae													
	Chironomini	Chironomini sp.	0	0	0	0	0	0	1	0	0	0	0	0
		Chironomus aff. *alternans*	4	2	2	3	0	0	0	0	4	0	4	3
		Cladopelma curtivalva	0	0	0	0	0	0	0	0	3	3	0	0
		Dicrotendipes sp.	0	0	0	2	0	0	0	0	3	0	0	0
		Dicrotendipes jobetus	0	0	0	0	0	2	0	0	0	0	0	3
		Dicrotendipes sp. `CA1`	3	2	0	0	4	1	2	0	0	4	4	4
		Dicrotendipes sp. P4	0	0	0	0	3	2	0	0	0	0	0	3
		Kiefferulus intertinctus	0	0	0	0	0	0	0	0	4	0	0	0
		Paracladopelma sp. M1	0	0	0	0	0	0	0	0	0	3	0	0
		Parakiefferiella sp.	0	0	0	0	0	0	0	0	0	2	0	0
		Paratendipes sp. `K1`	0	0	0	0	0	0	0	0	0	0	4	0
		Polypedilum sp. K1	0	0	0	0	0	0	0	0	0	0	0	3
		Polypedilum sp. S1	0	0	0	0	0	0	1	0	0	0	0	0
		Polypedilum watsoni	0	0	0	0	3	0	2	0	0	0	0	0
		Skusella subvittata	0	0	0	0	0	0	1	0	0	0	0	0
		Stempellinella sp.	0	0	0	0	0	0	1	0	0	3	0	0
		Stenochironomus watsoni	0	0	0	0	0	0	0	1	0	0	0	3
	Tanytarsini	*Cladotanytarsus* sp.	0	0	0	0	4	0	0	0	3	0	0	3
		Paratanytarsus sp.	0	0	0	0	4	2	1	2	0	0	0	0
		Tanytarsus sp.	0	1	0	0	4	2	3	3	4	4	4	3
	Orthocladiinae	*Corynoneura* sp.	0	0	0	0	0	0	0	2	0	0	2	1
		Cricotopus albitarsis	0	0	0	0	0	0	0	2	0	0	2	2
		Nanocladius sp.	0	0	0	0	3	2	0	0	0	0	0	0
		nr. *Gymnometriocnemus* sp.	0	2	0	0	0	0	2	0	0	0	0	0
		Parametriocnemus sp.	0	0	0	0	0	0	0	1	0	0	0	0
		Rheocricotopus sp.	0	0	0	0	0	0	0	1	0	0	2	0
		Thienemanniella sp.	0	0	0	0	0	0	0	2	0	0	2	2
	Tanypodinae	*Ablabesmyia hilli*	0	0	0	0	0	0	0	0	0	3	0	3
		Larsia ?albiceps	0	2	0	0	4	2	3	2	5	4	4	4
		Paramerina sp. 1	0	0	0	0	3	1	2	2	3	0	3	3
		Paramerina sp. 2	0	0	0	0	0	0	0	0	0	3	2	0
		Procladius sp.	0	0	0	0	2	1	2	0	3	4	4	3
		Thienemannimyia sp.	0	0	0	0	0	0	0	1	0	0	0	0
	Culicidae	Culicidae sp. (P)	4	2	3	2	2	0	0	0	2	0	0	0
		Aedes sp.	3	2	2	0	2	0	1	0	0	0	0	0
		Anopheles sp.	0	0	0	0	0	0	0	2	0	0	1	2
		Culex sp.	4	2	2	0	2	1	0	0	0	3	2	0
	Dolichopodidae	Dolichopodidae sp.	0	0	0	0	0	0	0	0	0	0	2	0
	Ephydridae	Ephydridae sp.	0	1	0	0	0	0	0	1	0	0	0	0
	Sciomyzidae	Sciomyzidae sp.	0	0	0	1	0	0	0	0	0	0	0	0
	Simuliidae	Simuliidae sp.	0	0	0	0	0	0	0	0	0	0	3	2

			Survey Area						Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6a**	**MarC6b**	**MACREF2**	**WWS**	**BENS**	**MUNJS**	**SS**	**RW**
	Stratiomyidae	Stratiomyidae sp.	0	0	1	0	0	0	1	0	1	0	0	0
	Tabanidae	Tabanidae sp.	0	0	0	0	0	0	1	0	1	1	0	0
	Tipulidae	Tipulidae sp.	0	0	0	0	0	0	2	0	0	0	0	0
Ephemeroptera	**Baetidae**	Baetidae sp.	3	3	2	2	4	3	2	3	3	4	0	3
		Cloeon sp.	2	0	0	0	0	0	0	0	0	4	0	0
		Cloeon fluviatile	0	0	0	0	0	2	0	3	3	0	4	3
		Cloeon sp. Red Stripe	0	0	0	0	2	0	0	0	3	0	4	3
		Offadens G1 sp. WA2	0	0	0	0	0	0	0	3	0	0	0	0
		Pseudocloeon hypodelum	0	0	0	0	0	0	0	0	0	0	4	3
	Caenidae	Caenidae sp.	0	0	0	0	3	1	2	2	3	0	0	3
		Tasmanocoenis sp.	0	0	0	0	0	0	0	0	0	0	3	0
		Tasmanocoenis sp. M	0	0	0	0	0	0	0	0	1	0	2	3
		Tasmanocoenis sp. P/*arcuata*	0	0	0	0	0	0	0	2	2	5	4	3
	Leptophlebiidae	Leptophlebiidae sp.	0	0	0	0	0	0	0	0	0	2	0	0
		Atalophlebia sp. AV17	0	0	0	0	0	0	0	0	0	2	0	0
Hemiptera	**Belostomatidae**	*Diplonychus eques*	0	0	0	0	0	0	0	0	2	3	3	1
	Corixoidea	Corixoidea sp.	0	0	0	0	2	2	0	0	0	0	0	2
	Corixidae	*Agraptocorixa parvipunctata*	0	1	0	0	0	0	0	0	0	0	0	0
	Gelastocoridae	*Nerthra* sp.	0	0	0	0	0	0	0	0	0	0	1	0
	Gerridae	Gerridae sp.	2	0	2	3	0	0	3	2	0	2	0	0
		Limnogonus fossarum gilguy	1	0	0	0	0	2	0	0	0	0	0	0
		Limnogonus luctuosus	0	0	0	0	0	0	1	0	0	0	2	0
		Rhagadotarsus anomalus	0	0	0	0	0	0	0	0	2	0	0	0
	Hebridae	*Hebrus axillaris*	2	0	0	0	0	0	0	0	0	0	0	0
		Merragata hackeri	0	1	0	0	0	0	0	0	0	1	0	0
	Mesoveliidae	Mesoveliidae sp.	0	0	0	0	1	0	0	0	0	2	0	0
		Mesovelia hungerfordi	0	0	0	0	0	0	0	0	0	2	0	0
		Mesovelia vittigera	0	0	0	0	1	0	0	0	0	0	0	0
	Micronectidae	Micronectidae sp.	0	0	0	0	0	0	0	0	2	0	0	0
		Austronecta bartzarum	0	0	0	0	2	0	0	0	0	0	0	0
		Micronecta annae	0	0	0	0	0	0	0	0	1	0	0	0
		Micronecta paragoga	0	0	0	0	0	0	0	0	0	1	0	0
	Nepidae	*Laccotrephes tristis*	0	0	0	0	0	0	0	0	0	0	1	0
		Ranatra dispar	0	0	0	0	0	0	0	0	0	0	1	0
	Notonectidae	Notonectidae sp.	0	0	0	0	0	0	0	0	0	3	0	0
		Anisops sp.	2	2	0	0	0	0	0	0	1	1	0	0
		Anisops elstoni	0	0	0	0	0	0	0	0	0	2	0	0
		Anisops hackeri	0	0	1	0	0	0	0	0	0	1	0	0
		Anisops stali	2	0	0	0	0	0	0	0	0	0	0	0
		Enithares woodwardi	0	0	0	0	0	0	0	0	0	1	0	0
	Pleidae	*Paraplea* sp.	0	0	0	0	2	1	0	0	0	0	0	0
		Paraplea brunni	0	0	0	0	0	0	1	0	2	2	3	2
	Veliidae	Veliidae sp.	0	0	0	0	0	0	0	0	0	0	0	1
		Nesidovelia sp.	0	0	0	0	0	0	0	0	0	2	0	0

			Survey Area						Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC3	MarC4	MarC5	MarC6	MarC6a	MarC6b	MACREF2	WWS	BENS	MUNJS	SS	RW
		Nesidovelia peramoena	0	0	0	0	0	0	0	0	0	2	0	0
Lepidoptera	**Crambidae**	Acentropinae sp.	0	0	0	0	0	0	0	0	0	0	3	0
		Margarosticha sp. 3	0	0	0	0	0	0	0	0	0	0	3	0
Odonata														
Zygoptera		Zygoptera sp.	0	2	2	0	2	3	2	2	3	4	2	2
	Coenagrionidae	Coenagrionidae sp.	0	0	0	0	0	0	0	0	0	0	2	2
		Argiocnemis rubescens	0	0	0	0	2	0	0	0	0	0	0	0
		Austroagrion sp.	0	0	0	0	0	2	0	0	0	2	0	0
		Pseudagrion sp.	0	0	0	0	0	0	0	1	0	0	0	0
		Pseudagrion aureofrons	0	0	0	0	0	0	0	0	0	0	1	0
	Isostictidae	Isostictidae sp.	0	0	0	0	0	0	0	0	1	0	0	2
Anisoptera		Anisoptera sp.	0	0	0	0	3	2	1	2	3	4	2	2
	Aeshnidae	Aeshnidae sp.	0	0	0	0	0	0	0	0	2	0	0	0
		Adversaeschna brevistyla	0	0	0	0	0	0	0	0	0	3	0	0
		Hemianax papuensis	0	0	0	0	0	0	0	0	3	0	0	0
	Corduliidae	Corduliidae sp.	0	0	0	0	0	0	0	0	2	0	0	0
		Hemicordulia koomina	0	0	0	0	0	0	0	2	2	4	2	0
	Gomphidae	*Austrogomphus gordoni*	0	0	0	0	0	2	1	1	0	2	0	2
	Libellulidae	*Diplacodes haematodes*	0	0	0	0	2	0	0	2	0	3	0	2
		Orthetrum caledonicum	0	0	0	0	0	2	0	0	0	0	0	0
		Tramea sp.	0	0	0	0	0	0	0	0	0	4	0	0
	Lindeniidae	*Ictinogomphus dobsoni*	0	0	0	0	0	0	0	0	0	2	0	0
	Platycnemididae	*Nososticta* sp.	0	0	0	0	0	0	0	2	0	0	0	0
Trichoptera	**Ecnomidae**	*Ecnomina* sp. F group	0	0	0	0	0	0	0	0	0	4	0	0
		Ecnomus pilbarensis	0	0	0	0	0	0	0	1	0	1	2	2
	Hydropsychidae	*Cheumatopsyche wellsae*	0	0	0	0	0	0	0	3	0	0	4	3
	Hydroptilidae	*Hellyethira* sp.	0	0	0	0	0	0	0	0	0	0	2	0
		Orthotrichia sp.	0	0	0	0	0	2	0	2	0	0	2	0
	Leptoceridae	Leptoceridae sp.	0	0	0	0	0	0	0	0	0	0	0	2
		Leptocerus sp.	0	0	0	0	0	1	0	0	0	0	0	0
		Oecetis sp. Pilbara 4	0	0	0	0	0	0	0	0	0	1	2	3
		Triaenodes sp.	0	0	0	0	0	0	0	0	0	0	2	0
		Triplectides ciuskus seductus	0	0	0	0	0	0	0	0	1	0	2	0
	Philopotamidae	Philopotamidae sp.	0	0	0	0	0	0	0	0	0	0	0	1
		Chimarra sp. AV17	0	0	0	0	0	0	0	2	0	0	3	0
		Taxa richness	**27**	**38**	**31**	**21**	**66**	**37**	**46**	**46**	**64**	**85**	**81**	**68**

Appendix I: Raw Rehydrate Data

Wet 2023

			Survey Area		Reference
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MACREF1**
CHLOROPHYTA					
CHAROPHYCEAE					
Charales	**Characeae**	*Chara* sp.		**x**	
PLANTAE					
		Indet. macrophyte	**x**		**x**
ANIMALIA					
PLATYHELMINTHES					
Turbellaria		Turbellaria sp.	0	0	1
NEMATODA		Nematoda sp.	2	0	3
ANNELIDA					
Polychaeta	Aeolosomatidae	Aeolosomatidae sp.	0	0	4
ROTIFERA		Rotifera sp.	0	0	3
ARTHROPODA					
Arachnida		Acari sp.	0	1	0
Branchiopoda					
Diplostraca	Chydoridae	*Dunhevedia crassa*	0	0	4
		Leberis cf. *diaphanus*	0	0	3
	Daphniidae	*Ceriodaphnia* sp.	1	0	4
		Simocephalus sp.	0	0	4
	Moinidae	*Moina micrura*	0	0	5
Ostracoda					
Podocopida		Ostracoda sp. (imm/dam.)	2	0	0
	Cyprididae	*Cypretta* sp.	0	0	4
		Cypridopsis sp.	0	0	4
		Cypridopsis sp. 'Biologic-OSTR011'	0	0	3
		Cyprinotus cingalensis	0	0	1
		Riocypris cf. *fitzroyi*	0	0	4
		Stenocypris major	0	2	3
	Limnocytheridae	*Limnocythere dorsosicula*	0	1	0
Maxillopoda					

			Survey Area		Reference
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MACREF1**
Cyclopoida	Cyclopidae	*Mesocyclops brooksi*	0	0	4
		Mesocyclops sp.	0	0	3
		Pescecyclops sp.	0	0	3
Insecta					
Diptera	Ceratopogonidae	Ceratopogoninae sp.	0	0	2
		Dasyhelea sp.	0	0	2
Odonata	Corduliidae	*Hemicordulia tau*	0	0	2
	Libellulidae	*Orthetrum caledonicum*	0	0	2
		Taxa richness	**4**	**4**	**23**