MAC Phase 4

Aquatic Monitoring Dry 2023 and Wet 2024

Report to BHP Western Australia Iron Ore

18 November 2025

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Executive Summary

Biologic Environmental Survey (Biologic) was commissioned by BHP Western Australia Iron Ore (WAIO) to undertake a two-season aquatic ecology survey for the Mining Area C (MAC) Phase 4 Project (the Survey), located in the East Pilbara region of WA. 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), as well Reference sites outside this area. The Survey represents the fourth aquatic ecology survey undertaken in this reach of Marillana Creek.

Sampling was conducted in the dry season of 2023 (Dry 2023) and wet season of 2024 (Wet 2024), with up to 12 sites sampled in each season; six in the Survey Area (MarC1-MarC6) and six Reference sites. In the Dry 2023, all six long-term monitoring sites in the Survey Area were dry and sediments were collected for rehydration trials. Additional sites downstream of MarC6 were inundated (MarC6a and MarC6b) and able to be sampled using the full suite of aquatic ecology sampling methods. In January 2024, a high intensity fire burnt through much of the Survey Area. The Wet 2024 survey was undertaken two months post-fire, where impacts such as dead trees, burnt understorey, and ash was noticeable across the Survey Area. Surface water was present at all Survey Area sites in the Wet 2024, except MarC5. A pool ~200 m downstream of MarC5, and 987 m upstream of MarC6 was sampled in its place (named MarC5a).

The aquatic survey included habitat assessments and sampling of water quality, macrophytes (submerged and emergent) and dominant riparian vegetation, hyporheos fauna, macroinvertebrates (including microcrustacea) and fish. Sampling of the hyporheic zone was not undertaken in the Dry 2023, either due to the sites being too dry, or the bedrock substrate.

The Survey Area is characterised by the presence of creek pools currently ranging in persistence from ephemeral to semi-permanent which occur over a range of substrate types, from clay and bedrock to more transmissive substrates such as sand and gravel. Dominant vegetation generally comprised an open overstorey of *Eucalyptus camaldulensis*, *Melaleuca argentea* and *Melaleuca glomerata* over *Cyperus vaginatus*. Weeds were present throughout the Survey Area. Previous aquatic and flora surveys reported that the Survey Area supports potential Groundwater Dependent Ecosystems (GDEs) of varying levels of significance, based on the presence of High to Very High GDE indicator flora taxa. However, signs of decline in vegetation condition have become apparent, as well as a transition from permanent to more ephemeral surface water. During the Survey, much of the Groundwater Dependent Vegetation (GDV)/GDE indicator taxa were dying, including mature *M. argentea* at MarC3 and MarC4. The January fire exacerbated these impacts.

Surface waters across the Survey Area ranged from fresh to brackish, with circum-neutral to slightly basic pH and low dissolved oxygen (DO). 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 aluminium, chromium, and copper). Between all sampling events, several analytes were recorded in significantly higher concentration in the Wet 2024, all of which were influenced by higher concentrations recorded from the Survey Area. Such analytes included EC, pH, turbidity, alkalinity, major ions (sodium, magnesium, potassium, chloride and sulfate), total N, total P, and concentrations of dissolved aluminium, arsenic, cobalt, copper, iron, molybdenum, selenium, vanadium and zinc. These water quality changes were due to the drying conditions for some analytes, coupled with the fire and subsequent flushing following rainfall for others.

A total of 32 invertebrate taxa was recorded from hyporheic zones of the Survey Area during the Survey. Hyporheic taxa richness recorded in the Wet 2024 was lower than Reference sites at the time. Despite this, 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 ability for fauna to move into the groundwater as water recedes, and return to the hyporheic zone when this habitat becomes available. There was no significant difference in hyporheos fauna richness between site types, though there was a significant difference between sampling events, with the lowest richness recorded in the Wet 2023. There was a significant interaction between site types and sampling events, indicative of the high variability in richness within each site type and sampling event.

A total of 156 macroinvertebrate taxa was recorded from the Survey Area. Interestingly, macroinvertebrate richness in the Dry 2023 was notably high, despite only two pools (MarC6a and MarC6b) in the Survey Area having surface water at the time. These pools act as important refuges for aquatic fauna when the creek is drying, and biota are under stress. Conversely, macroinvertebrate richness in the Wet 2024 was the lowest to-date, despite all six long-term monitoring sites holding water at the time. Overall, there was a significant difference in macroinvertebrate taxa richness between sampling events, with significantly lowest taxa richness recorded in the Wet 2024. This difference was due to the low richness recorded from the Survey Area at this time. There was no significant difference between site type, but there was a significant interaction between site type and sampling event, suggesting that changes in richness within the Survey Area over time were different to that happening at Reference sites. Macroinvertebrate assemblage composition has also shifted over time, with separation of the Survey Area samples from the Wet 2023 and Wet 2024 from all other sampling events in ordination space. SIMPER analysis indicated several changes in taxa presence and abundance has led to these changes in composition, such as decline in odonate richness. Richness of odonate taxa was significantly lowest in the Wet 2024 compared to preceding sampling events, which again was due to the low richness of this group recorded from the Survey Area at this time.

Of the two species of freshwater fish previously known from the Survey Area, only one was recorded during the Survey (spangled perch *Leiopotherapon unicolor*). Spangled perch abundance in the Survey Area has declined over time, and their range within the creek has retracted. Spangled perch have not been recorded from the upper reaches of Marillana Creek (MarC1 and MarC2) since the Dry 2021 and have not dispersed back into this area since, despite being present at MACREF2 in all sampling events except the Dry 2023. Spangled perch abundance was significantly lowest in the Wet 2023 and Wet 2024. This was influenced by low abundances both within the Survey Area and at Reference sites. However, of importance is the fact that spangled perch have not recolonised inundated areas in Marillana Creek, and that adverse changes to abundance and recruitment of spangled perch has been observed across the Marillana/Weeli Wolli Creek catchment. Given the number and extent of mines and mining impacts throughout the catchment, further work should be undertaken to understand the spangled perch populations across the catchment.

The Survey Area was previously known to also support the Pilbara tandan *Neosilurus* sp. However, this species has not been recorded from the Survey Area since the Dry 2021. While this may represent a loss of this species from the Survey Area, Pilbara tandan have only ever been recorded in low abundance and from few sites. As they are a benthic and cryptic species, they can be difficult to capture.

Other aquatic vertebrate fauna recorded from the Survey Area included Main's frog (*Cyclorana mainii*) and at least one other species of frog that was unable to be determined at the time of the Survey as tadpoles need to be identified under a microscope. The tadpoles were likely to represent the desert tree frog (*Litoria rubella*) which is a common species and is known from the Survey Area.

While most taxa recorded from the Survey Area were common, ubiquitous species, several were of significance, either due to being relatively uncommon Pilbara endemics or with disjunct distributions (*Fierscyclops* \`sp. Biologic-CYCL034\`, *Fierscyclops* \`sp. Biologic-CYCL039\`, *Atopobathynella* \`sp. Biologic-PBAT019\`, *Limnadopsis pilbarensis*, *Ozestheria* \`sp. Biologic-BRAN002\`, *Rutacarus* \`sp. Biologic-ACAR007\`, Canthocamptidae \`sp. Biologic-HARP059, and Anostraca sp.), and/or or considered significant under international conservation listing (*Branchinella wellardi*; Vulnerable on the IUCN Red List and DBA Priority 3). This, coupled with the presence of groundwater dependent taxa within hyporheic zones, indicates a level of resilience of the fauna within the Survey Area, given the degree of drying of the creek and the intense fire which went through the Survey in January 2025.

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Glossary

BOM	Bureau of Meteorology
DBCA	Department Biodiversity, Conservation and Attractions
DGV	Default Guideline Value
DO	Dissolved oxygen
DPIRD	Department of Primary Industry and Regional Development
EC	Electrical conductivity
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
PBS	Pilbara Biological Survey
PEC	Priority Ecological Community
SRE	Short-range endemic
Study Area	The Survey Area and regional Reference sites combined
Survey Area	The reach of Marillana Creek targeted for sampling, located upstream of BHP WAIO's Jugari operations
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 survey of the aquatic ecosystems of Marillana Creek (the Survey) for the Mining Area C (MAC) Phase 4 Project. A reach of creek upstream of BHP WAIO's Jugari operations was targeted for survey (hereafter referred to as the Survey Area; Figure 1.1). The Survey Area is located to the north of the current BHP WAIO MAC operations, within the East Pilbara region of Western Australia (WA). The Survey Area, along with Reference sites sampled elsewhere, comprised the Study Area for the Survey.

Three previous aquatic ecology 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, 2022a), the dry of 2021 (Dry 2021) and wet of 2022 (Wet 2022) (Biologic, 2023a), and the dry of 2022 (Dry 2022) and wet of 2023 (Wet 2023) (Biologic, 2024b). 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. 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 (GDVs) and fish assemblages recorded in the Wet 2022 (Biologic, 2023a), Dry 2022 and Wet 2023 (Biologic, 2024b).

1.2 Scope of Works

The main objectives of the Survey were to obtain data to assess the current ecological values and health of Marillana Creek within the Survey Area, and examine the effects of declining water levels on the GDE and ecology of the pools. The scope of works included:

- A detailed, two-season aquatic survey (the Survey) at Survey Area and Reference sites in the dry season of 2023 (Dry 2023) and post-wet season of 2024 (Wet 2024)
- 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 monitoring period, incorporating data from all previous surveys (Biologic, 2022a, 2023a, 2024b).

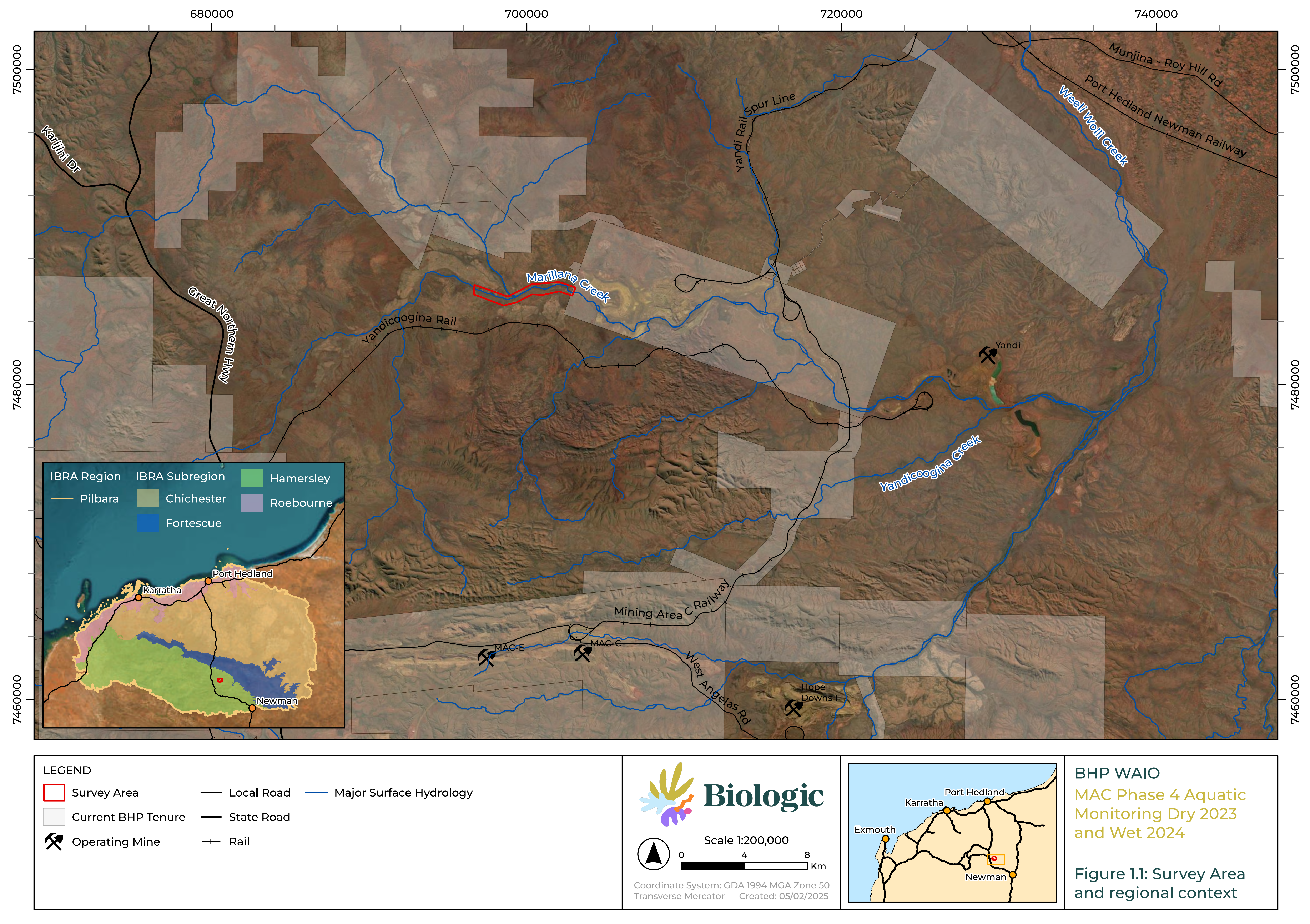

Figure 1.1: Survey Area and regional context

1.3 Compliance

Native flora and fauna are protected under the *Biodiversity Conservation Act 2016* (BC Act) at the state level, and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) at a national level. Any action that has the potential to impact native fauna or flora must be approved by relevant State and / or Commonwealth departments as dictated by the state *Environmental Protection Act 1986* (EP Act) and the EPBC Act. For the purposes of Environmental Impact Assessment (EIA), relevant environmental factors defined by the EPA for aquatic ecosystems include Inland Waters, Terrestrial Fauna[1], and Flora and Vegetation. With respect to Inland Waters, the EPA is primarily focused on significant ecosystems, which in the Pilbara include (but are not limited to):

- wetlands listed in the Directory of Important Wetlands in Australia (DIWA)
- 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 (DWER)
- 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).

Although there is currently no technical sampling guidance available for Inland Waters, there is relevant information in the Terrestrial Fauna guidance, with respect to timing, effort and the level of survey. In addition, Biologic have a strong understanding of best practice aquatic ecology, following national ANZG (2018) guidance and similar studies undertaken by universities and government agencies across Australia. Therefore, the Survey was undertaken in accordance with the following guidance and methods:

- Australian & New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)
- Environmental Factor Guideline, Inland Waters (EPA, 2018)
- Environmental Factor Guideline, Flora and Vegetation (EPA, 2016a)
- Technical Guidance, Terrestrial Fauna Surveys (EPA, 2016c)

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[1] The EPA defines terrestrial fauna 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).

- 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 undertaken for the Pilbara Biological Survey (Pinder *et al.*, 2010), and National Monitoring River Health Initiative (Choy & Thompson, 1995)
- Recent aquatic ecology surveys undertaken by Biologic for this (Biologic, 2022a, 2023a, 2024b), and other BHP projects in the East Pilbara (Biologic, 2020, 2021, 2022e, 2023c, 2023d, 2023e).

2 Existing 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 Upper Weeli Wolli Creek sub-catchment of the Upper Fortescue River catchment, with northern parts of the mining lease extending into the Marillana Creek sub-catchment. The Survey focused on Marillana Creek, as it is an option for discharge of excess groundwater for MAC Phase 4.

Marillana Creek is a major tributary of Weeli Wolli Creek, and has a catchment area of approximately 2,050 km^2 (Figure 2.1) (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 (site code MarC6 in the Survey), upstream of current BHP and Rio Tinto mining operations. Several tributaries contribute flows to Marillana Creek, including Lamb Creek, Phil's Creek, Jugaricoogina Creek and many smaller, un-named creeks (Figure 2.1). Marillana Creek flows into Weeli Wolli Creek, 40 km downstream of the Survey Area.

2.3 Groundwater Dependent Ecosystems (GDEs)

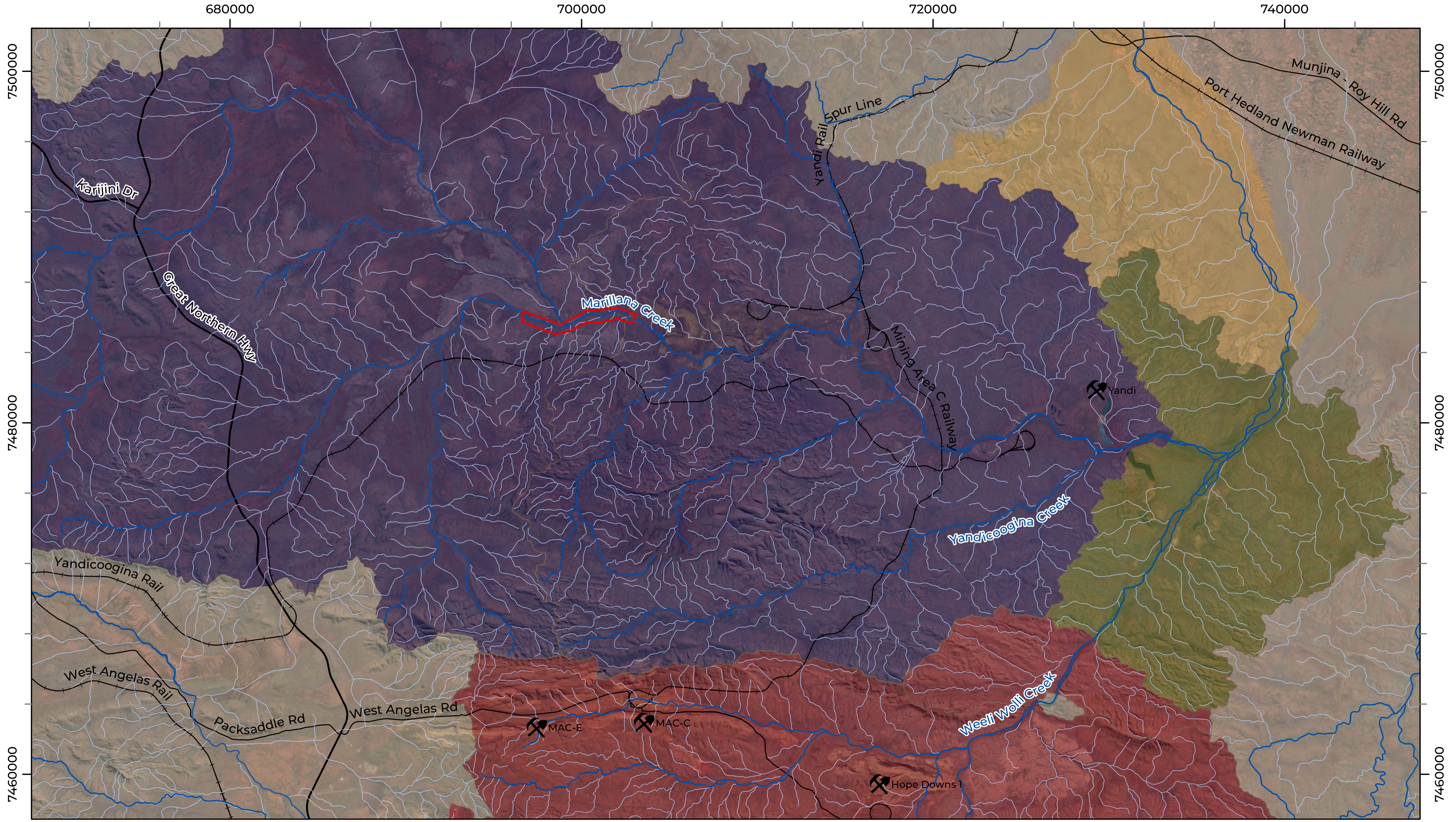
Although GDEs only cover a comparatively small proportion of the land surface, they provide specific ecosystem functions supporting unique and important biological diversity at both local and regional scales (Boulton & Hancock, 2006; Humphreys, 2006; Murray *et al.*, 2006; Thurgate *et al.*, 2001). In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

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 continual, seasonal, or episodic access to groundwater due to their complete (or high) reliance on 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).

Obligate phreatophytes are highly sensitive to changes in groundwater regime and respond negatively to rapid groundwater drawdown. As such, obligate phreatophytes are often the best indicator of consistently shallow groundwater tables, or permanent surface water presence in the Pilbara. Not all phreatophytic species display the same degree of dependency on groundwater and the dependency within species has been shown to vary both spatially and temporally, with the hydrological regime of a particular catchment, creek, or river system, a key factor in presence and dependency of a phreatophyte on groundwater (Eamus *et al.*, 2016).

Facultative phreatophytes use groundwater opportunistically, particularly during times of drought when moisture reserves in the unsaturated (vadose) zone of the soil profile become depleted. They are 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.



LEGEND

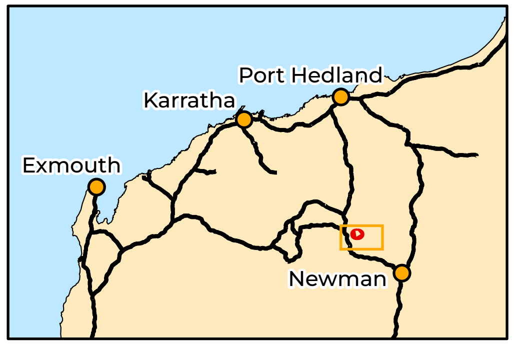
Survey Area
Operating Mine
Rail
Local Road
State Road
Surface Hydrology
Minor
Major
Subcatchment
Lower Weeli Wolli Creek
Marillana Creek
Unnamed
Upper Weeli Wolli Creek
Weeli Wolli/ Marillana

Biologic

Scale 1:200,000

0 4 8 Km

Coordinate System: GDA 1994 MGA Zone 50 Transverse Mercator Created: 05/02/2025



BHP WAIO

MAC Phase 4 Aquatic Monitoring Dry 2023 and Wet 2024

Figure 2.1: Hydrology of the Survey Area

In the Pilbara, tree species are often used as a tool to indicate groundwater dependence. The key Pilbara tree species which are considered indicators of shallow groundwater and permanence are presented in Table 2.1. In addition, other Pilbara flora taxa can also indicate presence and availability of groundwater. Comparatively less information is known on the groundwater use strategies of understorey species, however, some taxa are generally accepted as hydrophytic/ mesophytic (i.e., plants that live in aquatic environments, and plants only requiring a moderate amount of water respectively) and occur in association with landforms and sub-landforms with groundwater close to the surface. Several species that strongly indicate the presence of consistently shallow groundwater or perennial surface water are known to occur in the Survey Area, including *Melaleuca argentea, Eucalyptus camaldulensis* and *Acacia ampliceps*.

Table 2.1: Groundwater dependence categories of common tree species of the Hamersley subregion

Species Dependence on Groundwater categorisation	Plant Physiology/ water use strategy	Relevant Species in the Pilbara
High	Obligate Phreatophyte	*Melaleuca argentea*
Moderate	Facultative Phreatophyte	*Eucalyptus camaldulensis*
Low to Moderate	Facultative Phreatophyte / Vadophyte	*Eucalyptus victrix*, *Eucalyptus xerothermica*, *Corymbia candida*
Low (virtually negligible)	Vadophyte / Xerophyte	*Eucalyptus leucophloia*, *Corymbia hamersleyana*, *Corymbia deserticola*

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.

3 Methods

3.1 Field Survey and Laboratory Team

Field surveys were conducted by aquatic ecologists who have a combined experience of over 20 years undertaking aquatic ecosystem surveys throughout the Pilbara (Table 3.1). Invertebrate and flora specimens were identified in-house by qualified zoologists and botanists. Genetic analysis was undertaken in-house on selected micro-crustacea and hyporheos specimens by experienced geneticists (Table 3.1).

Table 3.1: Survey personnel and experience

Personnel	Role	Qualification	Experience
Jess Delaney Principal Aquatic Ecologist | Manager of Aquatic Ecology	Report Review Project Accounting Technical Guidance & Overall QA/QC	BSc (Hons) Environmental Science	23 years' aquatic ecology 22 years' consulting 23 years' field survey
Kim Nguyen Senior Aquatic Ecologist	Project Management Field Survey Lead Taxonomic IDs Data Analysis Reporting	BSc (Hons) Conservation Biology and Management	13 years' aquatic ecology 13 years' consulting 13 years' field survey
Mahabubur Rahman Aquatic Ecologist	Field Survey Sample Processing Taxonomic IDs	PhD Environmental and Conservation Sciences MSc Fisheries Technology BSc Fisheries	11 years' aquatic ecology 2 years' consulting 4 years' field work
Isabelle Johansson Senior Ecologist	Field Survey Taxonomic IDs	MSc Biological Sciences BSc Zoology	4 years' aquatic ecology 4 years' consulting 4 years' field work
Sammy Alatas Field Technician	Field Survey		1 year zoology 2 years' consulting 3 years' field survey
Matthew Durrant Field Technician	Field Survey		1 year aquatic ecology 1 year field survey
Chris Hofmeester Principal Aquatic Ecologist	Taxonomic IDs	BSc (Hons) Environmental Biology	13 years' aquatic ecology 13 years' consulting 13 years' field survey
Vanessa Nici Senior Aquatic Ecologist	Sample Processing Taxonomic IDs	BSc (Hons) Zoology and Wildlife Management	9 years' aquatic fauna 9 years' consulting 3 years' field survey
Fintan Angel Senior Aquatic Ecologist	Taxonomic IDs	BSc Environmental Biology	10 years' aquatic fauna 10 years' consulting 10 years' field survey

Personnel	Role	Qualification	Experience
Siobhan Paget Senior Aquatic Ecologist	Taxonomic IDs	BPhil (Hons) Conservation Biology and Zoology	5 years' aquatic ecology 4 years' consulting 5 years' field survey
Shae Surman Graduate Aquatic Ecologist	Sample Processing Data Management	BSc (Hons) Zoology BSc Zoology and Marine Science	1 year aquatic ecology 1 year consulting 2 years' field survey
Dr Joel Huey Principal Geneticist | Manager of Molecular Systematics	Genetic analysis	PhD Molecular Ecology BSc (Hons) Environ. Science Ecology and Conservation	18 years' molecular / ecology 4 years' consulting 18 years' field survey
Dr Rachel Meissner Senior Botanist	Riparian flora IDs	PhD Environmental Science BSc Environmental Science	27 years' botany 8 years' consulting 25 years' field survey

3.2 Licences

Aquatic ecology sampling was conducted under appropriate Department Biodiversity, Conservation and Attractions (DBCA) and Department of Primary Industries and Resource Development (DPIRD) licences (Table 3.2). Animal ethics was certified under Licence U244/ 2022-2024 and Permit RW 3354/21.

Table 3.2: Licence and exemption information under which the current survey was undertaken

Type	Licence Number	Valid	Issued To
DBCA Fauna Taking (Biological Assessment Regulation 27)	BA27000290-3	17/03/2023 - 16/03/2024	Jessica Delaney
DBCA Flora Taking (Biological Assessment Regulation 62)	FB62000428	5/05/2022 - 4/05/2025	Kim Nguyen
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 Survey included sampling in two seasons; the Dry 2023 and the Wet 2024. The Dry 2023 survey was undertaken between the 1st and 4th of September 2023. Average maximum temperature (33.7 °C) in September 2023 was 3.2 °C warmer than the long-term average maximum for the month (BoM, 2024). In the months preceding the Survey, Newman received 8.8 mm of rain in June 2023 which was below the long-term average of 15.8 mm, and there was no rainfall between July and September 2023 (Figure 3.1).

In January 2024, a high intensity fire passed through the Survey Area, burning much of the vegetation across the area previously classified as a high significance GDE, near MarC1 (Biologic, 2022a, 2022d), with the extent of the fire impacting the creek as far downstream as Flat Rocks (near MarC6). The Wet 2024 survey was undertaken between the 8th and 11th of March 2024, approximately two months post-fire. Average maximum daytime temperature for March 2024 (34.1 °C) was 1.5 °C cooler than the March long-term average maximum temperature. Newman received 188 mm of rainfall in January 2024, considerably greater than the long-term average for the month (67.7 mm), followed by minimal rain in February (0.4 mm compared to the long-term average of 71.6 mm). Total rainfall in March 2024 (104 mm) was more than two times the long-term average for the month (40.8 mm), with 88.4 mm falling in the two days prior to the Survey (Figure 3.2). An additional 5.4 mm of rain fell during the Survey.

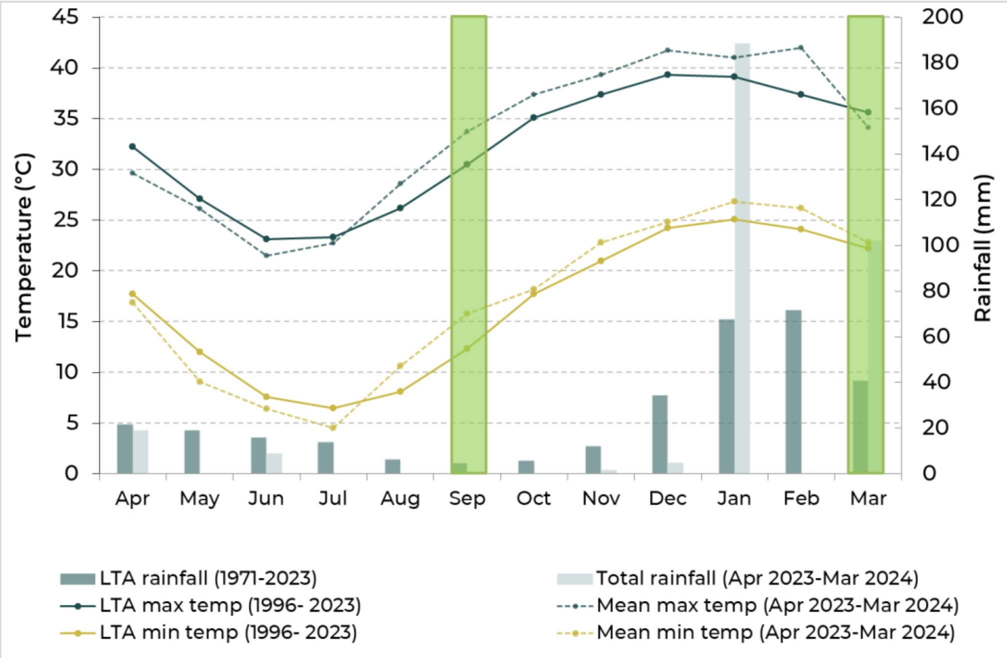


Figure 3.1: Total and long-term average monthly temperature (°C) and rainfall (mm) recorded from the Newman Aero BoM gauging station in the months preceding the Marillana Creek aquatic surveys

Green bars indicate wet and dry season survey timing.

The Flat Rocks gauging station (GS; station number 505011) is located on Marillana Creek approximately 18 km north-west of the Survey Area (DWER, 2024). Like Newman Aero, rainfall recorded from Flat Rocks GS was below average in 2023. A total of 11.4 mm was recorded in June 2023, compared to the monthly average rainfall of 23.3 mm (Figure 3.2). Much of Marillana Creek was dry at the time of the Dry 2023 survey, though surface water was present at some locations within the Survey Area. In the months prior and during the Wet 2024 survey, the Flat Rocks GS recorded above average rainfall in January and March, with 78.2 mm falling five days prior to the survey (Figure 3.2). Surface water pools were present across the Survey Area, with some sites (MarC1 and MarC3) flowing at the time of sampling.

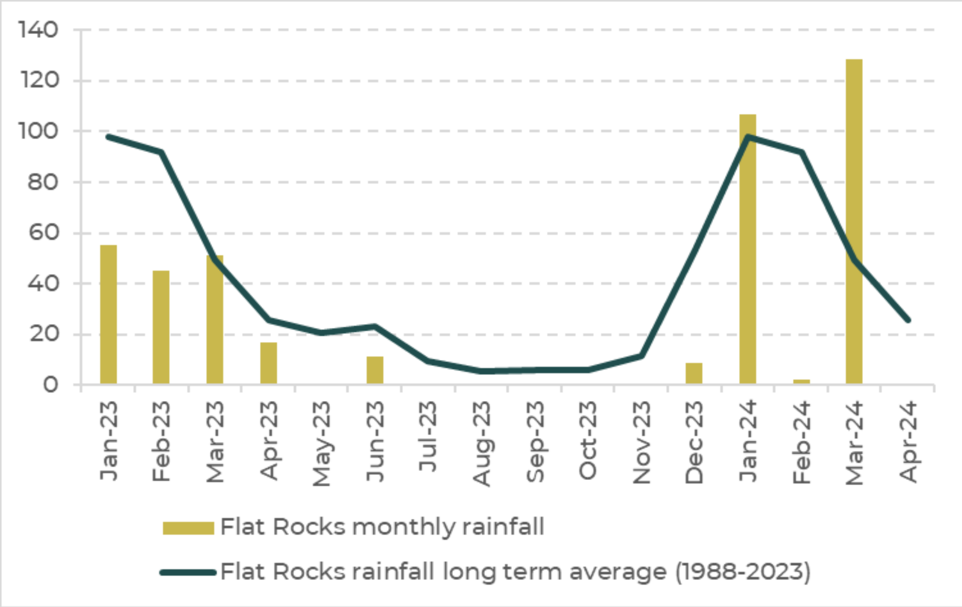


Figure 3.2 Monthly rainfall data (mm) at the DWER Flat Rocks GS on Marillana Creek, including monthly totals between Jan-23 and Apr-24 and long-term averages (1988-2023)

Long-term average annual streamflow at Flat Rocks GS on Marillana Creek (station number 708001) is 6,996 ML (1988 – 2020). In 2023, total streamflow at Flat Rocks GS was 5.8 ML, more than 1,000 times below the long-term average. 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 low streamflow recorded in 2023 is a direct response to the below average annual rainfall in 2023 (189.2 mm compared to the long-term average of 405.8 mm) (DWER, 2024). Consecutive dry years can also influence streamflow, with higher rainfall required to maintain surface water expression. In previous years, the Flat Rocks GS recorded an annual total rainfall of 322.4 mm and 354.4 mm in 2021 and 2022, respectively.

3.4 Sampling Design

A total of 12 sites were sampled in each season, six in the Survey Area and six Reference sites located elsewhere (Table 3.3 and Figure 3.3). In the Dry 2023, all previously established sampling locations (MarC1 through to MarC6) were dry. However, pools within 1 km of MarC6 were inundated at the time, and were targeted for sampling using the full suite of aquatic ecosystem sampling methods (named MarC6a and MarC6b). Sediment samples were collected from MarC1 through to MarC6 to allow rehydrate-emergence trials to be undertaken in the laboratory, and provide information on aquatic ecosystem values in the absence of water at these long-term sampling sites. In the Wet 2024, all sites except MarC5 held water and were successfully sampled. A pool approximately 200 m downstream from the original MarC5 was sampled in its place (MarC5a).

A brief description of each site is provided below.

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 Since the Dry 2021, additional sites downstream of MarC6 have been added to the program when established monitoring sites are dry (MarC6a and MarC6b).

Reference Sites

- MAC Reference 1 (MACREF1): permanent pools and riffle sequences located on a tributary of Jugaricoogina Creek, between the BHP WAIO MAC operations to the southwest and BHP WAIO Jugari operations to the north. Located approximately 11 km southeast of the Survey Area.
- MAC Reference 2 (MACREF2): series of permanent pools and riffles located on Marillana Creek, upstream of the confluence with the un-named tributary and just outside the Survey Area.
- Weeli Wolli Spring (WWS): spring site on Weeli Wolli Creek, within the Weeli Wolli Spring Priority 1 Priority Ecological Community (PEC). Located 31 km to the southeast of the Survey Area.
- Ben's Oasis (BENS): spring site on Weeli Wolli Creek which represents the second occurrence of the Weeli Wolli Spring Priority 1 PEC. Located 41 km southeast of the Survey Area.
- Munjina Spring (MUNJS): a spring site located on Munjina Creek, within the Priority 2 PEC: *Riparian flora and plant communities of springs and river pools with high water permanence of the Pilbara*. This site was not able to be accessed in the Dry 2020 or Wet 2021, but has been sampled consistently since the Dry 2021.
- 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 (Table 3.3 and Figure 3.3).

Table 3.3: Site information and sampling effort during the Survey

Type	Creek/System	Site	Site Code	Dry 2023	Wet 2024
Survey Area	Tributary 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	×	d
		Marillana Creek 5a	MarC5a	-	✓
		Marillana Creek 6	MarC6	×	✓
		Marillana Creek 6a	MarC6a	✓^	-
		Marillana Creek 6b	MarC6b	✓^	-
Reference	Marillana Creek	Mining Area C Reference 2	MACREF2	✓^	✓^
	Tributary of Jugaricoogina Creek	Mining Area C Reference 1	MACREF1	✓	✓^
	Weeli Wolli Creek	Weeli Wolli Spring	WWS	✓	✓
		Bens Oasis	BENS	✓	✓
	Munjina Creek	Munjina Spring	MUNJS	✓^	✓^
	Davis River	Skull Springs	SS	✓	✓

✓ full suite of methods completed
^ no hypo due to substrate
× dry at time of sampling, but flora sampled and sediments collected for rehydration-emergence trials
d dry at time of sampling, not sampled
- not sampled

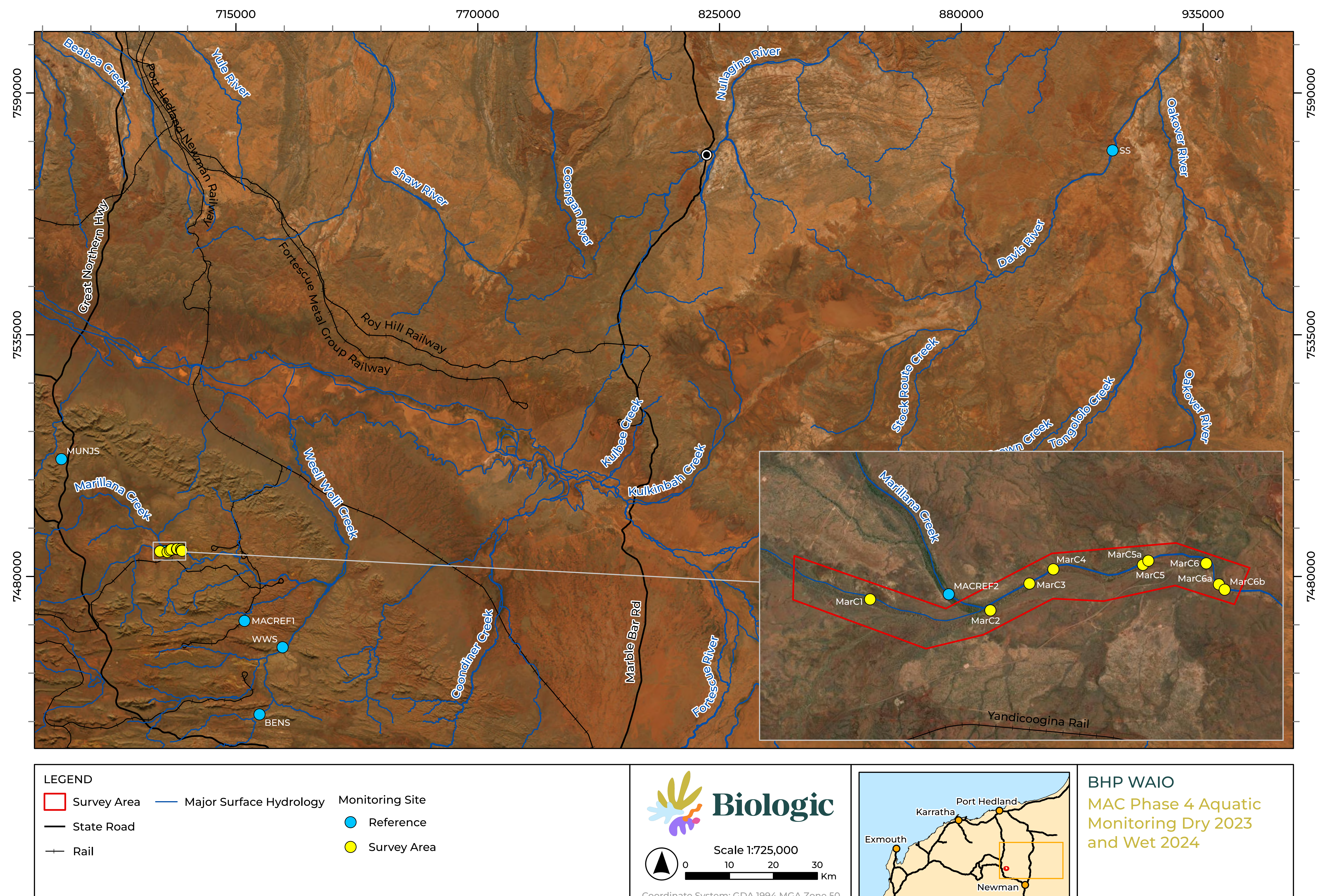


Figure 3.3: Monitoring sites

3.5 Sampling Components and Methods

For aquatic ecology surveys, ANZG (2018) and Smith *et al.* (2020) recommend sampling multiple lines of evidence across the pressure-stressor-ecosystem receptor (PSER) causal pathway to provide confidence in survey conclusions. Therefore, the following environmental and biological indicators were sampled:

- Habitat assessment
- Water quality (Plate 3.1)
- Macrophytes and dominant riparian vegetation
- Hyporheic fauna
- Macroinvertebrates, including micro-crustacea (Plate 3.2)
- Rehydration trials on sediments collected from dry sites (Plate 3.3 and Table 3.3)
- Fish
- Other vertebrate aquatic and semi-aquatic fauna recorded or observed over the course of sampling.

Detailed descriptions of sampling methods are provided in Appendix A.

Plate 3.1: Water quality sampling methods (Dry 2023, MarC6a)

Plate 3.2: Macroinvertebrate sampling methods (Wet 2024, MarC2)

Plate 3.3: Sediment collection and rehydrates trial tank set up (Dry 2023, MarC2 and MarC4)

3.6 Data Analysis

3.6.1 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 guideline values (DGVs) for the protection of aquatic ecosystems in the tropical north-west of Western Australia (see Appendix B for DGVs). For this purpose, sites sampled in the Survey 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). As the Survey Area is currently impacted by cattle and other land use activities, data for stressors (pH, DO, EC and turbidity) were compared against DGVs for slightly-moderately disturbed ecosystems (equivalent to 95% species protection DGVs). Toxicants (nutrients and dissolved metals) were compared to the 95% toxicity DGVs, while toxicants that may bioaccumulate (i.e. dSe) were assessed against the 99% toxicity DGVs.

3.6.2 Macrophytes

The classification of GDVs in Western Australia is broad and lacks a clear definition or repeatable framework between scientists. As discussed in section 2.3, GDVs are known to include obligate phreatophytes such as *Melaleuca argentea* and facultative phreatophytes such as *Eucalyptus camaldulensis*. While this broadly outlines the potential for GDV, the inclusion of hydrophytic and mesophytic understorey species in GDE classification systems, provides a more detailed picture of potential significance of a GDE.

To create a streamlined approach to GDV classification, Biologic has defined an assessment framework which combines botanical expertise based on years of field experience in riparian environments, published articles, presentations on GDVs, and discussion with other botanical and ecohydrological experts. This assessment framework is provided in Appendix C.

Generally, this framework defines the presence of GDV and then rates the dependence on groundwater through species composition and density cover. This dependence rating is based on a five-point scale; High, Moderate, Low, Negligible and None. The classification of ‘High’ indicates high soil moisture availability, very likely to be from a perennial source, as confirmed by the taxa present. Classification of ‘Low’ indicates soil moisture availability is more likely to be ephemeral. Negligible to None refers more to the riparian systems that would rely on surface flows to support habitat. The GDV assessment framework considers the following factors:

- The presence, density and maturity of four key indicative phreatophytes; *Melaleuca argentea* (obligate phreatophyte), *Eucalyptus camaldulensis* (facultative phreatophyte), *Eucalyptus victrix* (facultative phreatophyte to vadophyte) and *Sesbania formosa* (obligate to facultative phreatophyte)
- The presence, diversity and density of indicative hydrophytes and mesophytes and their relative reliance on groundwater (Appendix C)

- The structure of the vegetation with respect to obligate phreatophytes, facultative phreatophytes, hydrophytes and mesophytes. For example, a woodland of *Eucalyptus camaldulensis* is more dependent on groundwater presence (the woodland structure requires more groundwater for persistence) compared to scattered trees
- The presence of water bodies and an assessment of their permanence
- Broad understanding on the geology and creek morphology (i.e., presence of calcrete which may be slowly leaking groundwater into the creek).

It should be noted that a GDV unit may be assigned an overlapping rating (e.g., Moderate to Low) due to the presence of semi-mature obligate phreatophytes, increased diversity or varying densities of mesophytes and hydrophytes across the GDV unit.

3.6.3 Invertebrates

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

- Stygobite – obligate groundwater species, with special adaptations to survive such conditions such as small size, elongated body, lack of eyes, and loss of body pigmentation.
- Permanent hyporheos stygophiles - is a permanent inhabitant of the hyporheic zone.
- 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 and do not have specialised adaptations 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 D). 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 – taxon 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.

3.6.4 Fish

Analysis of population structure and age-class distribution provides a way of characterising recruitment, the health of local fish assemblages, and therefore the environmental conditions present which can support or impede recruitment. Therefore, length-frequency analysis was undertaken for three freshwater fish species which were recorded within the Survey Area (spangled perch, western rainbowfish, and Pilbara tandan). This involved classifying each species 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 3.4).

Table 3.4: Standard lengths used for age class analysis for each species

	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

3.6.5 Univariate Statistics

Univariate statistics were undertaken on selected water quality analytes, habitat characteristics (percent macrophyte cover), invertebrate fauna and fish data. Changes in macrophyte cover over time were examined using linear regression. Two-way ANOVA was conducted to determine whether there were any significant differences in water quality concentrations, habitat cover, invertebrate richness (hyporheic fauna and macroinvertebrate fauna) and/or fish abundance between site types (Survey Area and Reference) and sampling event (including all previous survey data). For all water quality analytes, concentrations below the limit of detection (LOD) were halved to allow for their inclusion in the analysis.

Prior to undertaking the invertebrate comparisons, the datasets first had to be amalgamated, and taxonomy aligned, to ensure any differences in taxonomic knowledge over time was appropriately accounted for. Micro-crustacea collected in baseline zooplankton datasets were included in the macroinvertebrate fauna analyses.

3.6.6 Multivariate Statistics

Water quality data were 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. Water quality data were appropriately treated prior to analysis, including transformations (natural log) where appropriate, normalising the data, and removing collinear variables.

Macroinvertebrate assemblage structure was 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). Two-factor PERMANOVA was undertaken to test for significant differences in macroinvertebrate assemblages between site type (Survey Area and Reference) and sampling event. SIMPER analysis was then conducted to determine which species were contributing most to the differences between sample periods.

The relationship between macroinvertebrate assemblages and environmental characteristics (water quality and in-stream habitat data) was assessed using the BVSTEP routine in PRIMER. This analysis searches for the highest correlation between a fixed sample similarity matrix (biotic data) and environmental variables, with the aim of finding variables influencing the species assemblages the most (Anderson *et al.*, 2008). BVSTEP is useful where there are too many variables to undertake an exhaustive search (i.e. BIOENV), and instead conducts a step-wise procedure to determine the optimal set. BVSTEP was undertaken on data from the Survey Area alone, in order to assess which environmental variables were influencing macroinvertebrate assemblages within the Survey Area. Environmental data was appropriately treated prior to analysis, as described above.

4 Results

4.1 Habitat Assessment

Riparian vegetation across the Survey Area was characterised by an open overstorey of *Eucalyptus camaldulensis*, *Melaleuca argentea* and *Melaleuca glomerata* over *Cyperus vaginatus* (Table 4.1 and Appendix E). Weeds were present throughout, but were not in high diversity, density, or abundance. Lowering water levels and pool drying resulted in all six long-term monitoring sites being dry in the Dry 2023 (MarC1 to MarC6, inclusive). Surface water was present at all Reference sites in the dry season, though levels were notably receded at one site (BENS; Table 4.1). Due to the recent rainfall prior to the Wet 2024 survey, pools were inundated at most Survey Area sites (except MarC5), with some flowing sections of creek present at this time. A pool approximately 200 m downstream of the long-term monitoring site MarC5 was found to be inundated and sampled instead (MarC5a; Table 4.1). Reference sites were similarly flushed and full at the time of the Wet 2024 survey, with flooding at BENS. Impacts to the Survey Area from the January fire were obvious, including a reduction to complete loss of understorey, burnt and dead trees, and layers of ash near the banks.

Although several GDV taxa were present in the Survey Area, vegetation condition was variable. Stands of *M. argentea* showed signs of stress and decline in the Dry 2023, particularly at MarC3 and MarC4. Macrophytes such as *Typha domingensis* and *Schoenoplectus subulatus* were dead or dying at several sites. In the Wet 2024, the fire had burnt most understorey vegetation and much of the overstorey. Some epicormic regrowth was present on trees, and small immature annuals had recently emerged.

While most pools in the Survey Area were dominated by transmissive substrates such as pebbles and gravel, bedrock was dominant at MarC3, MarC5, MarC6a and MarC6b. MarC4 and MarC6 were mostly clay and gravel. At Reference sites, bedrock was dominant at MACREF1 and MUNJS, while MACREF2 was predominantly clay. All other Reference sites consisted of more transmissive sediments, including pebbles, gravel and sand.

At MarC6a and MarC6b, in-stream habitat diversity was high in the Dry 2023, comprising complex heterogenous substrates with which to support aquatic fauna, such as submerged and emergent macrophytes, LWD, algae and detritus. However, most of the Survey Area was dry, providing little habitat for aquatic fauna at this time, and suggesting MarC6a and MarC6b provide important refuges. Habitat diversity was low in the Wet 2024, with open sediment the most dominant habitat type at all Survey Area sites. Reference sites were comparable or had greater habitat diversity to Survey Area sites and generally showed little seasonal change. The exception was BENS in the Dry 2023, where pool size was the smallest on record since the course of the baseline monitoring period (Biologic, 2022a, 2023a, 2024b). BENS was in flood during the Wet 2024 sampling.

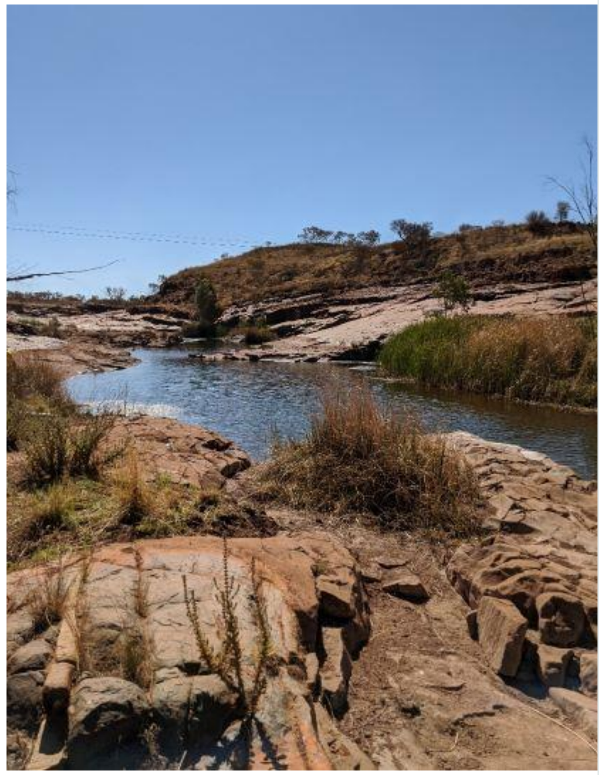
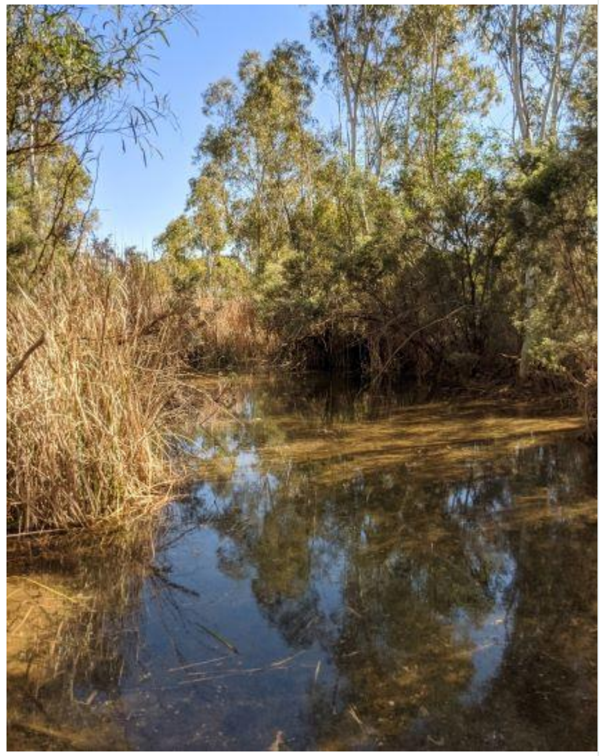
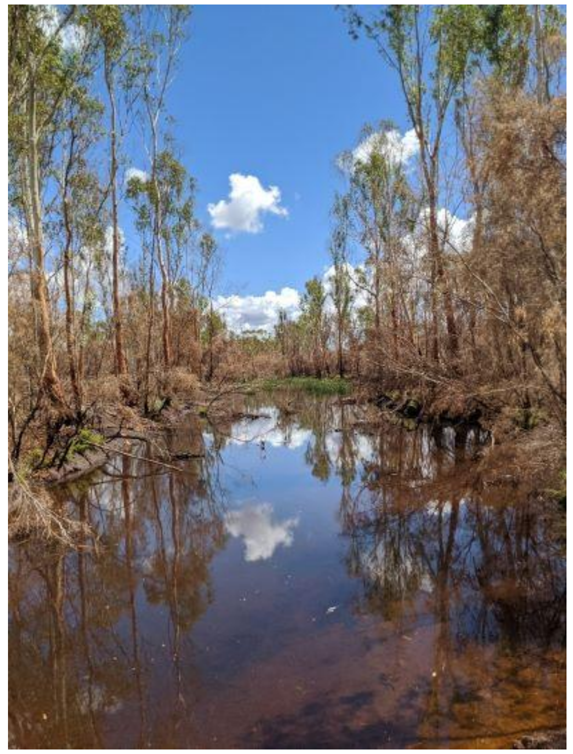
Table 4.1: Site descriptions including site photographs

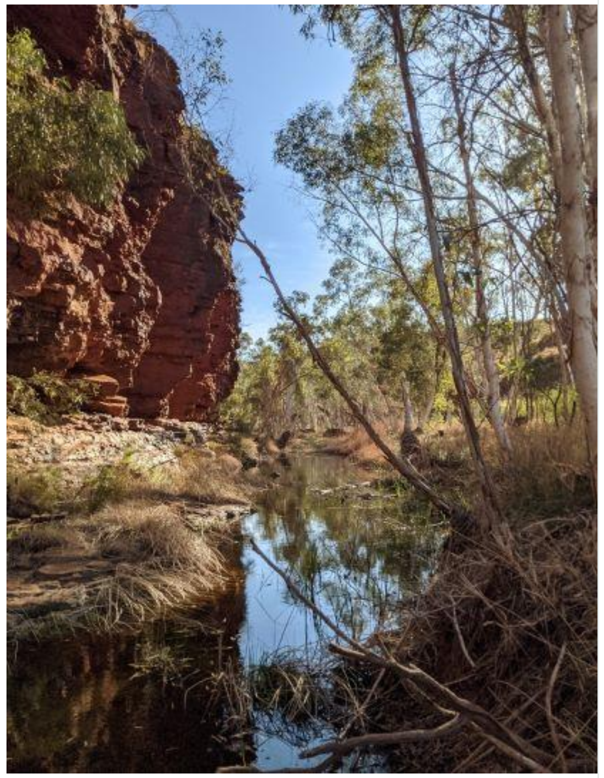
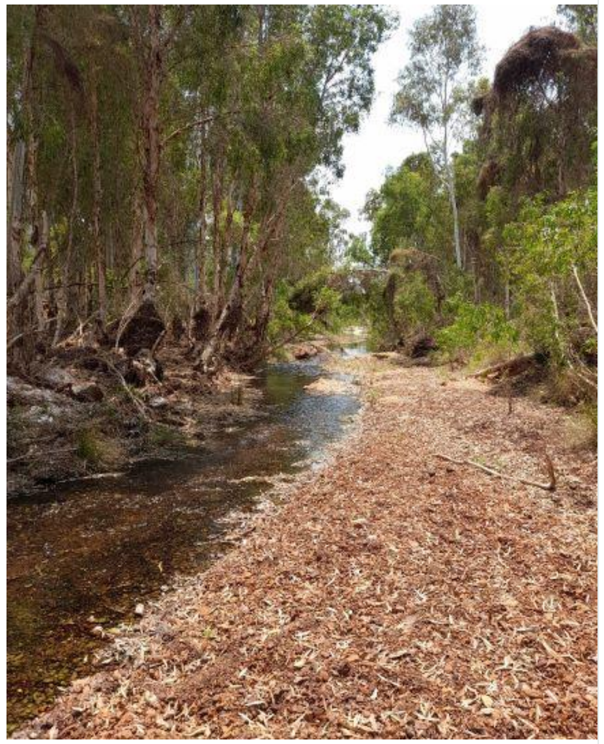
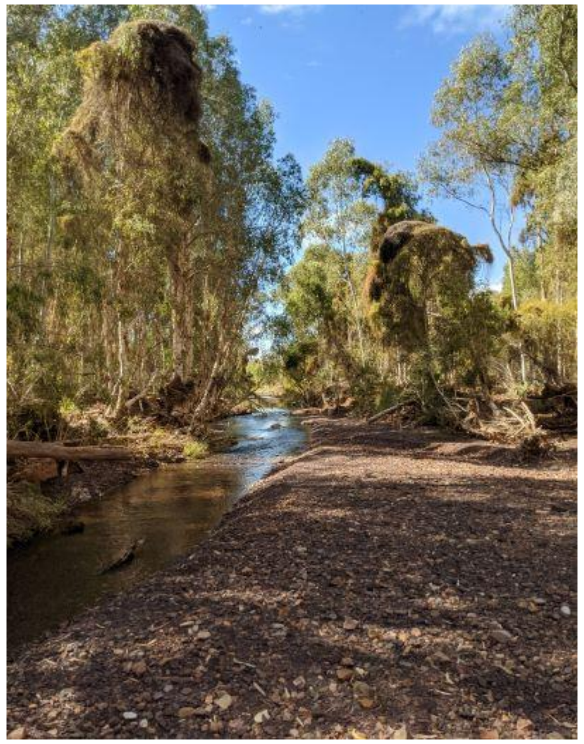
Site	Pool type	Site description	Pool size	Maximum depth	Site photographs	
					Dry 2023	Wet 2024
MarC1 (tributary)	Small pools	Series of ephemeral, shallow pools and riffles located on an un-named tributary of Marillana Creek. Open overstorey of *Melaleuca argentea*, *M. glomerata*, *M. bracteata* and *Acacia* spp. In-stream habitat comprising emergent macrophytes (*Cyperus vaginatus*), 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 Dry 2023 survey. *Typha domingensis* and *Schoenoplectus subulatus* were present, but dead. *Eleocharis geniculata* and submerged charophytes that had been recorded on previous baseline surveys (Biologic, 2024b) were absent in both seasons. In the Wet 2024, flowing riffles were present, connecting small shallow pools.	Dry 2023 = dry Wet 2024 = 50 m x 7 m.	Dry 2023 = dry Wet 2024 = 0.5 m.		
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 detritus, LWD, roots and trailing vegetation. Mineral substrate predominately comprised gravel and clay, with some sand, silt, cobbles and pebbles also present. Site was dry at the time of the Dry 2023 survey, with stands of *Typha domingensis* all dead. In the Wet 2024, most of the riparian vegetation was burnt, removing all emergent macrophyte cover. Epicormic growth was present on some trees. A layer of ash covered the banks.	Dry 2023 = dry Wet 2024 = 80 m x 13 m.	Dry 2023 = dry Wet 2024 = 0.6 m.		

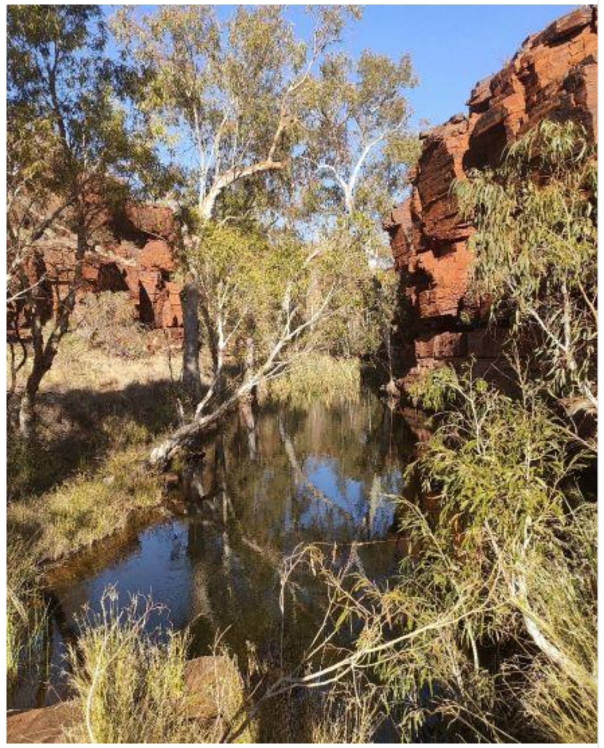
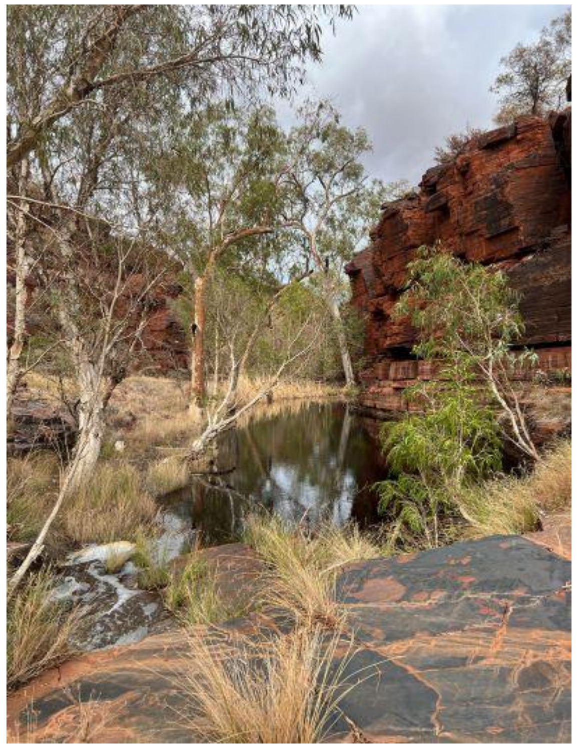
Site	Pool type	Site description	Pool size	Maximum depth	Site photographs	
					Dry 2023	Wet 2024
MarC3	Long pool	Long open pool over bedrock. *Eucalyptus camaldulensis*, *E. victrix*, *Melaleuca argentea*, *M. glomerata* and *M. bracteata* present. Predominantly open sediment with some algae, LWD, detritus, roots, and trailing vegetation. Substrate was dominated by bedrock with some gravel, pebbles, cobbles, boulders, silt, sand and clay. Site was dry in the Dry 2023. *M. argentea* showed continued signs of decline that was noted in previous baseline surveys (Biologic, 2024b), and Typha stands were dead. In the wet season, much of the vegetation had been burnt by the January fire, and remaining trees and shrubs were in poor condition. Surface water was present in the Wet 2024 and flowing in some sections.	Dry 2023 = dry Wet 2024 = 85 m x 5 m.	Dry 2023 = dry Wet 2024 = 0.8 m.		
MarC4	Small pool	A small semi-permanent pool. Riparian vegetation consisted of *Eucalyptus camaldulensis*, *Melaleuca argentea*, *M. bracteata* and *M. glomerata*. In-stream habitat comprised open sediment with some detritus, LWD and trailing vegetation. Mineral substrate primarily clay, with sand, silt, gravel, pebbles and some bedrock. The site was dry in the Dry 2023, with trees such as *Melaleuca argentea* and *Typha* stands continuing to decline as noted in previous baseline surveys (Biologic, 2022a, 2022b, 2024b). In the Wet 2024, most of the riparian vegetation had been burnt away, with a layer of ash present along the creek bank.	Dry 2023 = dry Wet 2024 = 70 m x 40 m.	Dry 2023 = dry Wet 2024 = 1.3 m.		

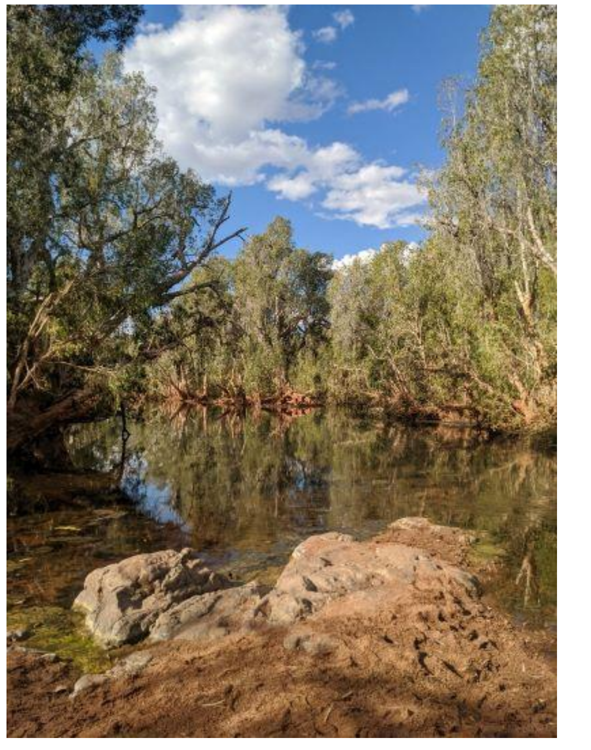
Site	Pool type	Site description	Pool size	Maximum depth	Site photographs	
					Dry 2023	Wet 2024
MarC5	Small pool	Series of semi-permanent, shallow pools. Riparian vegetation including *Eucalyptus camaldulensis*, *Melaleuca argentea*, *M. bracteata* and various *Acacia* spp. This site was dry at the time of the Survey, and sediments collected in the Dry 2023 for rehydration trials. In the Wet 2024, a long pool was present ~200 m downstream and sampled in its place.	Dry 2023 = dry Wet 2024 = dry.	Dry 2023 = dry Wet 2024 = dry.		
MarC5a	Long pool	Long, turbid pool located ~200 m downstream of original site. Riparian vegetation including *Eucalyptus camaldulensis*, *Melaleuca argentea*, *M. bracteata* and *Acacia* spp. In-stream habitat predominantly open sediment, with some algae, detritus, LWD, roots and trailing vegetation. Mineral substrate mostly bedrock and clay with a high amount of silt, as well as gravel, pebbles, cobbles and sand. The effects of the fire were obvious, with several burnt trees and ash along the banks. Unburnt vegetation was in poor condition.	Dry 2023 = not sampled Wet 2024 = 80 m x 15 m.	Dry 2023 = not sampled Wet 2024 = 1.0 m.	Not sampled	

Site	Pool type	Site description	Pool size	Maximum depth	Site photographs	
					Dry 2023	Wet 2024
MarC6	Small pool	Semi-permanent pool known 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 Jugari operations (WRM, 2018). Riparian vegetation comprised *Eucalyptus camaldulensis*, *Melaleuca argentea*, *M. glomerata*, *M. bracteata* and *Acacia coriaceae* subsp. *pendens*. In-stream habitat dominated by open sediment and detritus, with small amounts of LWD. Substrate comprised clay, gravel, cobbles, pebbles, sand, silt and bedrock. Site was dry in the Dry 2023. In the Wet 2024, vegetation was severely burnt, with most of the overstorey removed. Very few understorey plants were present, though some annuals such as *Arivela viscosa* were recorded. Epicormic growth was present on trees and shrubs.	Dry 2023 = dry Wet 2024 = 100 m x 17 m.	Dry 2023 = dry Wet 2024 = 1.5 m.		
MarC6a	Permanent creek pool	The upstream end of a large permanent bedrock pool, located downstream of MarC6 within the Survey Area and upstream of the active BHP Jugari 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. Sampled in the Dry 2023, as all the long-term monitoring sites in the Survey Area were dry.	Dry 2023 = 50 m x 11 m Wet 2024 = not sampled.	Dry 2023 = 1.5 m. Wet 2024 = not sampled.		Not sampled

Site	Pool type	Site description	Pool size	Maximum depth	Site photographs	
					Dry 2023	Wet 2024
MarC6b	Permanent creek pool	The downstream end of a large permanent bedrock pool, located downstream of MarC6 within the Survey Area and upstream of the active BHP Jugari 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. Sampled in the Dry 2023 only, as the rest of the Survey Area was dry.	Dry 2023 = 80 m x 13 m Wet 2024 = not sampled.	Dry 2023 = 1.5 m Wet 2024 = not sampled.		Not sampled
MACREF2	Permanent creek pool	Long series of permanent pools and riffle sequences on Marillana Creek, located upstream of the confluence with the un-named tributary. Likely groundwater fed. 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 comprised bedrock, pebbles, gravel, sand, silt, and clay. Little seasonal change in habitat types, despite obvious impacts from the January fire.	Dry 2023 = 40 m x 7 m Wet 2024 = 54 m x 9 m.	Dry 2023 = 0.7 m Wet 2024 = 0.7 m.		

Site	Pool type	Site description	Pool size	Maximum depth	Site photographs	
					Dry 2023	Wet 2024
MACREF1	Permanent creek pool	Series of permanent pools and riffles on a tributary of Jugaricoogina 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* sp.), 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 2024 survey. Submerged macrophytes and charophytes recorded during previous baseline surveys were absent in the Wet 2024. The highly invasive weed *Bidens bipinnata* was recorded in the Wet 2024.	Dry 2023 = 100 m x 4 m Wet 2024 = 135 m x 11 m.	Dry 2023 = 1.0 m Wet 2024 = 1.4 m.		
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. WWS is a Priority 1 PEC. 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. Open sediment with LWD and detritus present. Substrate comprising primarily gravel, pebbles, sand, and cobbles. *WWS was within continually flowing sections of creekline and therefore pool length was recorded as a maximum of 200 m.	Dry 2023 = 200* m x 5 m Wet 2024 = 200* m x 7 m.	Dry 2023 = 1.5 m Wet 2024 = 1.7 m.		

Site	Pool type	Site description	Pool size	Maximum depth	Site photographs	
					Dry 2023	Wet 2024
BENS	Spring	Series of pools and riffles on Weeli Wolli Creek, upstream of the main spring. Second occurrence of the WWS PEC. 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 Dry 2023 were the lowest recorded during MAC surveys. Highly turbid in the Wet 2024 due to the recent rainfall and flooding. *BENS in the Wet 2024 was within continually flowing sections of creekline and therefore pool length was recorded as a maximum of 200 m.	Dry 2023 = 65 m x 12 m Wet 2024 = 200* m x 15 m.	Dry 2023 = 0.5 m Wet 2024 = 1.5 m.		
MUNJS	Permanent creek pools	A series of long permanent pools over bedrock, with numerous riffle sections. Likely groundwater fed. 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 2023. Mineral substrate almost exclusively bedrock overlain by silt and organics.	Dry 2023 = 150 m x 7 m Wet 2024 = 250 m x 11 m, including main pool and riffle sections upstream	Dry 2023 = 2.5 m Wet 2024 = 2.0 m.		

Site	Pool type	Site description	Pool size	Maximum depth	Site photographs	
					Dry 2023	Wet 2024
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*). *SS was within continually flowing sections of creekline and therefore pool length was recorded as a maximum of 200 m.	Dry 2023 = 200* m x 10 m Wet 2024 = 200* m x 18 m.	Dry 2023 = 2.0 m Wet 2024 = 0.6 m.		

4.1.1 Habitat Change Over Time

Change in macrophyte cover (%) was examined using linear regression. In the Survey Area, there was a significant negative relationship recorded, with declining submerged macrophyte cover over time at MarC1, MarC3 and MarC4 (Table 4.2 and Figure 4.1). This negative relationship was also evident at MarC2, MarC5 and MarC6, although the decline was not significant at these sites (Table 4.2). Submerged macrophyte cover was more variable at Reference sites, with no relationship over time at WWS and weak negative correlations recorded from SS and MACREF2 (Table 4.2). A decline was recorded from both MACREF1 and BENS, although the correlation was only significant at MUNJS (Table 4.2; Figure 4.1).

Table 4.2: Summary of macrophyte cover (%) regression r-values

Type	Site	Submerged macrophyte		Emergent macrophyte	
		r-value	*p*-value*	r-value	*p*-value*
Survey Area	MarC1	-0.77	0.025	-0.42	0.306
	MarC2	-0.67	0.072	-0.55	0.160
	MarC3	-0.93	<0.001	-0.75	0.030
	MarC4	-0.73	0.041	-0.39	0.337
	MarC5	-0.64	0.088	-0.04	0.921
	MarC6	-0.68	0.065	-0.12	0.782
Reference	MACREF2	-0.44	0.270	-0.67	0.070
	MACREF1	-0.71	0.050	-0.64	0.086
	WWS	0	N/A	-0.37	0.365
	BENS	-0.63	0.093	-0.81	0.015
	MUNJS	-0.80	0.018	-0.32	0.434
	SS	-0.28	0.501	0.66	0.075

*Significant *p*-values in red

A negative relationship between percent emergent macrophyte cover and time was also recorded from MarC2 and MarC3 in the Survey Area (Figure 4.2), although this was only significant at MarC3 (Table 4.2). The relationship between emergent macrophyte cover and time was weak at all other Survey Area sites (r ≤ 0.42; Table 4.2). At Reference sites, a declining trend in emergent macrophyte cover was recorded from MACREF2, MACREF1, and BENS (r ≥ 0.64; Figure 4.2). However, this correlation was only significant at BENS (Table 4.2). One Reference site (SS) experienced an increase in emergent macrophyte cover over time (r = 0.66), although this correlation was not significant (Table 4.2; Figure 4.2).

Figure 4.1: Submerged macrophyte cover (%) regression showing change in cover over time

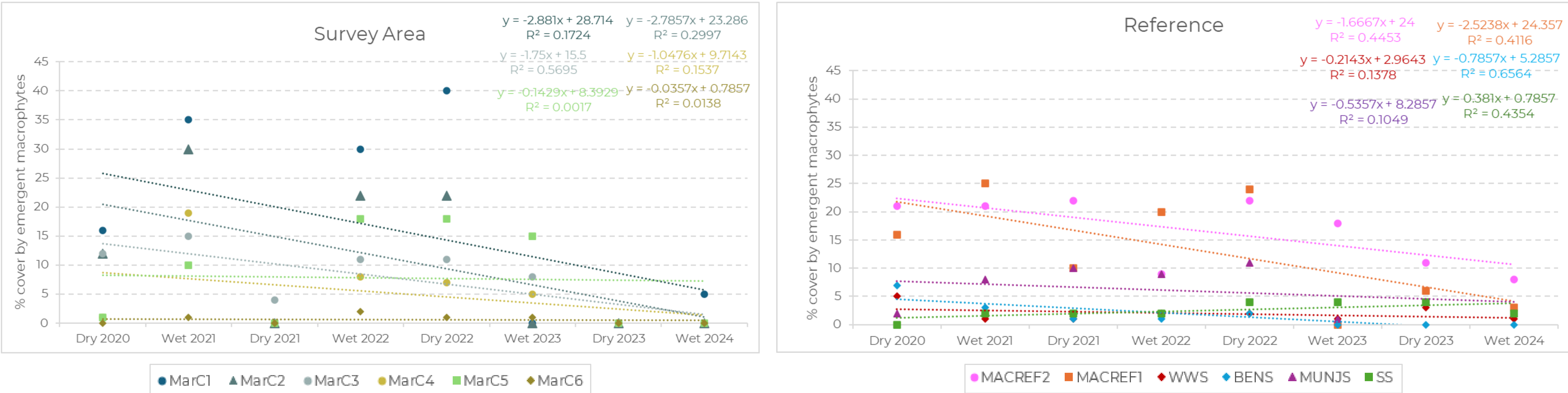


Figure 4.2: Emergent macrophyte cover (%) regression showing change in cover over time

4.2 Water Quality

4.2.1 In situ

Where water was present, electrical conductivity (EC) was variable across the Survey Area, ranging from fresh[2] (135.1 µS/cm at MarC5a in the Wet 2024) to brackish (1,967 µS/cm at MarC3 also in the Wet 2024; Figure 4.3 and Appendix F). Reference sites recorded a greater range in EC, from fresh (92.1 µS/cm at BENS in the Wet 2024) to saline (3,540 µS/cm; MACREF2 Wet 2024). EC values indicated most sites were fresh, except Survey Area sites MarC2 and MarC4 (Wet 2024) which were brackish, and Reference sites WWS (Dry 2023), MUNJS (Wet 2024) and MACREF2 (both seasons). EC at MACREF2 was saline (3,540 µS/cm; Figure 4.3). Nearly all sites recorded EC in excess of the ANZG (2018) DGV (> 250 µS/cm) in both seasons. The exceptions were MarC5a and MarC6 in the Survey Area, and Reference site BENS, all of which recorded low EC below the DGV in the Wet 2024 (Figure 4.3).

Surface waters were circum-neutral to basic in the Survey Area (7.29 at MarC2 and MarC4 in the Wet 2024 to 8.45 at MarC6a in the Dry 2023; Figure 4.3). Reference sites ranged from slightly acidic (6.94 at MACREF1 in the Wet 2024), to slightly basic (8.11 at MACREF2 in the Dry 2023). Most Survey Area sites fell within the ANZG (2018) DGVs, with the exception of MarC6a and MarC6b in the Dry 2023, and Reference MACREF2 in the Wet 2024 (Figure 4.3). These values exceeded the upper DGV, were slightly basic and not considered to be of ecological concern.

DO was highly variable between sites and seasons (Figure 4.3; Appendix F). Within the Survey Area, DO ranged from 15.6 % (at MarC2 in the Wet 2024) to 98.9% (at MarC6b in the Dry 2023). DO in Reference sites varied between 24.0% (at MACREF1 in the Wet 2024) and 102.9% (at MACREF2 in the Dry 2023). DO fell below the lower DGV (< 85%) at nearly all sites in both seasons, including almost all Reference sites in the Dry 2023 (except MACREF2), and all Survey Area sites and most Reference sites in the Wet 2024 (except BENS; Figure 4.3).

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[2] Salinity categories are based on the Department of Water and Regulation (DWER) classification system, where fresh/marginal < 1,000 mg/L (~1,500 µS/cm), brackish = 1,000 mg/L – 2,000 mg/L (~1,500 µS/cm to 3,000 µS/cm), saline = 2,000 mg/L – 10,000 mg/L (~ 3,000 µS/cm – 15,000 µS/cm), and hypersaline > 10,000 mg/L (> 15,000 µS/cm) (Mayer et al., 2005).

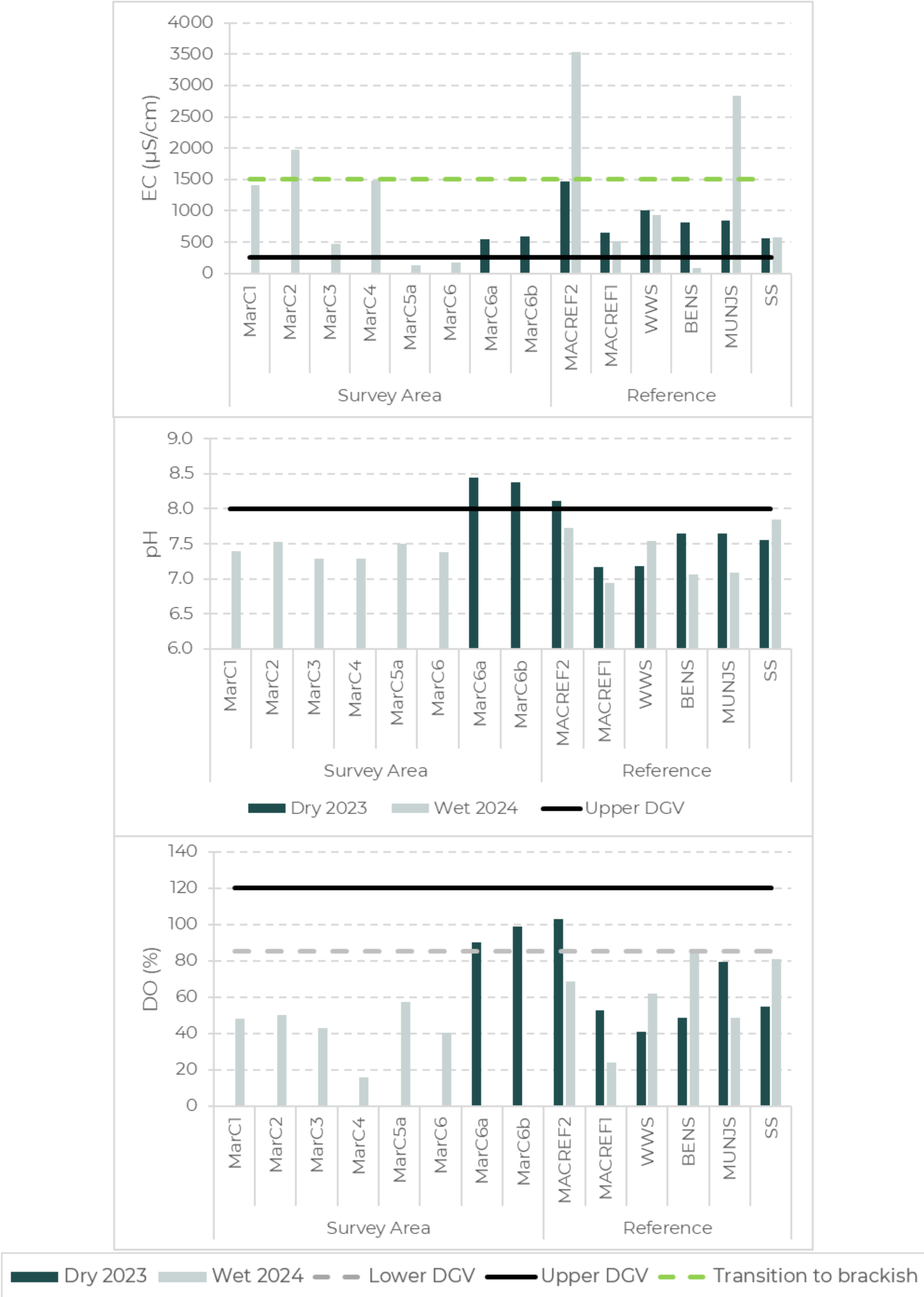

Figure 4.3: In situ water quality concentrations recorded during the Survey

4.2.2 Ionic Composition and Alkalinity

In the Dry 2023, the downstream pools in the Survey Area were dominated by Na cations, closely followed by Mg, and HCO_3 anions. In the Wet 2024, Na was the dominant cation at all sites, except MarC5a and MarC6, where Ca was dominant (Appendix F). HCO_3 was generally the dominant anion at Survey Area sites in both seasons, except Mar1, MarC2 and MarC3 in the Wet 2024, where Cl was dominant. Ionic composition at Reference sites was variable, with WWS, BENS and SS dominated by Ca and HCO_3, but MUNJS dominated by Na and Cl. Ionic composition at MACREF2 varied between seasons, from Na and HCO_3 dominance in the Dry 2023, to Na and Cl in the Wet 2024 (Appendix F).

Alkalinity was generally high, indicating good buffering capacity. Nearly all Survey Area and Reference sites recorded alkalinity greater than 100 mg/L, with the exception of Survey Area sites MarC5a and MarC6, and Reference site MUNJS in the Wet 2024 (Appendix F).

4.2.3 Water Clarity

Pools in the Survey Area and at Reference sites were clear in the Dry 2023, with low turbidity. In the Wet 2024, turbidity was more variable, with five sites recording values greater than the ANZG (2018) DGV of 15 NTU (Survey Area sites MarC2, MarC5a and MarC6, and Reference sites MACREF1 and BENS). The greatest turbidity was recorded from MarC5a in the Wet 2024 (497 NTU), which was more than 33 times the DGV (Appendix F).

4.2.4 Nutrients

N_NH_3 concentrations were low, and below the ANZG (2018) 95% toxicity DGV at both Survey Area and Reference sites. The only exception was MarC3 in the Wet season (1.26 mg/L compared to the DGV of 0.9 mg/L; Appendix F). N_NO_3 concentrations were also generally low and below the 95% toxicity DGV. However, there were two exceedances, both of which were from the Survey Area in the Wet 2024, at MarC3 (3.86 mg/L) and MarC4 (3.17 mg/L).

Most sites recorded high N_NO_x concentrations, in excess of the eutrophication DGV, in both the Dry 2023 (MarC6b, MACREF2, WWS, BENS and SS) and Wet 2024 (MarC1, MarC2, MarC3, MarC4, MarC5a, MarC6, WWS, BENS and SS; Figure 4.4). N_NO_x was notably high at Survey Area sites MarC3 (4.13 mg/L) and MarC4 (3.17 mg/L) in the Wet 2024. At MarC3 it was more than 400 times the eutrophication DGV (of 0.01 mg/L).

Total N concentrations were also high in the Survey Area. Concentrations greater than the ANZG (2018) eutrophication DGV (0.30 mg/L) were recorded from all Survey Area sites in both seasons (Figure 4.4). Total N at MarC3 was particularly high, being more than 18 times the DGV in the Wet 2024. At Reference sites, total N exceeded the DGV at one site in the dry season (SS) and two sites in the wet (MACREF1 and MUNJS).

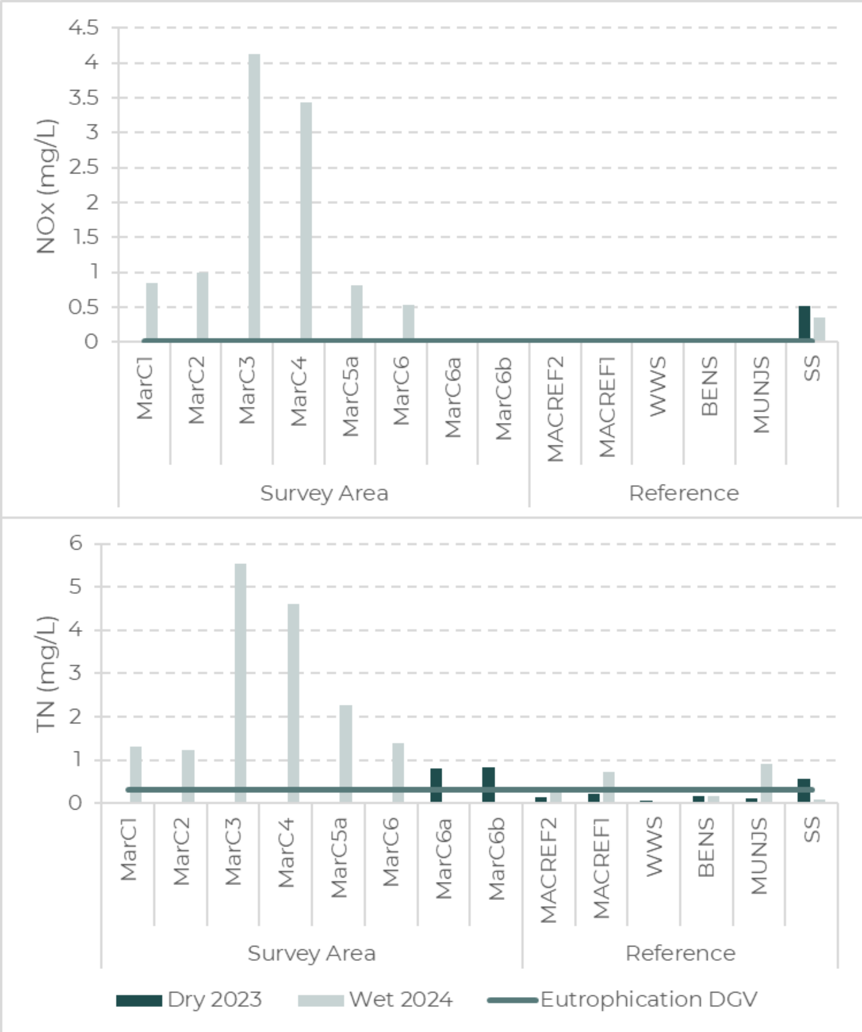

Figure 4.4: Nitrogen nutrient concentrations recorded during the Survey

Total P concentrations were high at all sites in both seasons. All values were in excess of the ANZG (2018) eutrophication DGV. In the Dry 2023, total P ranged from 0.01 mg/L (Reference site WWS) to 0.027 mg/L (Reference site MACREF1). Total P concentrations in the Wet 2024 ranged from 0.01 mg/L (Reference site SS) to 0.275 mg/L (MarC5a in the Survey Area; Appendix E).

4.2.5 Dissolved Metals

Dissolved metal concentrations were generally low at both Survey Area and Reference sites, in both seasons, with several analytes recording concentrations below LODs at most, if not all sites (i.e., dCd, dNi, dPb, dZn). However, some dissolved metals were recorded in concentrations greater than 95% toxicity DGVs at some sites. Such dissolved metals included:

- dAl – elevated at MarC5a and MarC6, and Reference site MACREF1 in the Wet 2024
- dCr –at MarC5a and MarC6 in the Wet 2024
- dCu – all Survey Area sites, and at Reference sites MACREF1 and BENS, in the Wet 2024.

4.2.6 Water Quality Change Over Time (Dry 2020 to Wet 2024)

4.2.6.1 In situ

In early sampling events, average EC in the Survey Area was greater than that of Reference sites, with much of the Survey Area being brackish and saline on one occasion (Figure 4.5). Since the Wet 2023, the reverse has been true, with average EC now slightly higher at Reference sites than the Survey Area. Overall, there was no significant difference in EC between site type (Two-way ANOVA; df = 1, p = 0.081), but there was between sampling events (df = 7, p= 0.024). Although the Tukey's post-hoc test could not locate the significant difference, lowest average EC was recorded in the Dry 2023 and highest in the Dry 2021. There was a significant interaction between sampling events and site type, due to the difference in change over time between site types (df = 7, p = 0.002; Figure 4.5).

Variability over time was also evident in pH, with higher average pH recorded from the Survey Area than Reference sites between the Dry 2020 and Dry 2022, but then slightly lower or similar pH since (Figure 4.5). Overall, pH was significantly higher in the Survey Area compared to Reference sites (Two-way ANOVA; df = 1, p = 0.002; Figure 4.5). There was also a significant difference between sampling events (df = 7, p = 0.028), but no significant interaction between these two factors. While the sampling event difference could not be located using the Tukey's post-hoc test, lowest average pH was recorded in the Wet 2024, and the highest was recorded in the Dry 2020.

There was no significant difference in DO saturation between site types (Two-way ANOVA; df = 1, p = 0.074), but there was between sampling events (df = 7, p = 0.011). Significantly lowest DO was recorded in the Wet 2023 and Wet 2024 (Figure 4.5). Due to the changes in highest DO over time between site types, the interaction between site type and sampling event was significant (df = 7, p = 0.046; Figure 4.5).

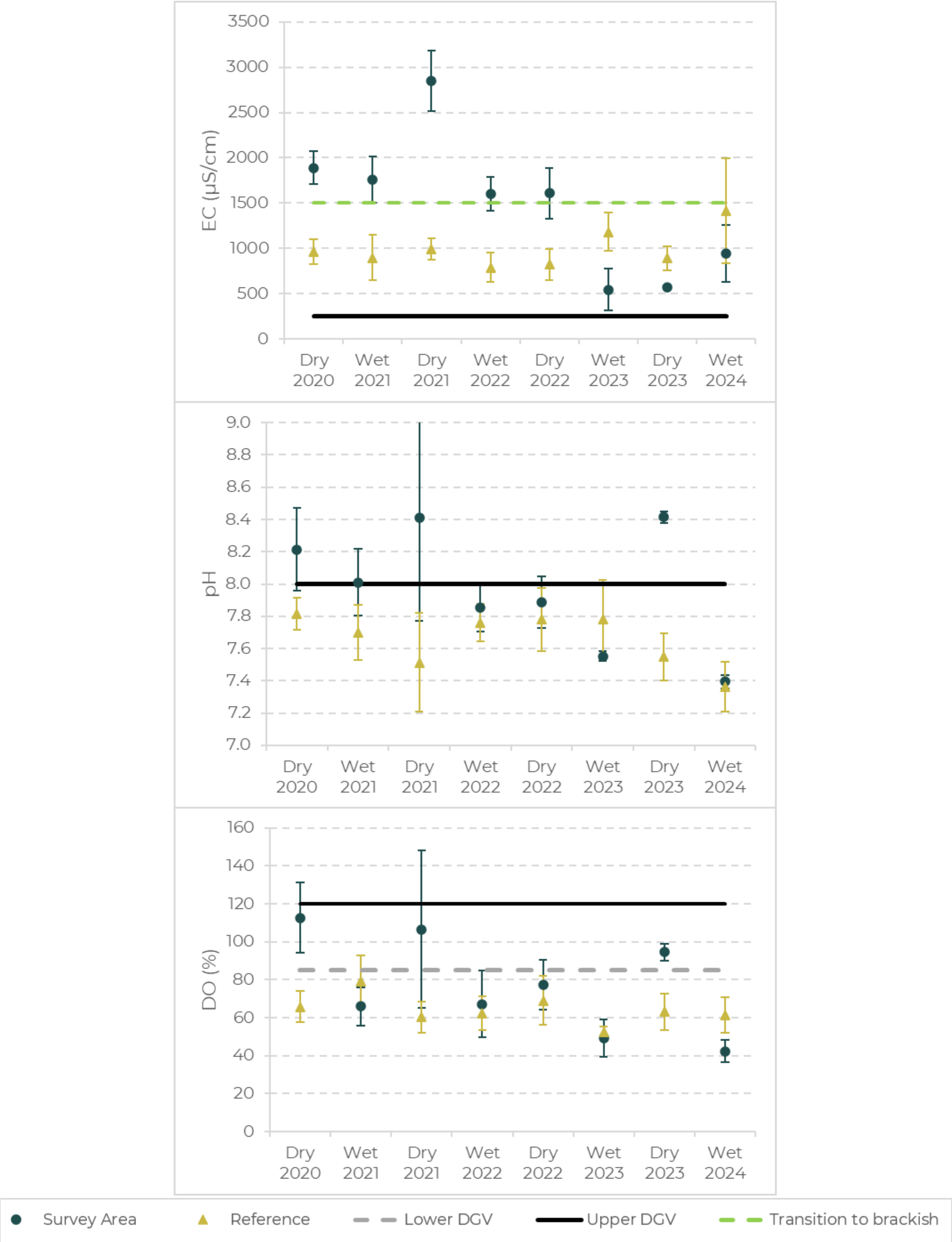

Figure 4.5: Average in-situ water quality parameters (± se)* recorded in each sampling event

*The Dry 2021 and Dry 2023 averages are based on two replicates, not six

4.2.6.2 Major ions

The concentrations of major ions showed markedly greater variation in the Survey Area compared to Reference sites, with Reference sites generally showing minimal change over time. Several ions recorded significant differences in average concentration between site type, with Na, Mg, K, Cl, and S_SO_4 all being significantly higher in the Survey Area than at Reference sites.

While alkalinity was not significantly different between site types (Two-way ANOVA; df = 2, p = 0.344), there was a significant difference between sampling events, with significantly lowest alkalinity recorded in the Wet 2023 and Wet 2024, and significantly highest alkalinity recorded in the Dry 2020 and Dry 2021 (df = 7, $p < 0.001$). There was also a significant interaction between sampling event and site type (df = 7, $p < 0.001$), suggesting that the change in average alkalinity over time was not consistent between site types.

4.2.6.3 Water Clarity

Turbidity was significantly higher in the Survey Area than Reference sites (Two-way ANOVA; df = 2, $p < 0.001$). There was also a significant difference in turbidity between sampling events (df = 7, $p = 0.001$), with significantly highest levels recorded in the Wet 2024. Interaction between site type and sampling event was not significant (df = 7, $p = 0.091$).

4.2.6.4 Nutrients

Concentrations of most nutrients (N_NH_3, N_NO_3 and N_NOx) were statistically similar between site type (Two-way ANOVA; df = 1, $p \geq 0.05$), but were significantly different between sampling events (df = 7, $p < 0.001$). Significantly highest concentrations of these nutrients were recorded in the Wet 2024 compared to all preceding sampling events (Figure 4.6). Both total N and total P concentrations were significantly higher in the Survey Area compared to Reference (Two-way ANOVA; df = 1, $p < 0.001$). There were also significant differences in total N and total P between sampling events, with concentrations from the Wet 2024 being significantly higher than all other sampling events (df = 7, $p < 0.001$; Figure 4.6). Significant interactions were recorded for both these analytes (df = 7, $p \leq 0.05$).

4.2.6.5 Dissolved metals

Including data from all sampling events, average concentrations of dAs, dB, dCo, dCu, dSe, dV and dZn were all significantly higher in the Survey Area than Reference sites (Two-way ANOVA; df = 1, $p \leq 0.05$). Variation between sampling events was also evident, with a high number of analytes recording significantly higher concentrations in the Wet 2024 compared to other sampling events. These dissolved metals were dAl, dAs, dCo, dCr, dCu, dFe, dSe, dV and dZn (df = 7, $p \leq 0.05$; Figure 4.7).

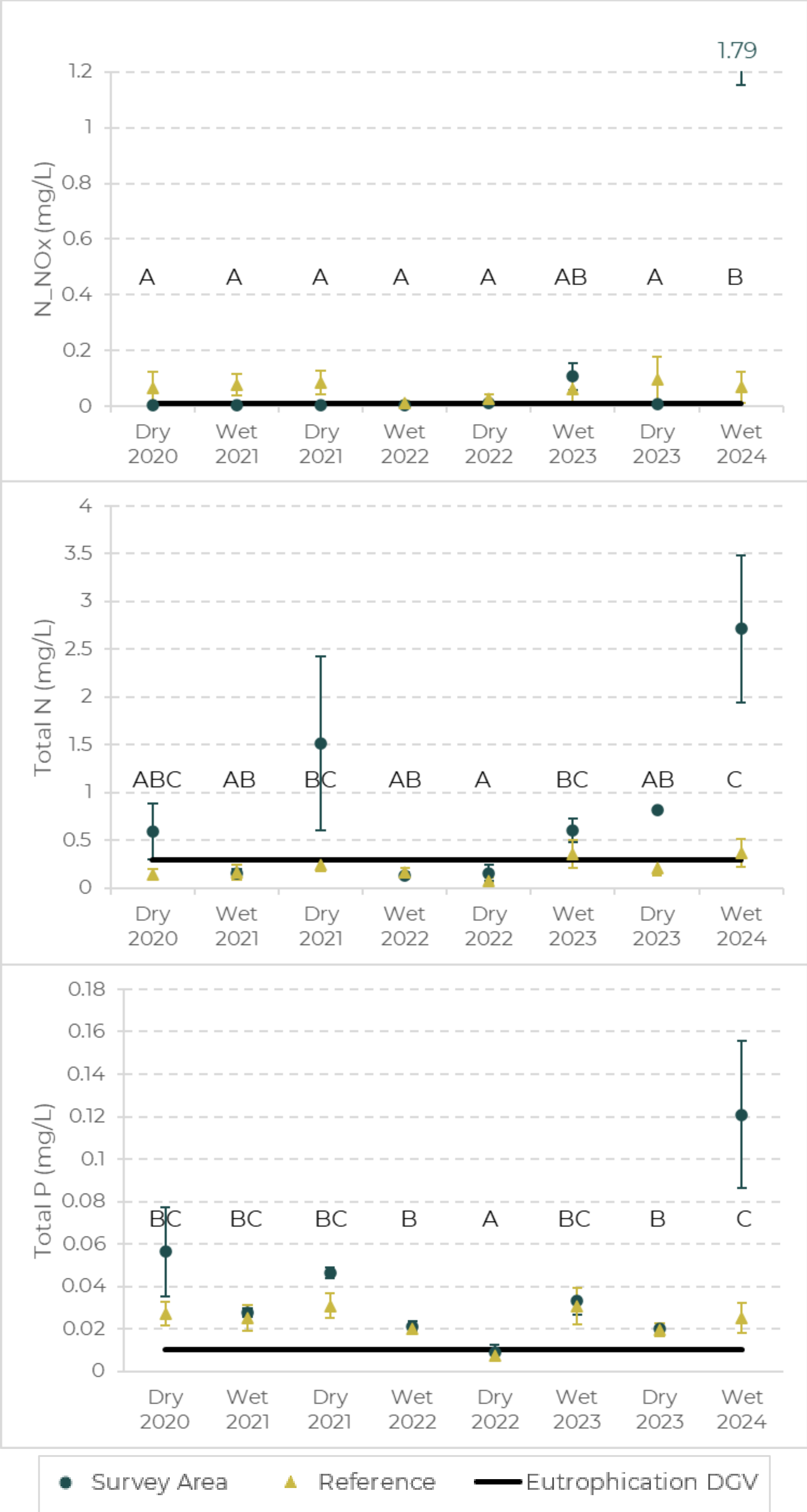

Figure 4.6: Average nutrient concentrations (± se)* recorded in each sampling event

*The Dry 2021 and Dry 2023 averages are based on two replicates, not six. Letters denote equal means (Tukey's post-hoc results)

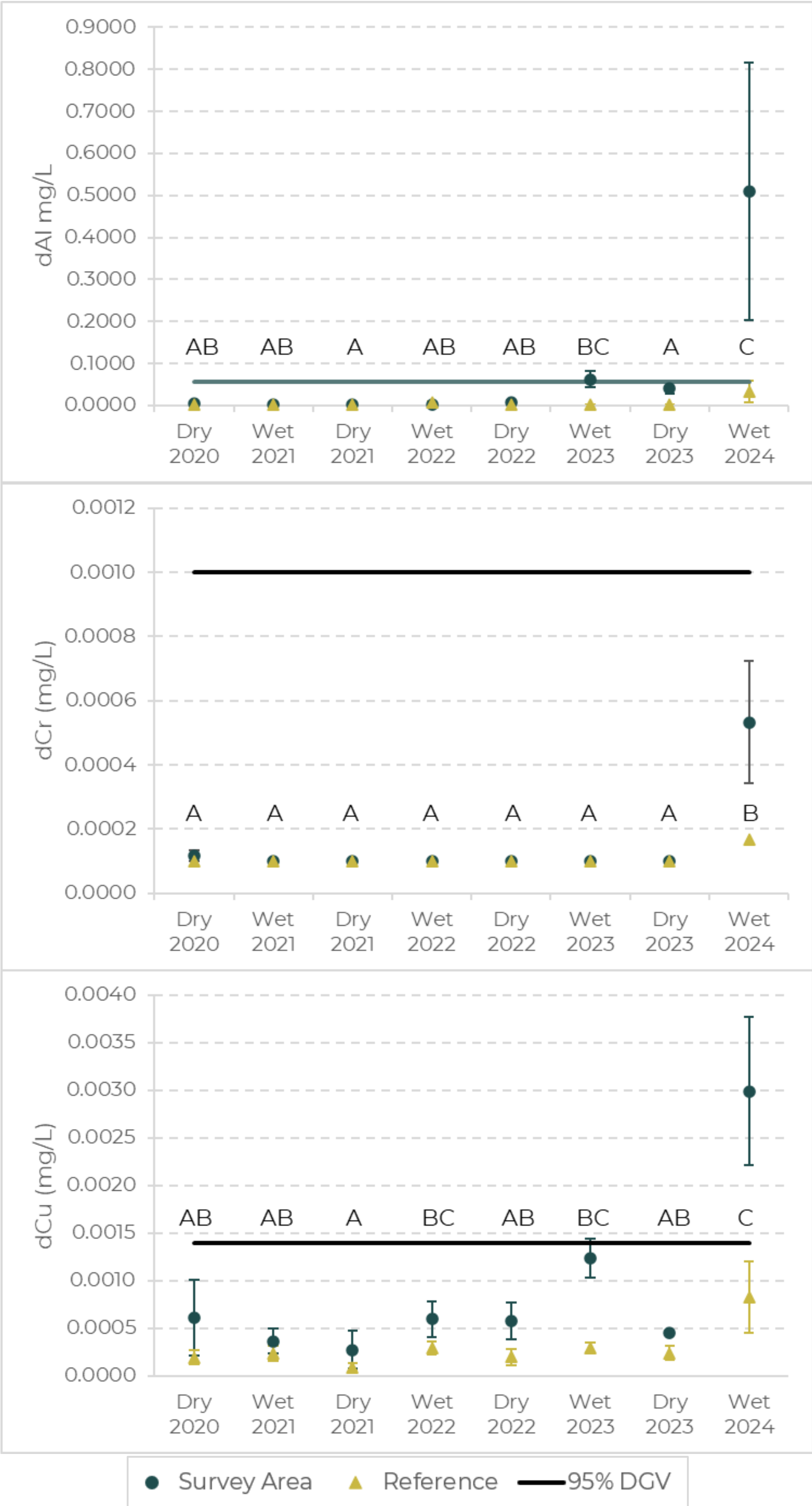

Figure 4.7: Average dissolved metal concentrations (± se)* recorded in each sampling event

*The Dry 2021 and Dry 2023 averages are based on two replicates, not six. Letters denote equal means (Tukey's post-hoc results)

4.2.6.6 Multivariate analysis

Unsurprisingly, most water quality samples collected from the Survey Area in the Wet 2024, sat apart from other sampling events in the PCA ordination. Reference sites generally showed minimal variation between sampling events and sites, with a relatively tight cluster of samples present within the ordination. Early samples from the Survey Area also fell within this cluster, indicating water quality was more similar to Reference sites in the earlier sampling events, but has become more different over time (Figure 4.8 and Figure 4.9).

Together, PC1 and PC2 explained over 45% of the variation amongst water quality samples (Table 4.3). Survey Area sites MarC3, MarC5a and MarC6 from the Wet 2024 separated from other samples along the PC1 due to higher turbidity, total N, and concentrations of dissolved metals (dAl, dCo, dCr, dCu and dNi). Samples also separated along PC2, with MarC6a in the Dry 2021 recording higher EC, alkalinity, dAs, dB and dMo, and MarC6a and MarC6b in the Wet 2023 having lower concentrations of these analytes (Figure 4.8 and Figure 4.9).

Table 4.3: PCA results of variation amongst water quality samples

Principal Component	Eigen value	% Variation	Cumulative % variation
1	7.86	28.1	28.1
2	4.83	17.2	45.3
3	2.76	9.9	55.2
4	2.05	7.3	62.5
5	1.52	5.4	67.9

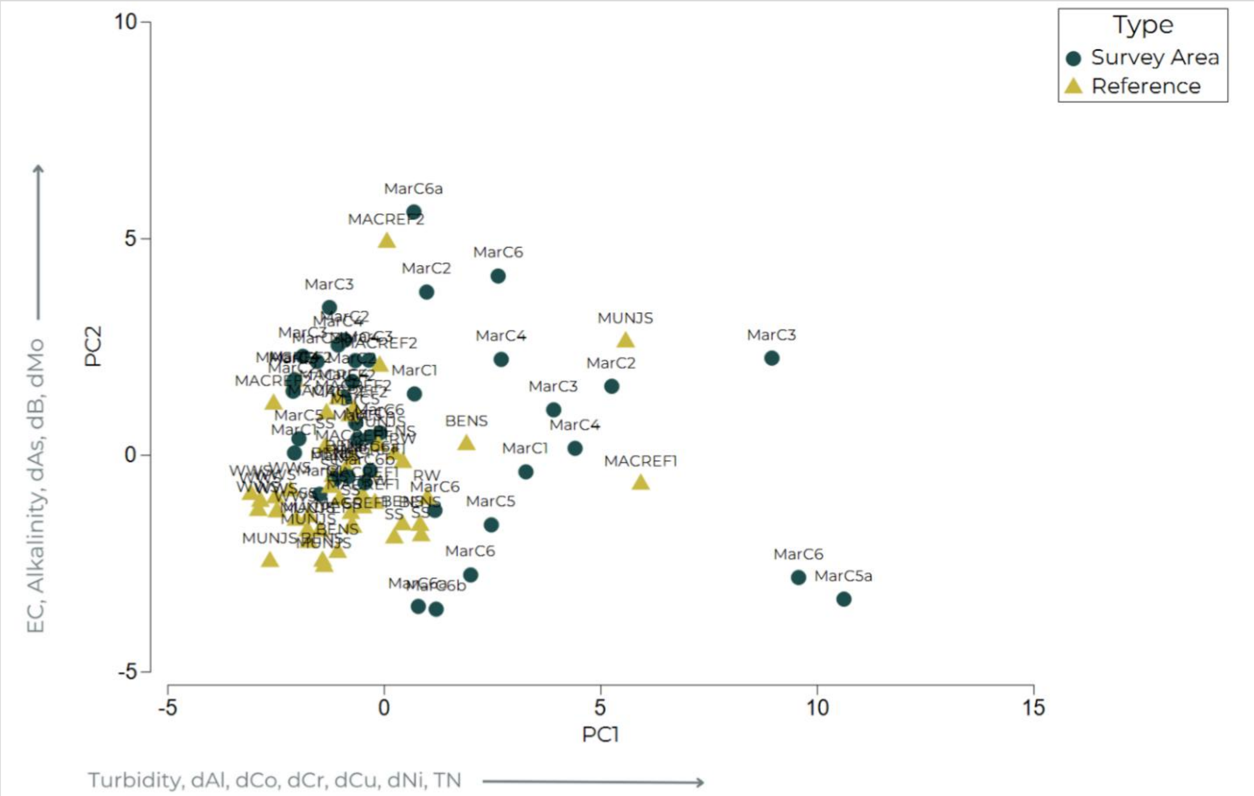

Figure 4.8: PCA of all water quality data, with samples identified by site type

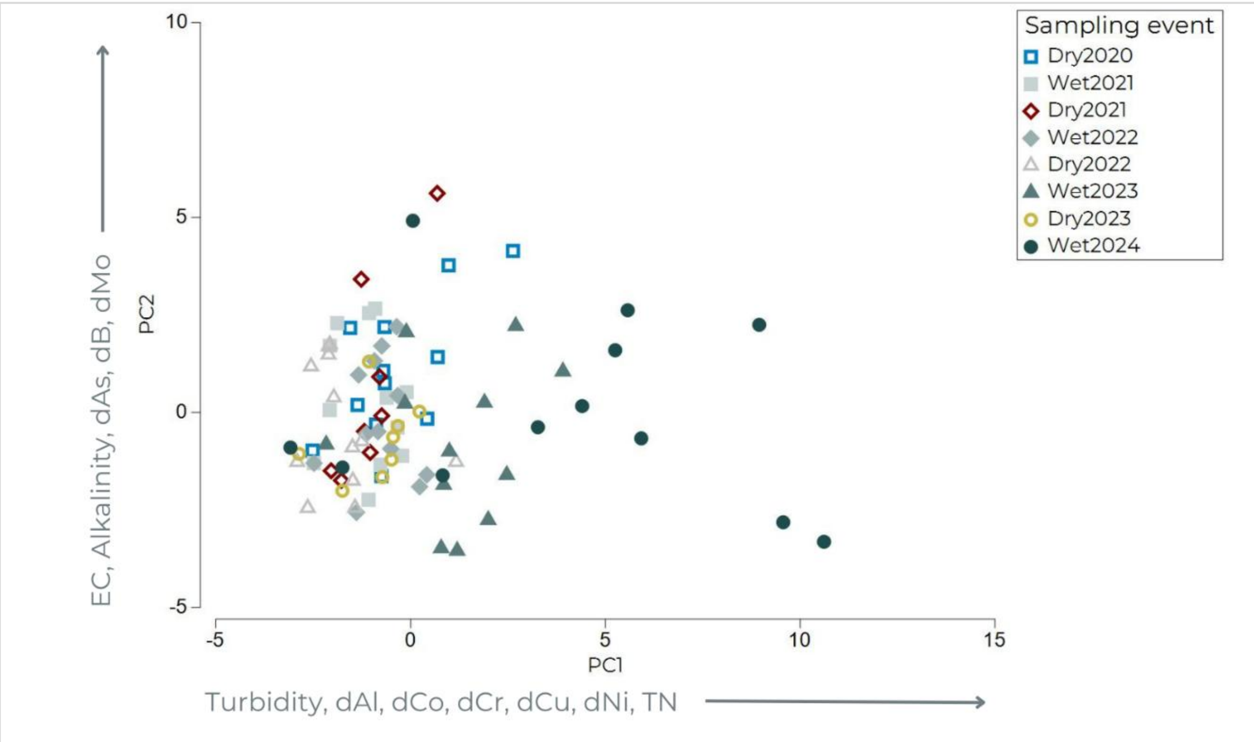

Figure 4.9: PCA of all water quality data, with samples identified by sampling event

4.3 Macrophytes

4.3.1 Macrophyte Taxa Composition and Richness

Overall floristic richness in the Survey Area ranged from nine (MarC6a) to 27 taxa (MarC2) (Appendix G). Floristic richness was generally lower in the Survey Area than Reference sites, where richness ranged from 23 to 41 taxa. Greatest richness was recorded from Reference site SS (Appendix G). Similarly, overall macrophyte and GDV indicator taxa richness was lower in the Survey Area compared to Reference sites. Submerged macrophytes were largely absent from the Survey Area, except at MarC6a and MarC6b in the Dry 2023.

Seven macrophytes were recorded from the Survey Area, comprising four emergent macrophytes and three submerged macrophytes (Appendix G). Emergent macrophytes included *Cyperus* sp., *Cyperus vaginatus*, *Schoenoplectus subulatus*, and *Typha domingensis*. Submerged macrophytes were *Chara* sp., *Najas marina* and *Potamogeton tepperi*.

Other dominant riparian flora species recorded from the Survey Area included the GDV indicator species *Melaleuca argentea*, *Eucalyptus camaldulensis* and *Eucalyptus victrix*. Herbs, shrubs and grasses associated with riparian landforms were also recorded in the Survey Area. Such taxa included *Melaleuca bracteata*, *Melaleuca glomerata*, *Pluchea dentex*, *Pluchea rubelliflora*, *Acacia ampliceps*, *Acacia coriacea* subsp. *pendens*, *Schenkia clementii*, *Stemodia grossa*, *Corchorus crozophorifolius*, *Sesbania cannabina* and *Gossypium sturtianum* var. *sturtianum* (Appendix G). In the Dry 2023, many of the trees and shrubs were in poor condition and showed signs of decline, while *Typha* stands and grasses had died. In the wet season, much of the vegetation across the Survey Area had been burnt by the fire in January, with some herbs starting to germinate and epicormic growth observed on eucalypts.

Reference sites supported six submerged macrophytes and 11 emergent macrophytes. Nearly all macrophytes and riparian vegetation recorded from the Survey Area were found at Reference sites. Additional species from Reference sites included *Lobelia arnhemiaca*, *Stylidium fluminense*, *Stylidium weeliwolli*, *Cullen leucanthum*, *Stylobasium spathulatum*, *Ammannia baccifera*, *Dodonaea lanceolata* var. *lanceolata*, *Machaerina rubiginosa*, *Schoenus falcatus*, *Imperata cylindrica*, *Eleocharis geniculata*, *Fimbristylis sieberiana*, *Cyperus cunninghamii* subsp. *cunninghamii*, *Cyperus difformis*, *Chara fibrosa*, *Vallisneria* sp., *Vallisneria nana* and *Potamogeton* cf. *tricarinatus*.

Macrophyte and GDV/GDE indicator taxa richness was greater at Reference sites than in the Survey Area, except BENS (Figure 4.10). The Survey Area was mostly absent of submerged macrophytes, except at sites MarC6a and MarC6b. Richness was lowest at site MarC4, where neither emergent nor submerged macrophytes were recorded in either season (Figure 4.10). The highest richness of macrophytes plus GDV/GDE indicator taxa was recorded from Reference site SS.

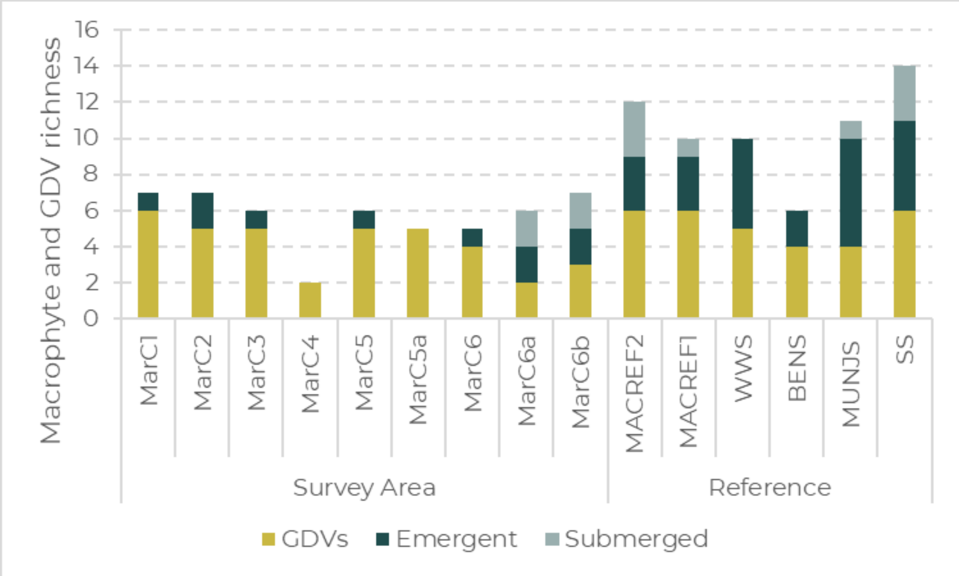

Figure 4.10: Macrophyte and GDV richness recorded from the Dry 2023 and Wet 2024

Where a macrophyte is also a GDE indicator species, it is indicated on the plot as a macrophyte. Only High to Moderate GDE indicator species were included in the total.

4.3.2 Groundwater Dependent Species

The presence of certain flora species can indicate consistently shallow groundwater and/or perennial surface water. The degree to which these species are associated with groundwater and therefore indicate a GDE, can be classified from Negligible to High (see Appendix C). Using this classification system, nine GDV/GDE indicator species were recorded from the Survey Area during the Survey, including two High and seven Moderate GDV/GDE indicator taxa (Table 4.4). In comparison, 29 GDV/GDE indicator species were recorded from Reference sites, including 13 High and 16 Moderate indicator taxa. The richness of GDV/GDE indicator taxa recorded from the Survey Area has declined over time (see section 4.3.5), with previous surveys reporting comparable GDV richness between the Survey Area and Reference sites (Biologic, 2022a, 2023a, 2024b).

Within individual sites in the Survey Area, the number of GDV/GDE indicator species ranged from two to five, with the greatest number recorded from MarC2. At least one High level indicator taxon was recorded in Survey Area sites, with the exceptions of MarC4 and MarC6a (Table 4.4). The number of GDV/GDE indicator taxa recorded from the Survey Area was generally lower than Reference sites, which ranged from six to 14 taxa. The greatest richness was recorded from SS (Appendix G).

Table 4.4: GDV/GDE indicator species present in the Survey Area in the Dry 2023 and Wet 2024

			Survey Area								
Indicator level	**Abundance level indicator**	**Taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC5a**	**MarC6**	**MarC6a**	**MarC6b**
High	Present	*Acacia ampliceps*	X	X	X		X	X	X		X
	Abundant	*Potamogeton tepperi*								X	X
		Total High	1	1	1	0	1	1	1	1	2
Moderate	Common	*Eucalyptus camaldulensis*	X				X		X		
	Present	*Melaleuca bracteata*	X	X	X			X	X		
	Present	*Schenkia clementii*				X					X
	Present	*Gossypium sturtianum* var. *sturtianum*	X	X		X					
	Abundant/Common	*Cyperus vaginatus* (abundant)	X								
	Present	*Schoenoplectus subulatus*								X	X
	Abundant	*Typha domingensis*								X	X
		Total Moderate	4	2	1	2	1	1	2	2	3
		Total Moderate-High level	**5**	**3**	**2**	**2**	**2**	**2**	**3**	**3**	**5**

NB: *Melaleuca argentea* were previously recorded as mature and abundant at sites MarC2, MarC3 and MarC5, resulting in an overall high significant GDE for these sections of Marillana Creek. While some *M. argentea* are still present (at MarC1, MarC2, MarC5 and MarC6a), they are no longer abundant, with many mature trees being negatively affected by lowering water levels and/or the fire. *M. argentea* that are present, but not highly abundant or mature are classified as Low Level GDE indicators.

4.3.3 Conservation Significant Flora

None of the flora species recorded from the Survey Area are conservation significant (Priority or Threatened, listed under the BC Act or the EPBC Act). However, two conservation significant flora species were recorded from Reference sites. These were *Stylidium weeliwolli* (P3) *and Fimbristylis sieberiana* (P3), both of which were recorded from Weeli Wolli Creek. *S. weeliwolli* was recorded from WWS and BENS, while *F. sieberiana* was found at WWS.

Stylidium weeliwolli is an annual herb that grows predominantly in sandy soils on watercourse edges and in wet areas. It is listed as a Priority 3 species as it is known only from a few populations in north-west Western Australia. Where it occurs, it can be locally abundant. *Fimbristylis sieberiana* is a rhizomatous, tufted perennial, grass-like sedge that grows in mud and skeletal soil pockets at pool edges and on sandstone cliffs. It is also a Priority 3 species and is known only from a few populations in the Pilbara and Kimberley.

4.3.4 Introduced Flora

Six introduced flora species were recorded from the Survey Area (Table 4.5). Common sowthistle, buffel grass and mimosa bush were the most widespread. Nine additional weeds were present at Reference sites, but were not found in the Survey Area (Table 4.5). None of the invasive plants are listed as Weeds of National Significance (WoNS), though buffel grass, spiked malvastrum and mimosa bush are considered to have a high level of ecological impact and invasiveness (DBCA, 2013) (Table 4.5).

Table 4.5: Weeds recorded in the current survey

Ecological impact and invasiveness	Taxon	Survey Area	Reference
High impact, rapid spread	Buffel grass (*Cenchrus ciliaris*)	MarC1, MarC5	MACREF1, WWS, SS
	Spiked malvastrum (*Malvastrum americanum*)		SS
	Mimosa bush (*Vachellia farnesiana*)	MarC1, MarC2, MarC5	BENS
Low impact, rapid spread	Black nightshade (*Solanum nigrum*)		MACREF1
	Common sowthistle (*Sonchus oleraceus*)	MarC4, MarC5, MarC6, MarC6b	MACREF1
Unknown impact, rapid spread	Mexican poppy (*Argemone ochroleuca* subsp. *ochroleuca*)		SS
	Bipinnate beggartick (*Bidens bipinnata*)		MACREF1
	Indian weed (*Sigesbeckia orientalis*)		BENS
Low impact, slow spread	Asthma plant (*Euphorbia hirta*)		WWS

Ecological impact and invasiveness	Taxon	Survey Area	Reference
Low impact, unknown spread	Indian hedge mustard (*Sisymbrium orientale*)	MarC6	
Unknown impact, unknown spread	Giant calotrope (*Calotropis gigantea*)		SS
	Flax-leaved fleabane (*Erigeron bonariensis*)		MACREF1, SS
	Speedy weed (*Flaveria trinervia*)	MarC4	
	Milk thistle (*Lactuca serriola*)		MACREF1, WWS
	Lesser swinecress (*Lepidium didymium*)	MarC4	

4.3.5 Macrophyte Change Over Time (Dry 2020 to Wet 2024)

Average GDV/GDE indicator taxa richness in the Survey Area was relatively stable over time, with Reference sites showing some variability between sampling events (Figure 4.11). Average richness at Reference sites showed some seasonal change, with slightly higher richness in the dry seasons, but with a substantial increase in the Dry 2023 (Figure 4.11). Overall, there was a significant difference in GDV/GDE indicator taxa richness between sampling events (Two-way ANOVA; $p < 0.001$;) and between site type ($p = 0.001$; Table 4.6). Average GDV/GDE indicator richness was significantly greater at Reference sites than the Survey Area. Between sampling events, GDV/GDE indicator richness was significantly highest in the Dry 2023, compared to all other sampling events (Figure 4.11).

Average macrophyte richness (emergent and submerged macrophytes) in the Survey Area was generally comparable to Reference sites in early sampling events, before declining sharply in the Wet 2023 onwards (Figure 4.11). A decline was also recorded at Reference sites from the Wet 2023 on, though it was not as pronounced as the Survey Area decline. Overall, macrophyte richness was significantly lower in the Survey Area than Reference sites (Two-way ANOVA; (p = 0.007). There was also a significant difference between sampling events, and a significant interaction term (Table 4.6). Macrophyte richness recorded in the Wet 2024 was significantly lower than the richness recorded in the Dry 2021, Wet 2021, Dry 2020, Wet 2022 and Dry 2022, but was statistically similar to the Dry 2023 and Wet 2023 (Figure 4.11). In this case, the significantly low average richness recorded in the Wet 2024, Dry 2023 and Wet 2023 was due to the notably low number of macrophyte taxa recorded from the Survey Area (Figure 4.11).

Table 4.6: Two-way ANOVA results comparing macrophyte taxa richness between sampling event and site type

Source	df	F	*p*-value*
GDV taxa richness			
Sampling event	7	6.53	<0.001
Site type	1	11.52	0.001
Sampling event*Site type	7	3.91	0.001
Submerged and emergent macrophyte taxa richness			
Sampling event	7	4.23	<0.001
Site type	1	8.49	0.007
Sampling event*Site type	7	3.23	0.004

*Significant *p*-values in red

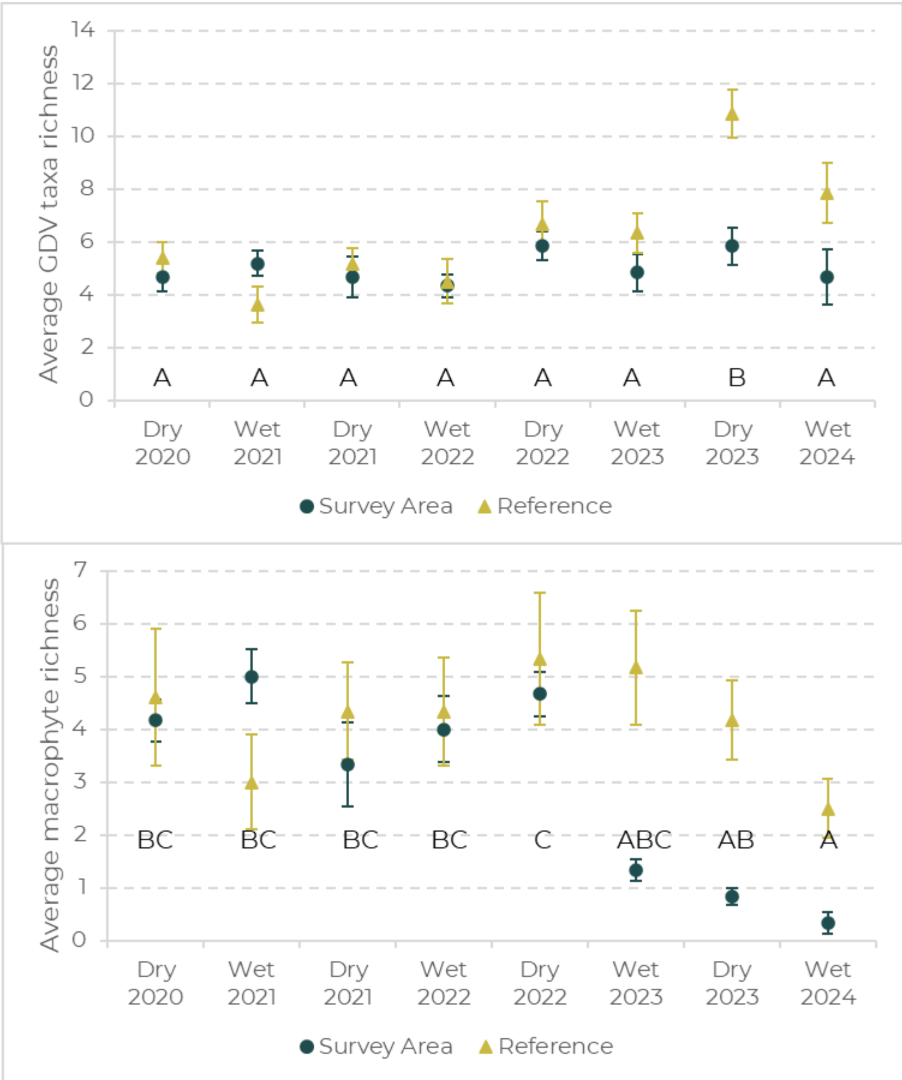

Figure 4.11: Average GDV and macrophyte taxa richness (± se) recorded in each sampling event

Letters denote equal means (Tukey's post-hoc results)

4.4 Hyporheic Fauna

A total of 12 samples was successfully collected from hyporheic zones during the Survey, four in the Dry 2023 and eight in the Wet 2024. Hyporheic sampling was only undertaken at inundated sites, where water was present below the creek bed. This meant that all samples collected in the dry season were from Reference sites (MACREF1, WWS, BENS and SS), as the Survey Area was largely dry aside from MarC6a and MarC6b. At these sites the hyporheic zone was not sampled as bedrock substrate is not conducive to hyporheic fauna due to the lack of interstitial habitat and water flow. In the Wet 2024, five Survey Area sites (MarC1, MarC2, MarC4, MarC5a and MarC6) and three Reference sites (WWS, BENS and SS) were sampled. Sediments were not conducive to sampling at MarC3, MACREF1 (wet only), MACREF2 or MUNJS.

4.4.1 Hyporheic Taxa Composition and Richness

Thirty-two invertebrate taxa were recorded from hyporheic zones of the Survey Area, all of which were recorded in the Wet 2024. Taxa included individuals from 11 higher taxonomic orders, including Nematoda (roundworm; 1 taxon), Platyhelminthes (flatworm; 1 taxon), Oligochaeta (aquatic segmented worms; 2 taxa), Acarina (water mites; 7 taxa), Ostracoda (seed shrimp; 1 taxon), Copepoda (5 taxa), Syncarida (1 taxon), Gastropoda (freshwater snail; 1 taxon), Collembola (springtails; 1 taxon), Coleoptera (beetles; 4 taxa) and Diptera (two-winged flies; 8 taxa; see Appendix H).

More than half of these taxa were stygoxene (56%) and do not have specialised adaptations for groundwater habitats. Hyporheic fauna[3] made up the remaining taxa collected, with 19% being directly dependant on groundwater for their persistence (stygobites and permanent hyporheos stygophiles), and 13% being occasional hyporheos stygophiles, utilising the hyporheic zone opportunistically. The percentage of groundwater dependant taxa was generally greater in the Survey Area (19%) than Reference sites (13% of taxa).

Invertebrate richness within hyporheic zones was dominated by stygoxenes at all sites, generally followed by occasional hyporheos stygophiles (Figure 4.12). The greatest richness of groundwater dependent taxa was recorded from WWS (4 taxa) in the Dry 2023, and in the Wet 2024 the highest richness was from MarC2 and Reference site SS (3 taxa each; Figure 4.12). Stygobites were recorded from all sites except MACREF1 in the dry season. At Reference sites WWS and BENS, invertebrate taxa richness within hyporheic zones decreased between seasons (22 to eight taxa at WWS and 22 to 17 taxa at BENS). In contrast, invertebrate richness

[3] Hyporheic fauna includes stygobites, permanent hyporheos stygophiles, occasional hyporheos stygophiles and possible hyporheic taxa. Hyporheic fauna are collectively referred to as the 'hyporheos'

at SS taxa richness increased from 14 taxa in the Dry 2023 to 32 taxa in the Wet 2024 (Figure 4.12).

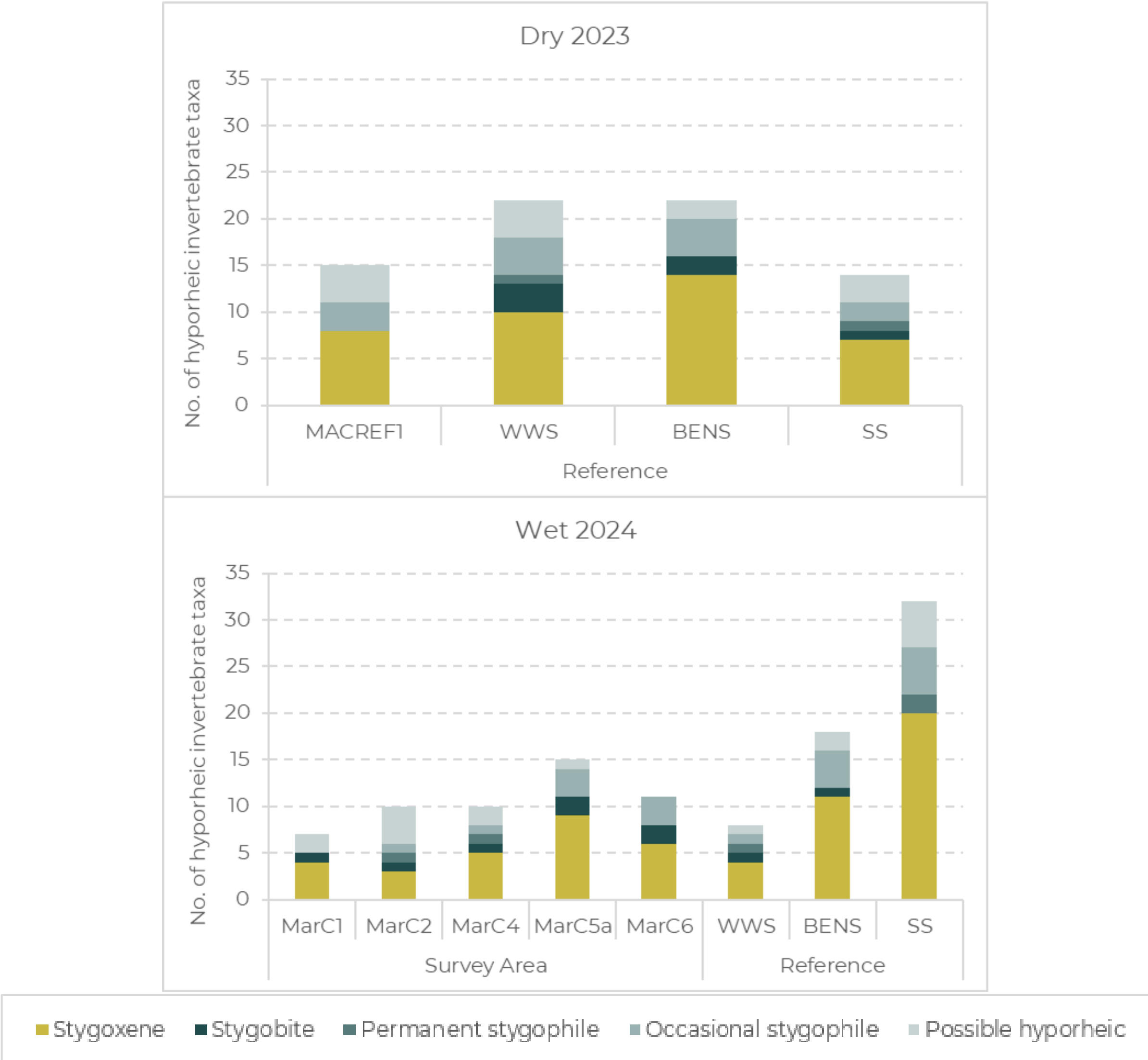

Figure 4.12: Invertebrate composition and richness recorded from the hyporheic zone at each site in each season

Hyporheos taxa recorded from the Survey Area included:

<u>Stygobites</u>

- syncarid *Atopobathynella* `sp. Biologic-PBAT019`
- cyclopoid copepod *Fierscyclops* `sp. Biologic-CYCL034`, *Fierscyclops* `sp. Biologic-CYCL039` and *Pescecyclops* `sp. WAM-CYLP001`

<u>Permanent stygophiles</u>

- water mites *Rutacarus* `sp. Biologic-ACAR007` and *Wandesia* `sp. Biologic-ACAR008`

Occasional hyporheos stygophiles

- cyclopoid copepod *Microcyclops varicans*
- ostracod *Candonopsis* cf. *tenuis* (`sp. Biologic-OSTR009`)
- oligochaete *Pristina longiseta*
- beetle Hydraenidae sp. (L).

Possible hyporheic taxa made up 9% of the taxa recorded from the Survey Area and included higher-level identifications for which taxa may have belonged to a stygal or hyporheos species.

4.4.2 Significant Hyporheic Fauna

Five taxa recorded from hyporheic zones of the Survey Area were potentially significant, and were either locally restricted or rarely collected. This included one water mite, one syncarid, and three copepods (Table 4.7, Figure 4.13, Figure 4.14).

Other potentially significant taxa were recorded at Reference sites only, and outside of the Survey Area. These included:

- water mites *Arrenurus* `sp. Biologic-ACAR034 (WWS), *Rutacarus* `sp. Biologic-ACAR006` (WWS), *Gondwanabates* `sp. Biologic-ACAR016` (WWS) and *Aspidiobates* `sp. Biologic-ACAR037` (WWS)
- copepods *Australocamptus* `sp. Biologic-HARP090` (SS) and *Kinnecaris* `sp. Biologic-HARP092` (BENS)
- amphipods *Chydaekata* sp. E (BENS) and Paramelitidae `sp. Biologic-AMPH103` (RW)
- syncarid *Atopobathynella* `sp. Biologic-PBAT043` (SS).

Table 4.7: Summary of significant hyporheos taxa recorded during the Survey

Group	Taxon	Conservation Status/ Significance	Current Survey Records (Wet 2024)	Previous Records
Water mite	*Rutacarus* `sp. Biologic-ACAR007`	• Genus poorly known from Western Australia • OTU has a linear range of 145 km	MarC1, MarC2	MarC4, MarC5 (Biologic, 2022a, 2024b), BENS (Biologic, 2022e), Fortescue River catchment, Ashburton River catchment (Biologic unpub. data) (Figure 4.13)
Syncarid	*Atopobathynella* `sp. Biologic-PBAT019`	• Stygal • Relatively broad (for an *Atopobathynella* species), but disjunct distribution • OTU has a 78.6 km linear range • Still constitutes a Potential SRE (Data Deficient) based on WAM's three-tier SRE classification system	MarC6, BENS	MarC4, MACREF2 and MC10 (Biologic, 2023a, 2024b), Jugaricoogina Creek (Biologic, 2023c), Turee Creek East sub-catchment, Weeli Wolli sub-catchment (including bores within the East Packsaddle Project), and the Upper Fortescue River catchment (Biologic unpub. data) (Figure 4.14). This still constitutes a Potential SRE (Data Deficient).
Copepoda	*Fierscyclops* `sp. Biologic-CYCL034`	• Genus is stygal, recorded only from groundwater • Current known linear range of 46.2 km	MarC6	Wonmunna Gorge (Biologic unpub data) (Figure 4.14)
	Fierscyclops `sp. Biologic-CYCL039`	• Genus is stygal, recorded only from groundwater • OTU with a linear range of 86 km	MarC5a	Recorded from hyporheic zones up to 86 km to the south-west of the Survey Area (Figure 4.14)
	Canthocamptidae `sp. Biologic-HARP059`	• Currently only known from five records on Marillana Creek within the Survey Area and Reference site MACREF2 • OTU may be more widespread. Further molecular and morphological work is required on this family	MarC2, MACREF2 (macro sample)	MarC2 and MarC4 (Biologic, 2024b) (Figure 4.14)

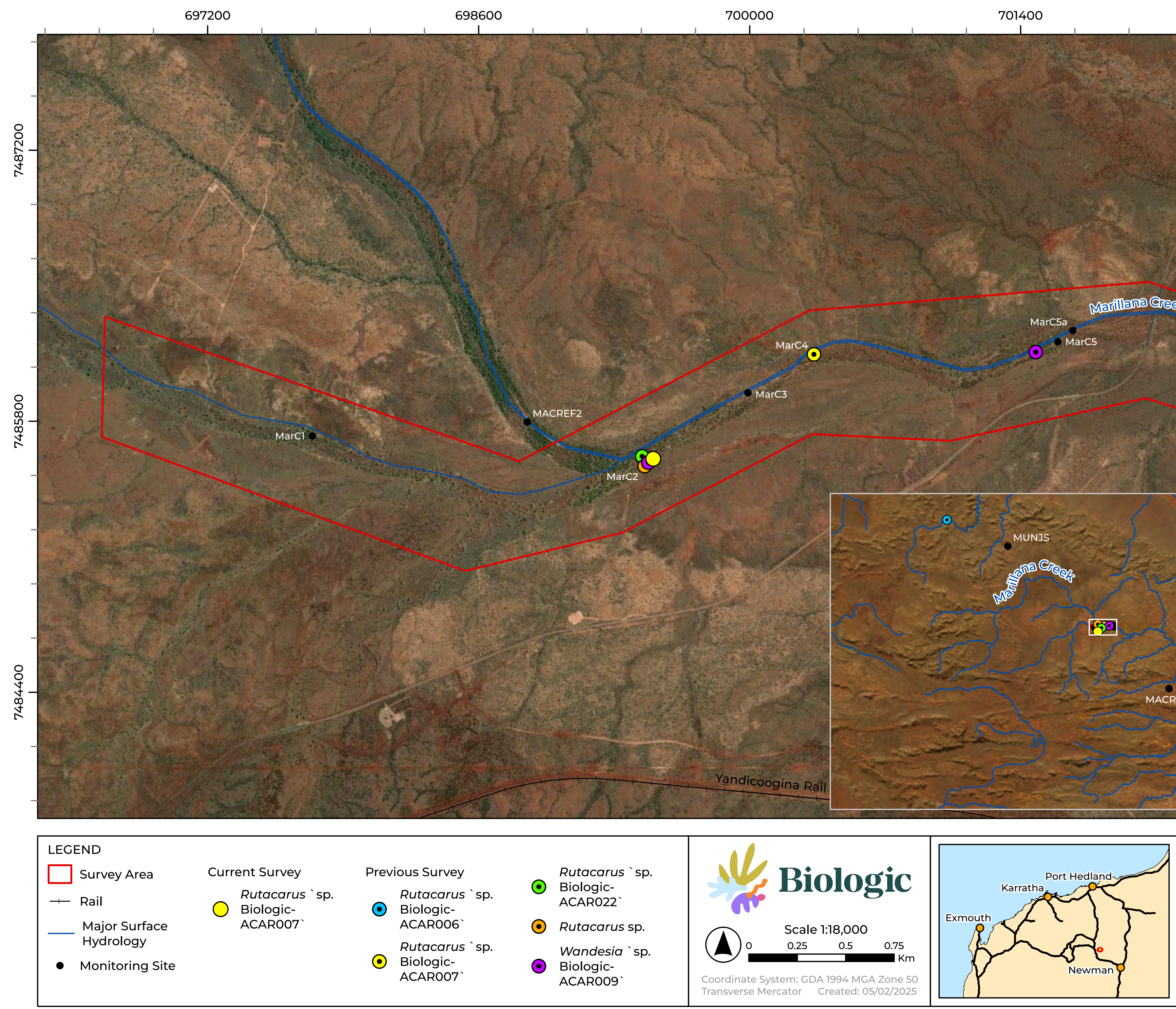

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Figure 4.13: Potentially significant water mites

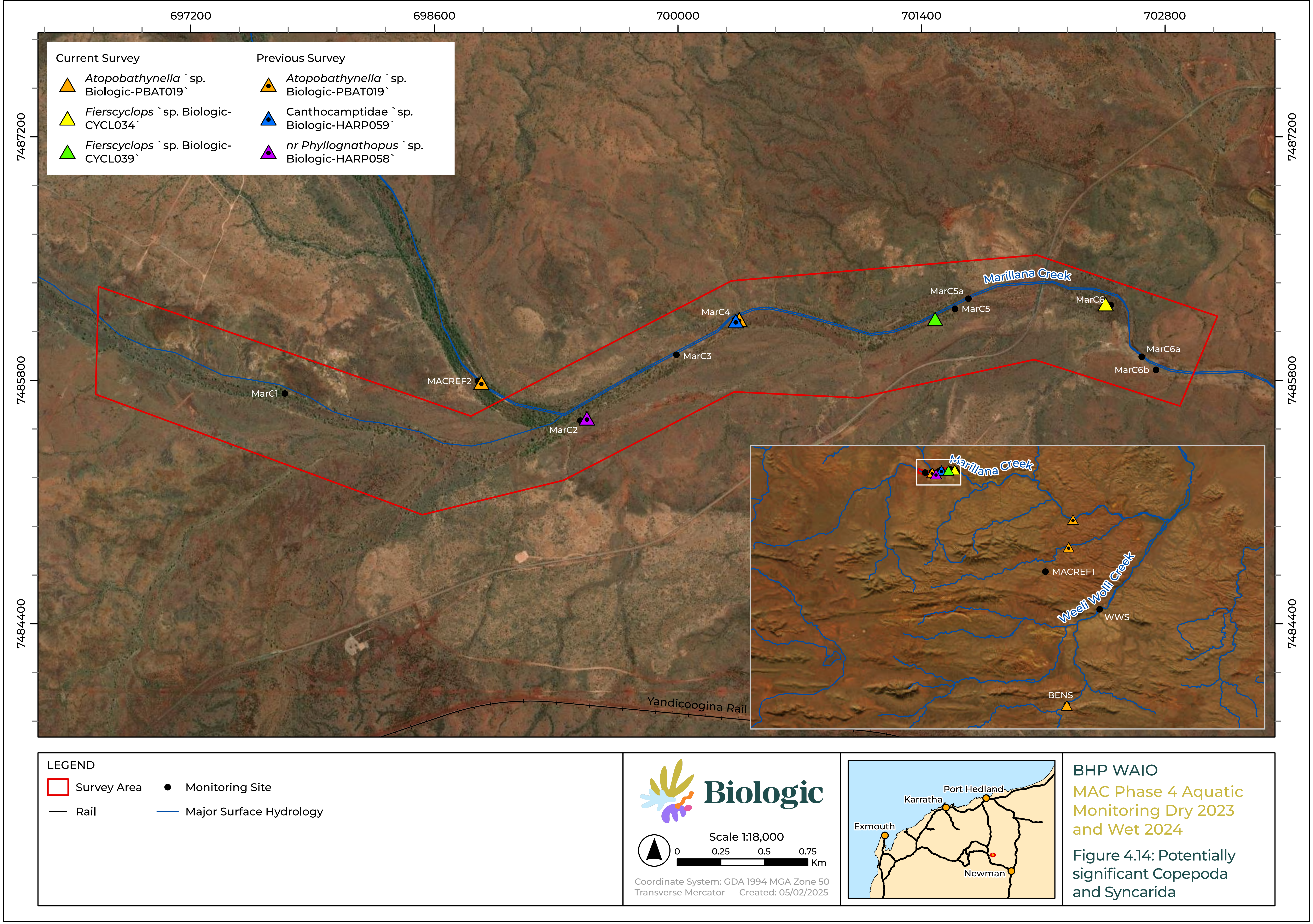

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Figure 4.14: Potentially significant Copepoda and Syncarida

4.4.3 Change Over Time in Hyporheic Fauna (Dry 2020 to Wet 2024)

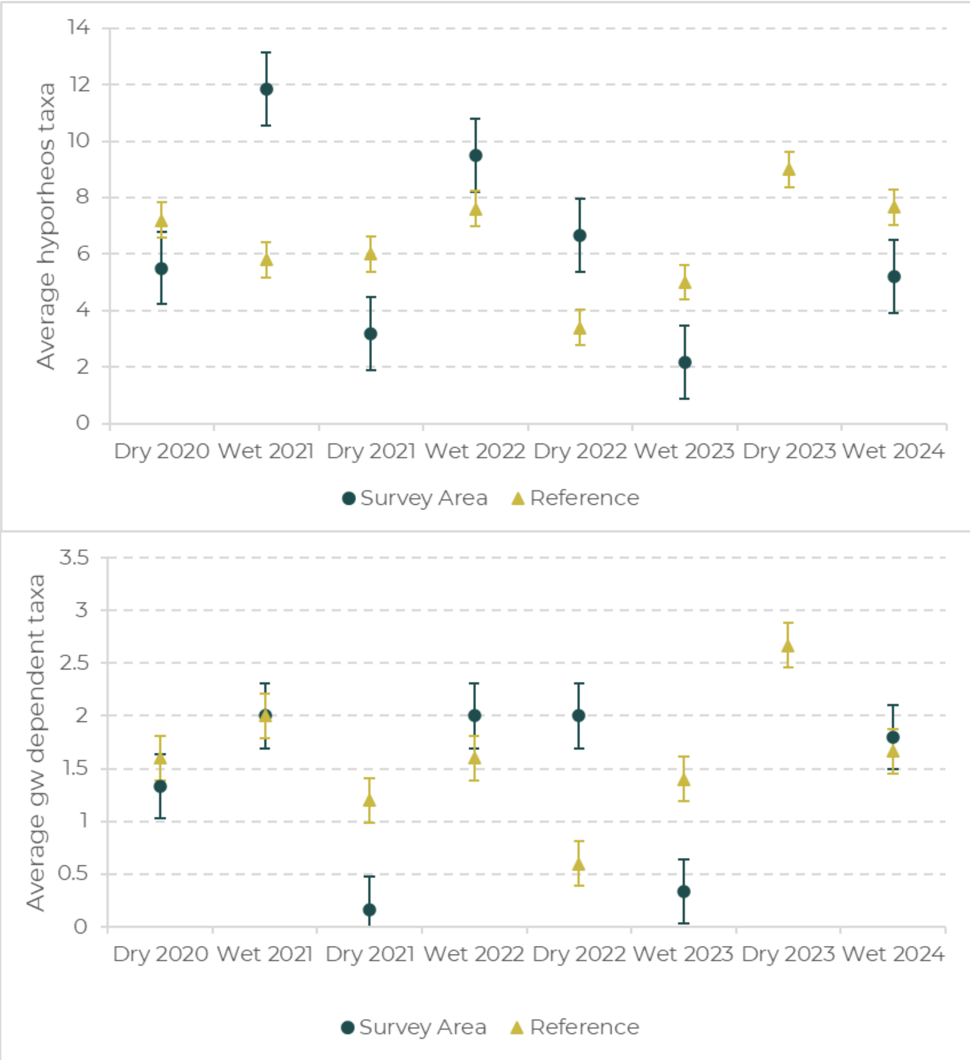
Average hyporheos taxa richness in the Survey Area varied greatly over time, in comparison to Reference sites which recorded more consistent average richness between sampling events. Hyporheos taxa richness in the Survey Area fluctuated over time (Figure 4.15). A seasonal influence was present in earlier sampling events, with higher average richness recorded in wet seasons. However, between the Wet 2022 and Dry 2023 there was a steady decline in richness over time within the Survey Area, followed by an increase in the Wet 2024 (Figure 4.15). Overall, there was a significant difference in hyporheos taxa richness between sampling events (Two-way ANOVA; p = 0.033; Table 4.8), but Tukey's could not locate these differences. Generally, lowest average hyporheos taxa richness was recorded in the Wet 2023, and highest average richness was recorded in the Wet 2021 (Figure 4.15). There was no significant difference between site type, but there was a significant interaction between sampling event and site type (p = 0.014; Table 4.8).

The average richness of groundwater dependent taxa (i.e. stygobites and permanent hyporheos stygophiles) was also variable (Figure 4.15). Richness of these taxa in the Survey Area has generally been comparable or greater than at Reference sites, except in the Dry 2021 and Wet 2023 where richness in the Survey Area was notably low. In the Dry 2023, the hyporheic zone was not able to be sampled in the Survey Area. Despite these differences, overall there was no significant difference in richness of groundwater dependent taxa (stygobites and permanent stygophiles only) between sampling events or site types (Two-way ANOVA; $p > 0.05$; Table 4.8), likely due to the large variability in richness within each site type and sampling event (relatively large standard error bars), as well as sampling events where average richness was similar between site types (Figure 4.15).

Table 4.8: Two-way ANOVA results comparing hyporheic taxa richness between sampling event and site type

Source	df	F	*p*-value*
Hyporheos fauna taxa richness			
Sampling event	7	2.5748	0.023
Site type	1	0.0224	0.984
Sampling event*Site type	6	2.9619	0.014
Groundwater dependent fauna taxa richness			
Sampling event	7	0.990	0.540
Site type	1	0.155	0.724
Sampling event*Site type	6	1.097	0.353

*Significant *p*-values in red



*The hyporheic zone was not able to be sampled in the Survey Area in the Dry 2023

Figure 4.15: Average total hyporheos taxa richness and groundwater dependent taxa richness (± se) recorded in each sampling event

4.5 Macroinvertebrates

4.5.1 Macroinvertebrate Composition and Richness

A total of 156 macroinvertebrate taxa was recorded from the Survey Area, with 114 taxa recorded in the Dry 2023 and 67 in the Wet 2024. Macroinvertebrate fauna of the Survey Area comprised Hydrozoa (freshwater hydra; 1 taxon), Platyhelminthes (flat worms; 1 taxon), Nematoda (round worms; 1 taxon), Hirudinea (leech; 1 taxon), Oligochaeta (aquatic segmented worms; 6 taxa), Gastropoda (freshwater snails; 2 taxa), Acarina (water mites; 21 taxa), *Dolomedes* (fishing spiders; 1 taxon), Anostraca (fairy shrimp; 2 taxa), Copepoda (3 taxa), Diplostraca (water fleas and clam shrimp; 4 taxa), Ostracoda (seed shrimp; 6 taxa), Collembola (springtails; 2 taxa), Coleoptera (beetles; 38 taxa), Diptera (two winged flies; 27 taxa), Ephemeroptera (mayflies; 7

taxa), Hemiptera (true bugs; 12 taxa), Lepidoptera (moth larvae; 1 taxon), Odonata (dragonflies and damselflies; 13 taxa) and Trichoptera (caddisflies; 7 taxa; see Appendix I).

In both seasons, most sites were dominated by groups known to be tolerant of a wide range of water quality and environmental conditions, i.e., Diptera and Coleoptera (Figure 4.16). Dominance of Diptera within aquatic macroinvertebrate assemblages of the Pilbara is common (Pinder *et al.*, 2010). Common taxa throughout the Survey Area included biting midges (Ceratopogoninae sp.), non-biting midges (*Chironomus* aff. *alternans* and *Procladius* sp.), mosquito larvae (Culicidae sp.) and springtails (Symphypleona sp.). In the Dry 2023, Odonata taxa richness was high (14 taxa) from the two sites sampled in the Survey Area (MarC6a and MarC6b). However, richness was considerably lower the following wet season, despite six sites being successfully sampled at that time (MarC1 to MarC6), with only one odonate taxon recorded from one site in the Survey Area.

Macroinvertebrate richness was variable. Within the Survey Area, richness ranged from 12 taxa (at MarC4 in the Wet 2024) to 81 taxa (at MarC6b in the Dry 2023). Richness was considerably higher in the Dry 2023 compared to the Wet 2024, though it should be noted that different sites were sampled between seasons due to the lack of surface water in the Survey Area in the dry season. Notably high richness was recorded from MarC6a and MarC6b in the Dry 2023, comparable to Reference site MUNJS and not much lower than SS. Overall, richness at Reference sites ranged from 40 (MACREF2 in the Wet 2024) to 93 taxa (at SS in the Dry 2023). Seasonal variation was mixed across sites, but was only able to be examined at Reference sites. Within Reference sites, higher richness was recorded in the Dry 2023 compared to the Wet 2024 at MUNJS and SS, while MACREF1 MACREF2, WWS and BENS showed little seasonal change (Figure 4.16).

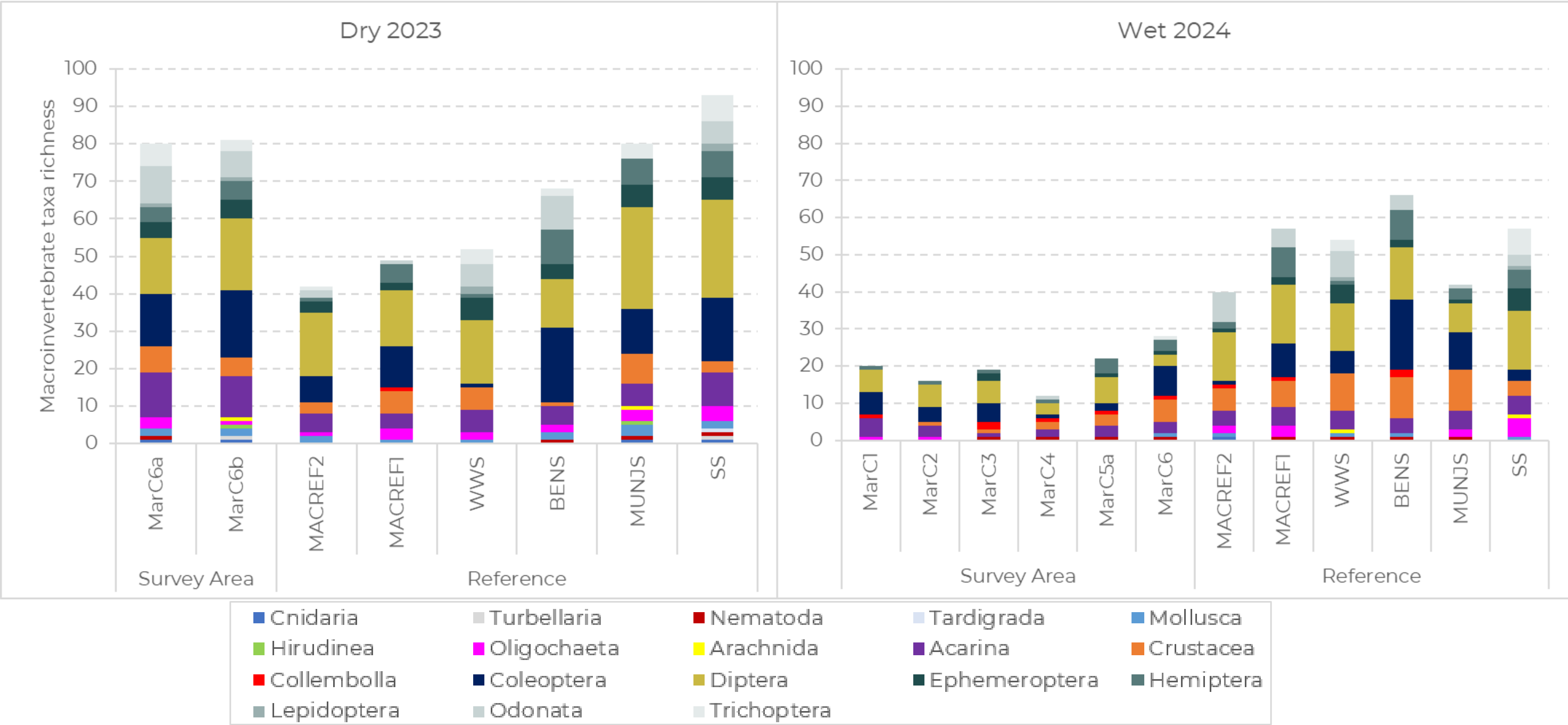


Figure 4.16: Macroinvertebrate taxa composition from each site, in each season

4.5.2 Significant Macroinvertebrates

Most aquatic macroinvertebrates recorded during the Survey were common, ubiquitous species. Excluding taxa which could not be assigned a distribution status due to insufficient information or taxonomy (juveniles/damaged specimens), most taxa from the Survey Area have distributions extending across Australia (40%), Northern Australia (16%), the Australasian region (11%), or the world (cosmopolitan taxa; 14%). A total of 4% are endemic to Western Australia and 3% are found across northern Western Australia. Taxa restricted to the Pilbara region represented 12% of the taxa recorded from the Survey Area.

Taxa endemic to the Pilbara region (9 taxa) were recorded from Survey Area sites MarC6a and MarC6b in the Dry 2023, and sites MarC1, MarC2 and MarC6 in the Wet 2024 (Figure 4.17). The greatest number of Pilbara endemic taxa was recorded from Reference site WWS in the Wet 2024 (seven Pilbara endemic taxa). Most Survey Area sites recorded no Pilbara endemic taxa in the Wet 2024, despite being inundated (MarC1 through to MarC5a). These sites were dry in the Dry 2023, while sites MarC6a and MarC6b were not sampled in the Wet 2024. At least one Pilbara endemic taxon was recorded at each Reference site in both seasons (Figure 4.17).

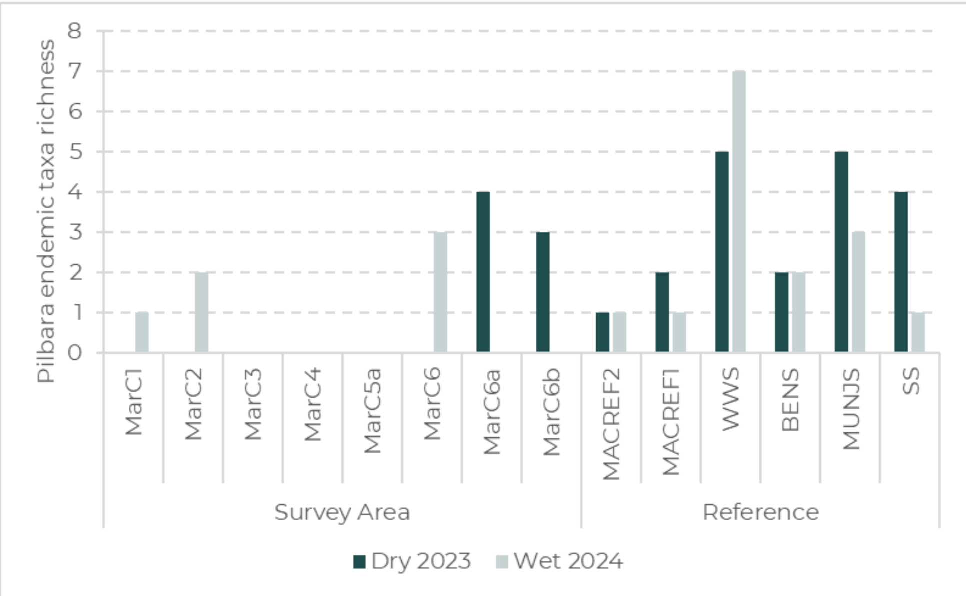


Figure 4.17: Number of Pilbara endemic macroinvertebrate taxa recorded

Three taxa recorded from the Survey Area were considered of significance. These included the fairy shrimp Anostraca sp. and *Branchinella wellardi* (*Branchinella* `sp. Biologic-ANOS002`), and the clam shrimp *Limnadopsis pilbarensis* (Figure 4.18). Anostraca sp. comprised immature nauplii from MarC5a that were not submitted for genetic analysis, but may represent taxa with a restricted distribution. *Branchinella wellardi* was recorded at MarC6 in the Wet 2024. This taxon is listed as Priority 3 by the DBCA (2025) and Vulnerable on the IUCN Red List (IUCN, 2025).

It is known from only 11 records currently, with locations in the Pilbara, Gascoyne, and New South Wales ((ALA, 2025).

The clam shrimp *Limnadopsis pilbarensis* was also recorded from surface waters at MarC6. This species is endemic to the Pilbara, but is relatively uncommon, with ALA (2025) indicating only five known records. It occurs in temporary pools only. During the PBS, it was recorded from one site, Burrup Rockhole northeast of Dampier (Pinder *et al.*, 2010), but has since 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 4.18).

Two terrestrial pseudoscorpions were also recorded in aquatic macroinvertebrate samples from the Survey Area and were submitted for molecular analysis (Biologic, 2025a). Sequence results indicated two distinct OTUs, *Indolpium* `sp. Biologic-PSEU241` which was recorded from MarC1 and *Indolpium* `sp. Biologic-PSEU242` which was recorded from MarC2. These taxa are terrestrial invertebrates and likely represent Potential SREs. Both represent the first records of these OTUs.

Additional significant macroinvertebrate taxa that were only recorded at Reference sites, outside the Survey Area, included *Eurysticta coolawanyah* (BENS), *Nososticta pilbara* (WWS), *Atopobathynella* `sp. Biologic-PBAT019` (BENS), *Chydaekata* sp. E `TLF-2008` (WWS) and Paramelitidae `sp. Biologic-AMPH024`(WWS). All of these were recorded from sites on Weeli Wolli Creek.

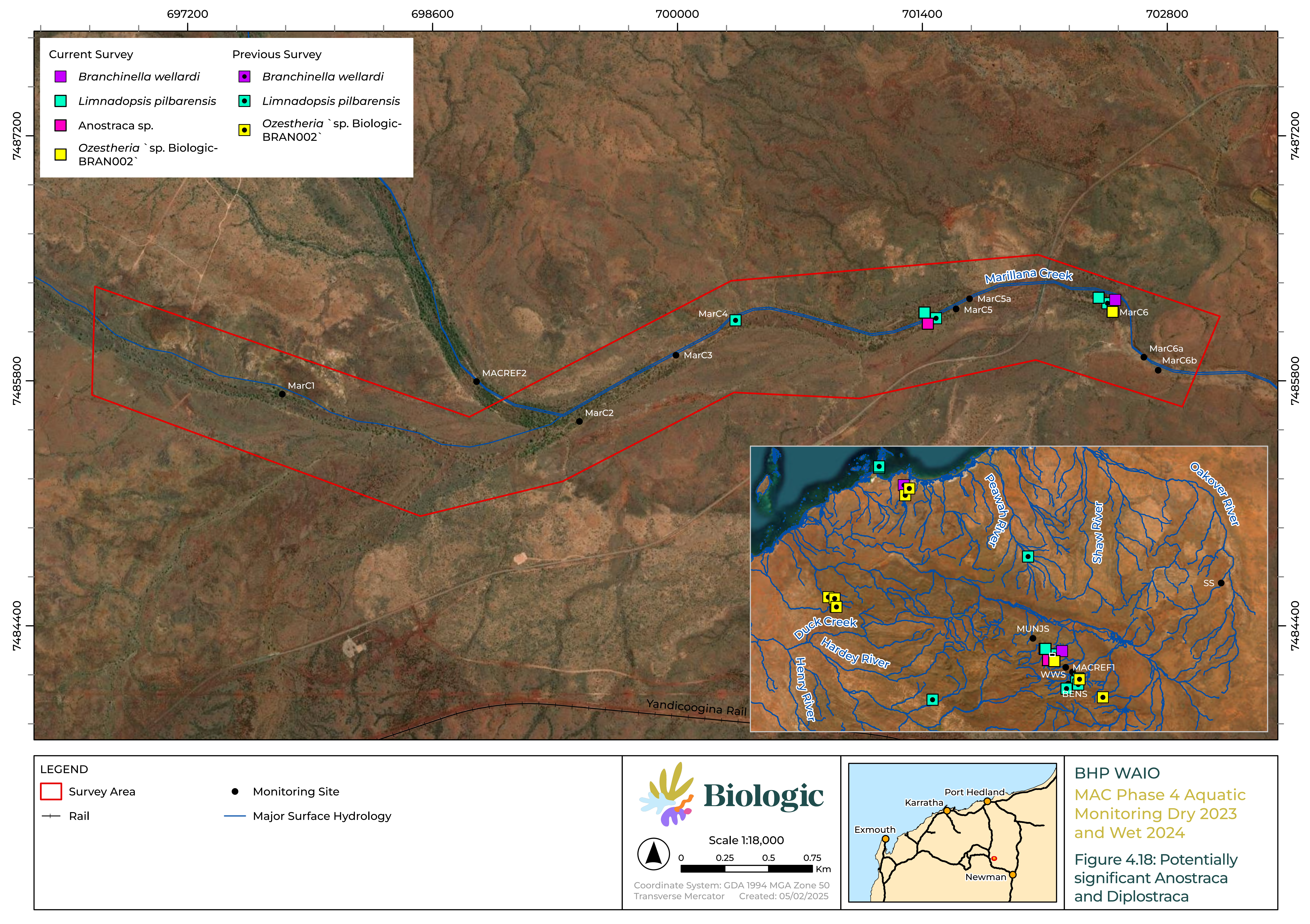


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Figure 4.18: Potentially significant Anostraca and Diplostraca

4.5.3 Change in Macroinvertebrates Over Time (Dry 2020 to Wet 2024)

4.5.3.1 Richness

In early sampling events, average macroinvertebrate richness in the Survey Area was comparable to Reference sites, both of which underwent a slight increase between the Dry 2020 and Dry 2022. In the Dry 2021, all but one of the six long-term monitoring sites were dry, but relatively high richness was recorded from the two sites sampled at the time (72 taxa from MarC3 and 79 taxa from MarC6a). Average richness in the Survey Area was then relatively consistent between the Dry 2021 and Dry 2022, and even slightly higher than Reference sites in the Wet 2022 and Dry 2022, before declining considerably in the Wet 2023. Following this, average richness was high in the Survey Area (sites MarC6a and MarC6b) in the Dry 2023 before a dramatic decline in the Wet 2024 (Figure 4.19).

Average richness at Reference sites also changed over time, although within a much tighter range than was seen in the Survey Area. There was a slight increase in richness between the Wet 2022 and Wet 2023, followed by a slight decline to the Wet 2024. The decline in the Survey Area in the Wet 2024 was much more pronounced than Reference sites (Figure 4.19).

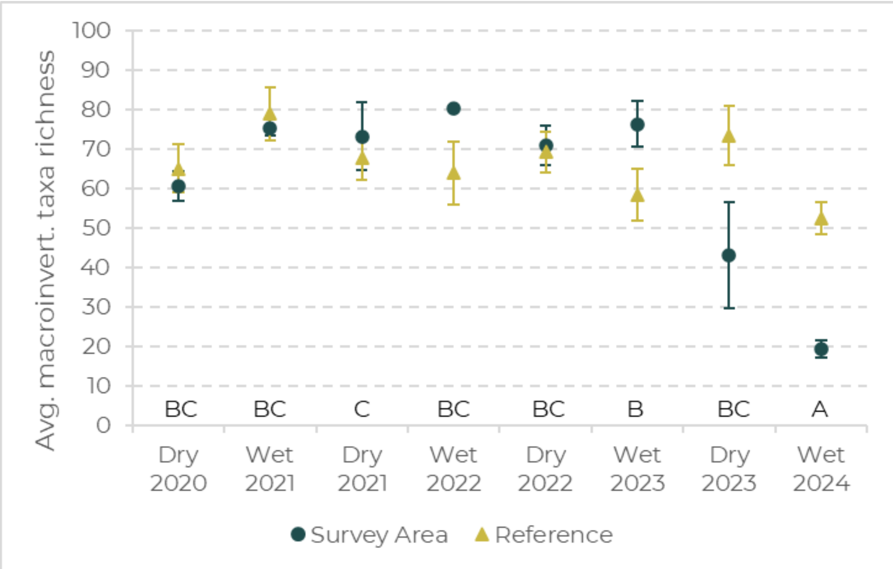

Figure 4.19: Average macroinvertebrate taxa richness (± se)* recorded in each sampling event

*The Dry 2021 and Dry 2023 averages are based on two replicates, not six. Letters denote equal means (Tukey's post-hoc results)

Overall, there was a significant difference in macroinvertebrate richness between sampling events, but not between site types (Table 4.9). Average macroinvertebrate richness was significantly lowest in the Wet 2024, than all other sampling events. Highest average richness was recorded in the Wet 2021, although this richness was statistically similar to several other events (Figure 4.19). There was a significant interaction between the two factors, suggesting that change over time was not consistent between the Survey Area and Reference sites (Table 4.9).

Table 4.9: Two-way ANOVA results comparing macroinvertebrate taxa richness between sampling event and site type

Source	df	F	*p*-value*
Macroinvertebrate fauna taxa richness			
Sampling event	7	8.55	<0.001
Site type	1	1.33	0.252
Sampling event* Site type	7	4.90	<0.001

*Significant *p*-values in red

Odonate richness over time

Odonate richness was notably low in the Wet 2024, with only one single immature dragonfly (Anisoptera sp.) recorded at one of the six Survey Area sites sampled (MarC1 to MarC6, inclusive). This compared to 13 taxa from two Survey Area sites in the Dry 2023 (MarCa and MarCb). No significant odonate taxa were recorded from the Survey Area in either season, despite previous surveys recording three IUCN-listed species: the Pilbara pin (*Eurysticta coolawanyah*), the Pilbara emerald (*Hemicordulia koomina*) and the Pilbara tiger (*Ictinogomphus dobsoni*; Figure 4.20). Odonate richness at Reference sites ranged from zero (MUNJS; Dry 2023) to five taxa (BENS and SS in the Dry 2023, MACREF2 in the Wet 2024).

The Survey Area previously supported high richness of dragonflies and damselflies, comparable or greater than Reference sites (Figure 4.21). Average richness in the Dry 2020 in particular was notable, with some individual sites recording as many as 11 odonate taxa (Biologic, 2022a). Average richness of odonates in the Survey Area declined considerably in the Wet 2023 followed by an increase in the Dry 2023 and then dramatic decline in the Wet 2024 (Figure 4.21). Odonate richness was significantly different between sampling events, with lowest average richness recorded in the Wet 2024 (Table 4.10 and Figure 4.21). Highest richness of odonates was recorded in the Dry 2022. There was no significant difference between site type, but there was a significant interaction between these two factors (Table 4.10).

Table 4.10: Two-way ANOVA results comparing Odonata taxa richness between sampling event and site type

Source	df	F	*p*-value*
Odonata taxa richness			
Sampling event	7	5.53	<0.001
Site type	1	0.05	0.825
Sampling event* Site type	7	4.18	<0.001

*Significant *p*-values in red

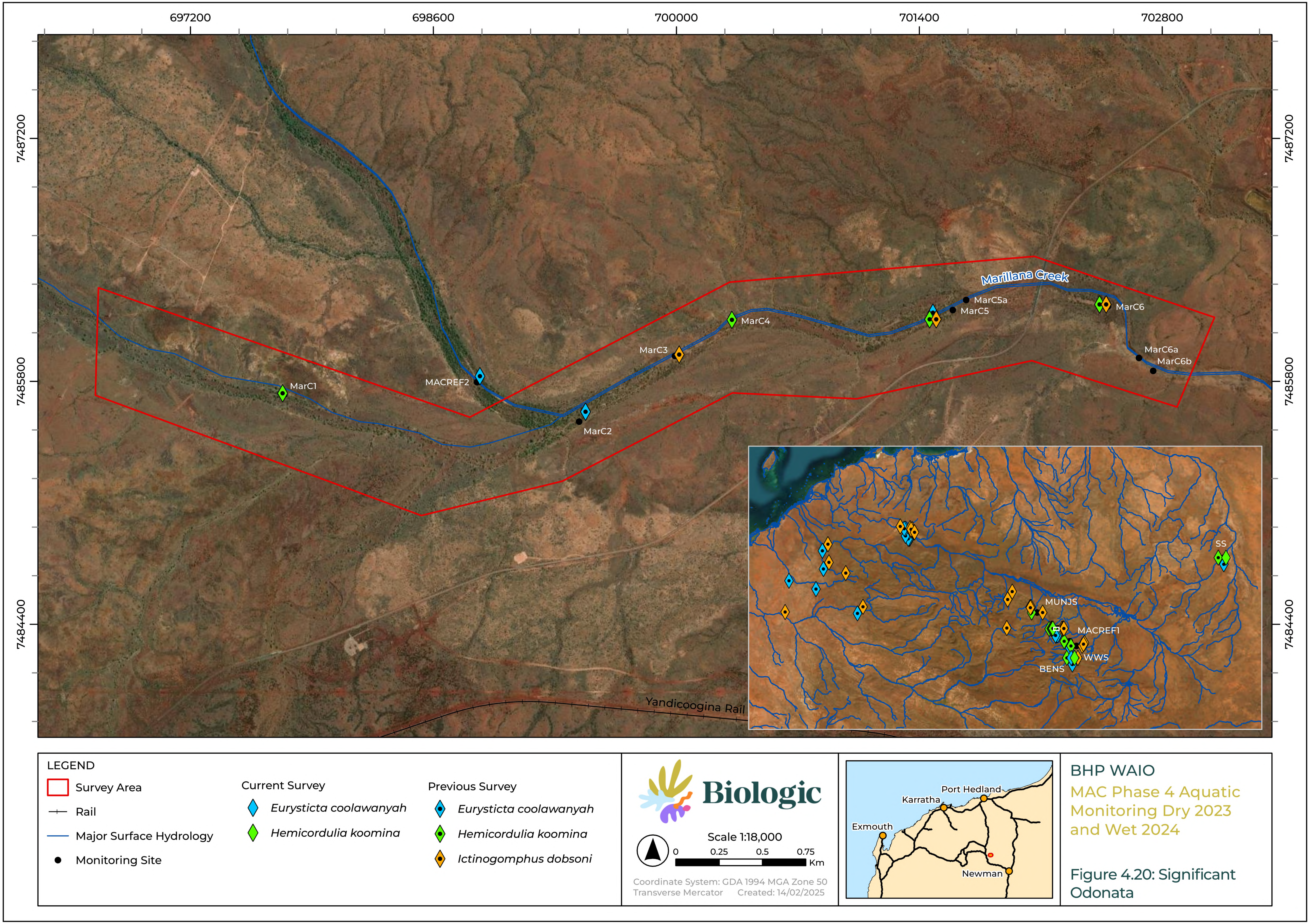

Figure 4.20: Significant Odonata

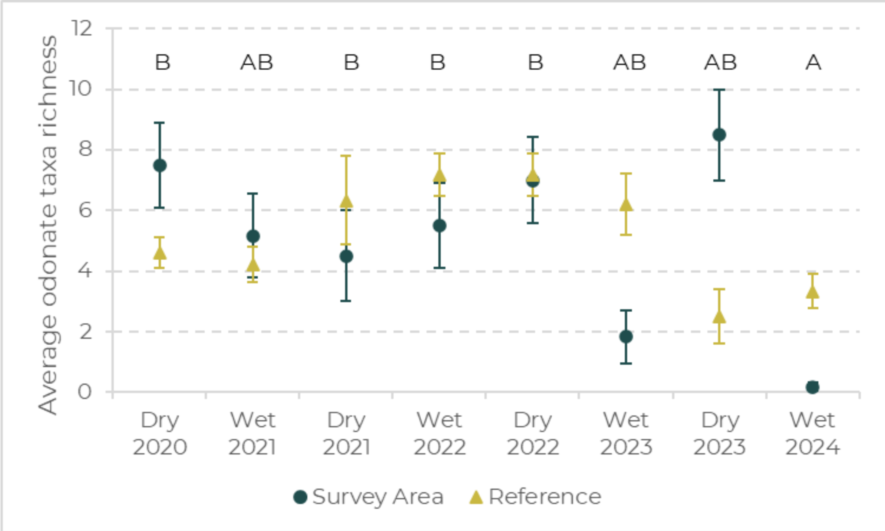

Figure 4.21: Average odonate taxa richness (± se)* recorded in each sampling event

* The Dry 2021 and Dry 2023 averages are based on two replicates, not six. Letters denote equal means (Tukey's post-hoc results)

4.5.3.2 Assemblage Composition

Patterns were evident within the nMDS ordination of all macroinvertebrate samples collected during this and previous surveys (Figure 4.22 and Figure 4.23). As was seen with the water quality data, macroinvertebrate samples collected from the Survey Area in the Wet 2023 and Wet 2024 separated from all other samples in ordination space. In earlier sampling events, samples from the Survey Area broadly grouped with Reference site samples, with some exceptions. Dry 2020 and Wet 2021 Survey Area sites, for example, separated slightly and formed a significant SIMPROF cluster group with the Dry 2020 Reference sites (Figure 4.22 and Figure 4.23). There was some site patterns amongst the Reference samples, with WWS samples generally forming a tight cluster and showing little temporal or seasonal variation.

These differences in macroinvertebrate assemblages were significant, with significant differences in assemblages found between both site types and sampling events (Table 4.11). The interaction between site type and sampling event was also significant. Pairwise post-hoc results found that assemblages from all sampling events were significantly different from one another ($p \leq 0.05$; Table 4.12).

Table 4.11: Two-factor PERMANOVA results comparing macroinvertebrate assemblages between site type and sample period

Source	df	Pseudo-F	*p*-value*
Sampling event	7	3.431	0.0001
Site type	1	4.6331	0.0001
Sampling event* Site type	7	1.6916	0.0001

*Significant *p*-values in red.

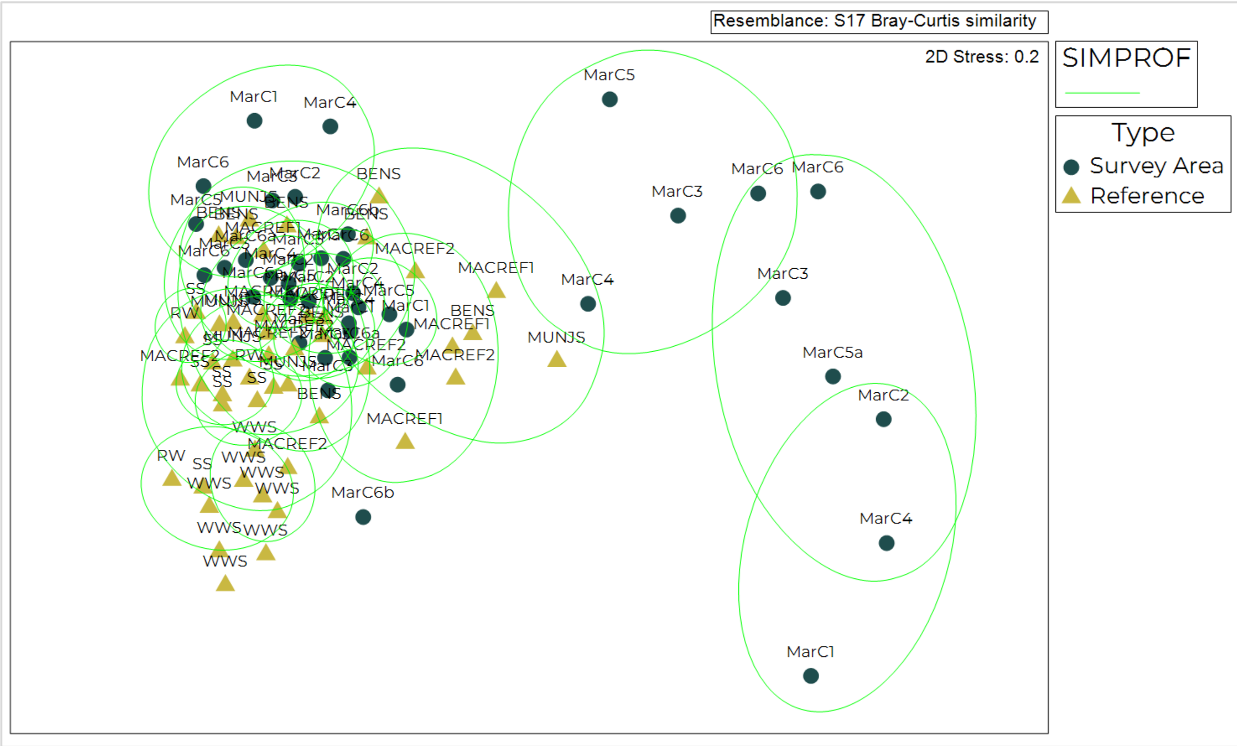

Figure 4.22: nMDS of macroinvertebrate assemblages recorded across all years, with samples grouped by sample type (Survey Area vs Reference). Significant SIMPROF groups outlined in green

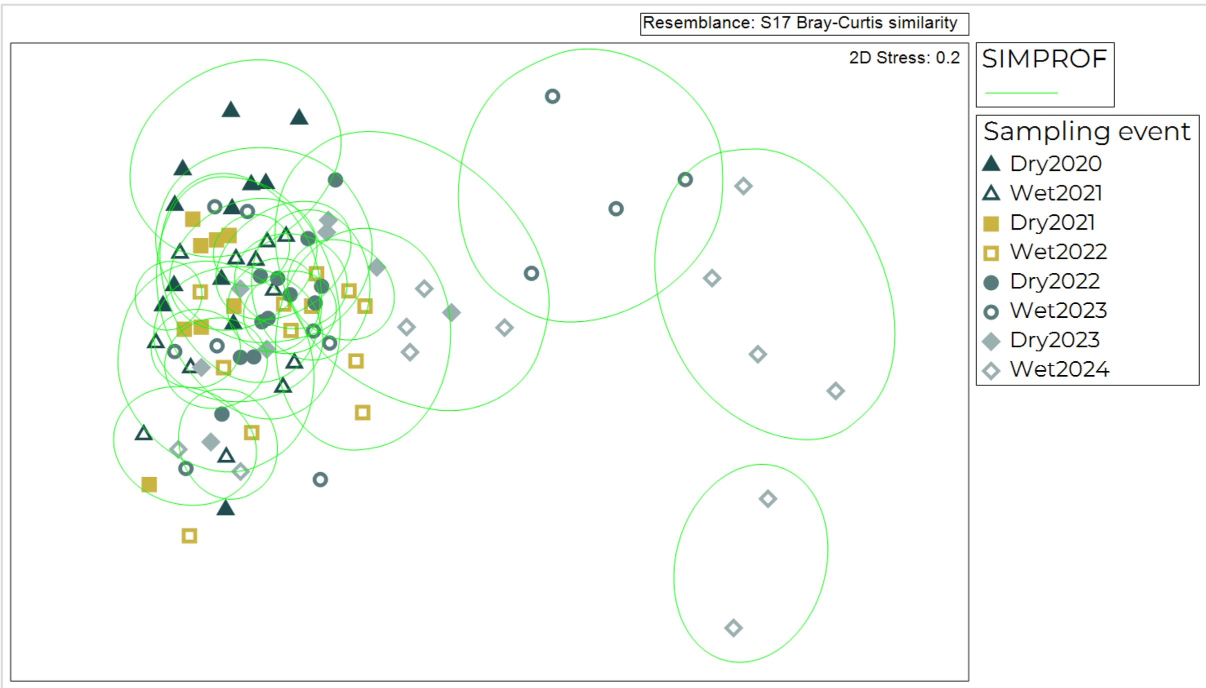

Figure 4.23: nMDS of macroinvertebrate assemblages recorded across all years, with samples grouped by sampling event. Significant SIMPROF clusters outlined in green

Table 4.12: PERMANOVA pairwise post-hoc results comparing macroinvertebrate assemblages between sampling events. Values in the table refer to the t-value, with the significance value (p) in parentheses*

Sampling event	Wet 2021	Dry 2021	Wet 2022	Dry 2022	Wet 2023	Dry 2023	Wet 2024
Dry 2020	1.75 (p = 0.0001)	1.61 (p = 0.0003)	2.06 (p = 0.0001)	2.02 (p = 0.0001)	2.07 (p = 0.0001)	1.95 (p = 0.0001)	2.61 (p = 0.0001)
Wet 2021		1.42 (p = 0.0019)	1.57 (p = 0.0002)	1.69 (p = 0.0001)	1.71 (p = 0.0001)	1.74 (p = 0.0001)	2.49 (p = 0.0001)
Dry 2021			1.52 (p = 0.0003)	1.43 (p = 0.0008)	1.50 (p = 0.009)	1.40 (p = 0.0035)	2.19 (p = 0.0003)
Wet 2022				1.41 (p = 0.0015)	1.55 (p = 0.0003)	1.53 (p = 0.0003)	2.21 (p = 0.0001)
Dry 2022					1.70 (p = 0.0001)	1.39 (p = 0.0019)	2.36 (p = 0.0001)
Wet 2023						1.37 (p = 0.016)	1.71 (p = 0.0013)
Dry 2023							1.83 (p = 0.0002)

*Significant *p*-values in red

SIMPER analysis indicated that several macroinvertebrate taxa influenced the differences in overall assemblage composition between sampling events. In the Survey Area, the average similarity between the initial Dry 2020 sampling event and the current Dry 2023 was 29.39%, while average similarity between the Wet 2021 and Wet 2024 was only 9.33%. Taxa which contributed to the overall differences between the initial and most recent dry season assemblages included a several taxa which were recorded in lower abundance or were entirely absent in the Dry 2020 compared to the Dry 2023. These were:

- *Hydra* sp.
- water flea *Simocephalus* sp.
- aquatic mites Acarina sp., *Coaustraliobates minor*, *Limnesia maceripalpis*, *Oxus* sp., *Piona cumberlandensis*
- copepods *Thermocyclops* sp. and *Mesocyclops notius*
- mosquito larvae Culicidae sp.
- non-biting midges *Cladopelma curtivalva*, *Nanocladius* sp., and *Ablabesmyia hilli*
- water scavenger beetle *Hydrochus interioris*
- mayfly *Cloeon* sp.
- seed shrimp *Ilyodromus* sp.
- damselflies *Xanthagrion erythroneurum* and *Pseudagrion aureofrons*
- caddisfly *Orthotrichia* sp.

Taxa which were present in the Dry 2020 but not the Dry 2023 included:

- copepod *Tropocyclops confinus*
- aquatic mite *Limnesia* sp. 4
- dragonfly *Austrogomphus gordoni*
- minute moss beetle *Hydraena* sp.

Differences between the initial and most recent wet season sampling events were largely driven by the absence or lower abundance of several taxa in the Wet 2024 compared to the Wet 2021, such as:

- mayflies Baetidae sp., *Cloeon* sp. Red Stripe, *Tasmanocoenis* sp., *Tasmanocoenis* sp. P/*arcuata*
- water mite *Limnesia* sp. `solida group`
- non-biting midges *Larsia ?albiceps*, *Paratanytarsus* sp., *Tanytarsus* sp. and *Paramerina* sp. 1
- other two-winged flies *Dasyhelea* sp., Stratiomyidae sp., Tabanidae sp.
- freshwater snails *Gyraulus* sp. and *Bullastra vinosa*
- seed shrimp *Stenocypris major* and *Cypretta* sp.
- copepods *Tropocyclops* cf. *confinus* and *Mesocyclops notius*

- immature damselfly Zygoptera sp.
- aquatic beetles *Hydraena* sp., *Hydroglyphus orthogrammus*, *Hydroglyphus leai*, *Hyphydrus lyratus*
- aquatic worms *Pristina* sp., *Pristina leidyi*, *Pristina longiseta*
- aquatic true bug *Paraplea brunni*

Taxa that were absent in the Wet 2021, but present in the Wet 2024 included the roundworm Nematoda sp. and the copepod *Thermocyclops* sp.

4.5.3.3 Correlations with environmental characteristics

Correlations between Survey Area macroinvertebrate assemblages and environmental data (water quality and habitat) was investigated using BVSTEP analysis. Spearman rank produced a significant and high correlation between the assemblages and three environmental variables (Rho = 0.769, p = 0.01). These were concentrations of dAs, dZn and N_NOx, all of which were recorded in higher concentrations during the Wet 2024 compared to other sampling events, when taxa richness was low and the assemblage composition was significantly different.

4.6 Rehydration Emergence Trials

Sediments were collected from six Survey Area sites in the Dry 2023 (MarC1, MarC2, MarC3, MarC4, MarC5 and MarC6) which underwent rehydration-emergence trials in the laboratory.

4.6.1 Rehydrate Trial Water Quality

EC ranged from 771.0 µS/cm (MarC6) to 3,975.0 µS/cm (MarC1) during Wetting 1 (W1) of the trials, and from 841.0 µS/cm (MarC6) to 1,860.0 µS/cm (MarC3) during Wetting 1 (W2; Appendix J). Most EC values were within the range of surface waters, and the majority of values exceeded the ANZG (2018) DGV (250 µS/cm) in the rehydration trials, although still reflected fresh waters (Mayer *et al.*, 2005). Exceptions included MarC1 (W1), MarC3 (W1 and W2) and MarC4 (W1), where the EC was brackish (> 1,500 µS/cm) on at least one occasion during the trial.

The pH in rehydrate trials ranged from 7.13 (MarC5) to 9.04 (MarC4) during W1, and 7.70 (MarC3) to 8.55 MarC1). Several pH records from rehydration tanks were in excess of the upper ANZG (2018) DGV, and five sites recorded maximum pH outside that recorded from surface waters during the Survey (Appendix J). Maximum pH was greater in W1 in all trial tanks except MarC5 and MarC6. Overall, the pH recorded during rehydration trials would not be considered to pose any issues for emergence of fauna as Pilbara riverine waterbodies are commonly basic (Pinder *et al.*, 2010).

DO saturation was variable during the trials, ranging from 16.5% (MarC2) to 92.5% (MarC1) in W1, and 71.9% (MarC3) to 97.5 (MarC1) in W2. Some of the records for DO during W1 were considered erroneous and removed from the dataset, likely due to a faulty probe. DO recorded from surface waters in the Survey Area was also highly variable, although generally comparable to DO recorded from rehydration trial tanks.

Water temperature in the rehydration trial tanks ranged from 21.7°C (MarC6, W1) to 23.7°C (MarC3, W2). This was also similar to surface water temperatures recorded in the field, suggesting appropriate temperature control was maintained during the trials, conducive to emergence.

4.6.2 Rehydrate Taxa Composition and Richness

Rehydration trials were productive, yielding 26 fauna taxa from six Survey Area sites in the Dry 2023. Across both wetting phases (W1 and W2), emergent invertebrate taxa included Turbellaria (flatworm; one taxon), Rotifera (rotifer; one taxon), Nematoda (roundworm; one taxon), Cladocera (water fleas; 12 taxa), Spinicaudata (clam shrimp; one taxon), Ostracoda (seed shrimp; 8 taxa), Collembolla (springtail; one taxon), and Diptera (two-winged flies; one taxon) (Appendix K; Figure 4.24). Although macrophytes germinated from all sites, they did not reach sufficient maturity to allow identification.

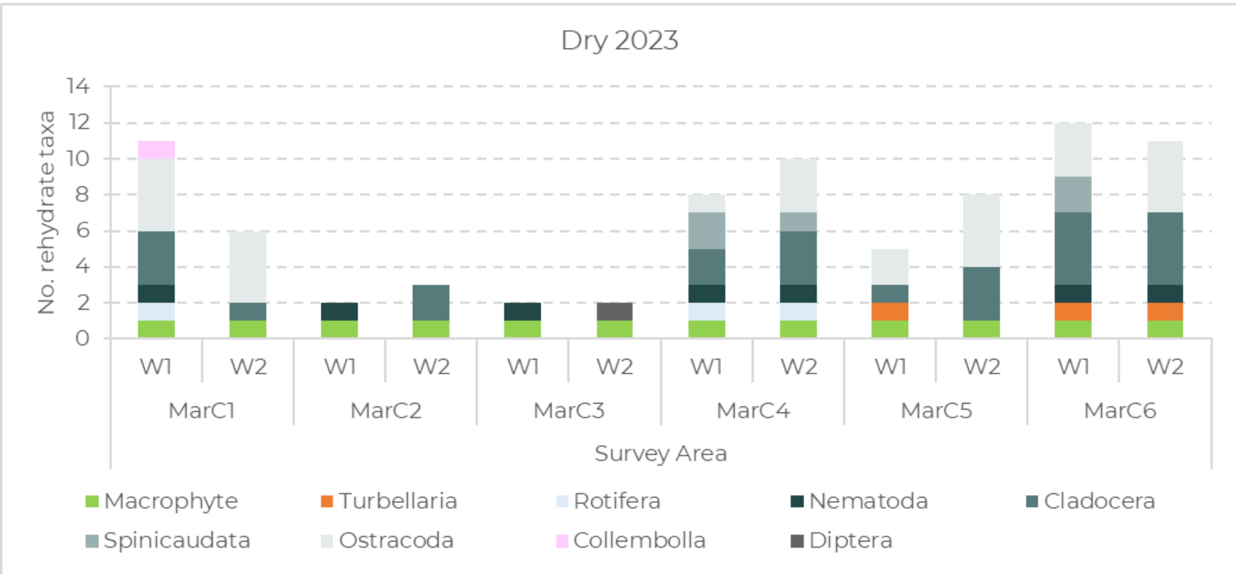

Figure 4.24: Richness and composition of taxa that emerged (or germinated) during rehydration trials

Richness ranged from three taxa (MarC3) to 15 taxa (MarC6). Crustacea, including water fleas, seed shrimp and clam shrimp, was generally the dominant group emerging within each trial tank, where more than one taxon emerged (Figure 4.24). This is consistent with other studies, where crustaceans 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) which are capable of withstanding long periods of drought (Rossi *et al.*, 2013; Timms, 1993). Macrophytes germinated at every site in each wetting phase (Figure 4.24).

Several taxa emerged from rehydration trials that were not recorded using other sampling methods. These included the Cladocera *Latanopsis* sp. and *Latanopsis australis* the clam shrimp *Limnadopsis occidentalis* and *Ozestheria* `sp. Biologic-BRAN002`, and the seed shrimp *Bennelongia tirigie*, *Cypretta* `sp. Biologic-OSTR016` and *Ilyocypris australiensis*.

4.6.3 Significant Emergent Taxa

Most taxa which emerged from sediments were common, widespread species. The exceptions were two clam shrimp taxa, which are either currently known from few records or have highly fragmented populations. These were *Limnadopsis pilbarensis* and *Ozestheria* `sp. Biologic-BRAN002`. *Limnadopsis pilbarensis* is endemic to the Pilbara, and although it is widespread, it is known from relatively few records (see Section 4.5.2 for further information). During the Survey, it emerged from sediments collected from MarC5 and MarC6, and was also recorded from surface waters at MarC6 (see Figure 4.18).

The remaining clam shrimp morphologically resembled *Ozestheria packardi*. However, *Ozestheria packardi* is known to exhibit high morphological variability, and several lineages are known with studies suggest it represents a complex of at least 14 species (Rogers, 2020; Schwentner *et al.*, 2015). Therefore, specimens were submitted for molecular analysis and one sequences matched a previously known OTU, *Ozestheria* `sp. Biologic-BRAN002` (Biologic, 2025a). This OTU emerged from MarC6 sediments (see Figure 4.18). *Ozestheria* `sp. Biologic-BRAN002` has a fragmented distribution and is currently known from few records. It has a linear range of 371 km, and has previously been recorded from the Harding River, Red Hill Creek, Cane River (Biologic unpub. data), and minor drainages of Weeli Wolli Creek (Biologic, 2024a).

4.7 Fish

4.7.1 Fish Species Composition and Richness

Four freshwater fish species were recorded during the Survey: western rainbowfish *Melanotaenia australis* (Melanotaeniidae), Pilbara tandan *Neosilurus* sp.[4] (Plotosidae), Pilbara bony bream *Nematalosa* sp.[5] (Clupeidae) and spangled perch *Leiopotherapon unicolor* (Terapontidae) (Table 4.13). Of these, two species (spangled perch and Pilbara tandan) have been recorded from the Survey Area on at least one occasion across all baseline sampling events. During the Survey, spangled perch were recorded from the Survey Area in the Dry 2023,

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

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

but no fish were recorded in the Survey Area in the Wet 2024. Pilbara tandan were not recorded from the Survey Area during the Survey. The highest fish species richness was recorded from Reference site SS (four taxa in both seasons; Table 4.13).

Spangled perch were the most widespread species in the Dry 2023, recorded from Survey Area sites MarC6a and MarC6b, and Reference sites BENS and SS. Western rainbowfish were the most widespread species in the Wet 2024, recorded at three Reference sites, WWS, BENS and SS. Pilbara bony bream were only recorded from Reference site SS on the Davis River.

4.7.2 Abundance

A total of 295 freshwater fish was recorded, with 202 recorded in the Dry 2023 (30 from the Survey Area and 172 from Reference sites) and 93 in the Wet 2024 (from Reference sites only; Table 4.13). In the Dry 2023, Reference site SS recorded the greatest abundance of fish (126 individuals), followed by Reference sites WWS and BENS (29 and 17 individuals, respectively). Reference site SS recorded the greatest abundance in the Wet 2024 (51 individuals), followed by WWS (40 individuals).

4.7.3 Significant Fish Species

No significant fish species were recorded from the Survey Area, with most species being common and ubiquitous, with distributions across the region and/or northern Australia. Two Pilbara endemic species were recorded during the Survey; the Pilbara tandan and Pilbara bony bream. Both taxa are representatives of genera which are wide-ranging across northern Australia, but the species recorded from the Pilbara are genetically distinct to their common and widespread congeners (i.e., *Nematalosa erebi* or *Neosilurus hyrtlii*) (Unmack, 2013). Neither of these Pilbara endemic fish were recorded from the Survey Area during the Survey, although the Pilbara tandan was previously recorded from MarC1 and MarC5 in the Dry 2020, at MarC4 in the Wet 2021, and at MarC3a in Dry 2021 (see Section 4.7.5 below).

Table 4.13: Abundance of each freshwater fish species recorded

Type	Site	Spangled perch		Western rainbow		Pilbara tandan		Bony bream		Abundance		Richness	
		D	W	D	W	D	W	D	W	D	W	D	W
Survey Area	MarC1	-	0	-	0	-	0	-	0	-	0	0	0
	MarC2	-	0	-	0	-	0	-	0	-	0	0	0
	MarC3	-	0	-	0	-	0	-	0	-	0	0	0
	MarC4	-	0	-	0	-	0	-	0	-	0	0	0
	MarC5	-	0	-	0	-	0	-	0	-	0	0	0
	MarC6	-	0	-	0	-	0	-	0	-	0	0	0
	MarC6a	15	n/s	0	n/s	0	n/s	0	n/s	**15**	n/s	**1**	n/s
	MarC6b	15	n/s	0	n/s	0	n/s	0	n/s	**15**	n/s	**1**	n/s
Reference	MACREF2	0	1	0	0	0	0	0	0	0	**1**	0	**1**
	MACREF1	0	0	0	0	0	0	0	0	0	0	0	0
	WWS	0	1	26	38	3	1	0	0	**29**	**40**	**2**	**3**
	BENS	2	0	15	1	0	0	0	0	**17**	**1**	**2**	0
	MUNJS	0	0	0	0	0	0	0	0	0	0	0	0
	SS	47	33	44	13	9	4	26	1	**126**	**51**	**4**	**4**
	Abundance	**79**	**35**	**85**	**52**	**12**	**5**	**26**	**1**	**202**	**93**		

dry sites denoted by '-'

n/s = not sampled

4.7.4 Length-Frequency Analysis

Spangled perch

Within the Survey Area, sub-adults constituted the greatest proportion of spangled perch recorded during the Dry 2023 (80%), while at Reference sites, spangled perch were mostly juveniles (37%) followed by adults (35%; Figure 4.25). Adults were dominant in the Wet 2024 (80%; Reference sites only). A single new recruit was recorded from Reference site SS in the dry season, and juveniles were recorded at this site in both seasons. A juvenile spangled perch was recorded in the Survey Area at MarC6a in the Dry 2023 (Figure 4.25).

Western rainbowfish

Western rainbowfish were recorded from Reference sites only. In the Dry 2023, western rainbowfish were predominantly juveniles and adults (both 33%), closely followed by new recruits (25%). In the Wet 2024, juveniles and sub-adults constituted the greatest proportion of western rainbowfish (50% and 25%, respectively). No new recruits were recorded in the wet season.

Pilbara tandan

Pilbara tandan were only recorded from Reference sites. Pilbara tandan comprised adults (67%) and sub-adults (33%) in the Dry 2023. In the Wet 2024, Pilbara tandan populations were dominated by adults (60%), followed by juveniles (40%). No Pilbara tandan new recruits were recorded from any site in either season.

Figure 4.25: Length frequency analysis for spangled perch

4.7.5 Change in Fish Over Time (Dry 2020 to Wet 2024)

All fish

Incorporating all fish from different species into the analysis, average fish abundance has decreased dramatically in the Survey Area since the Dry 2021 (Figure 4.26). In fact, fish have not been recorded from the long-term monitoring Survey Area sites (MarC1 to MarC6) since the Dry 2022, despite being recorded at downstream sites MarC6a and MarC6b, as well as nearby upstream Reference MACREF2 (Figure 4.26). Average fish abundance has also showed a general decline over time at Reference sites, with a sharp decline recorded between the Wet and Dry 2023 (Figure 4.26).

Overall, a significantly greater abundance of fish was recorded from Reference sites in comparison to the Survey Area (Table 4.14). There was also a significant difference in average fish abundance between sampling events (df = 7, p = 0.009), with greatest abundance recorded in the Dry 2021, and lowest abundances recorded in the Wet 2024 and Dry 2023 (Figure 4.26). The interaction between these two factors was not significant (Table 4.14).

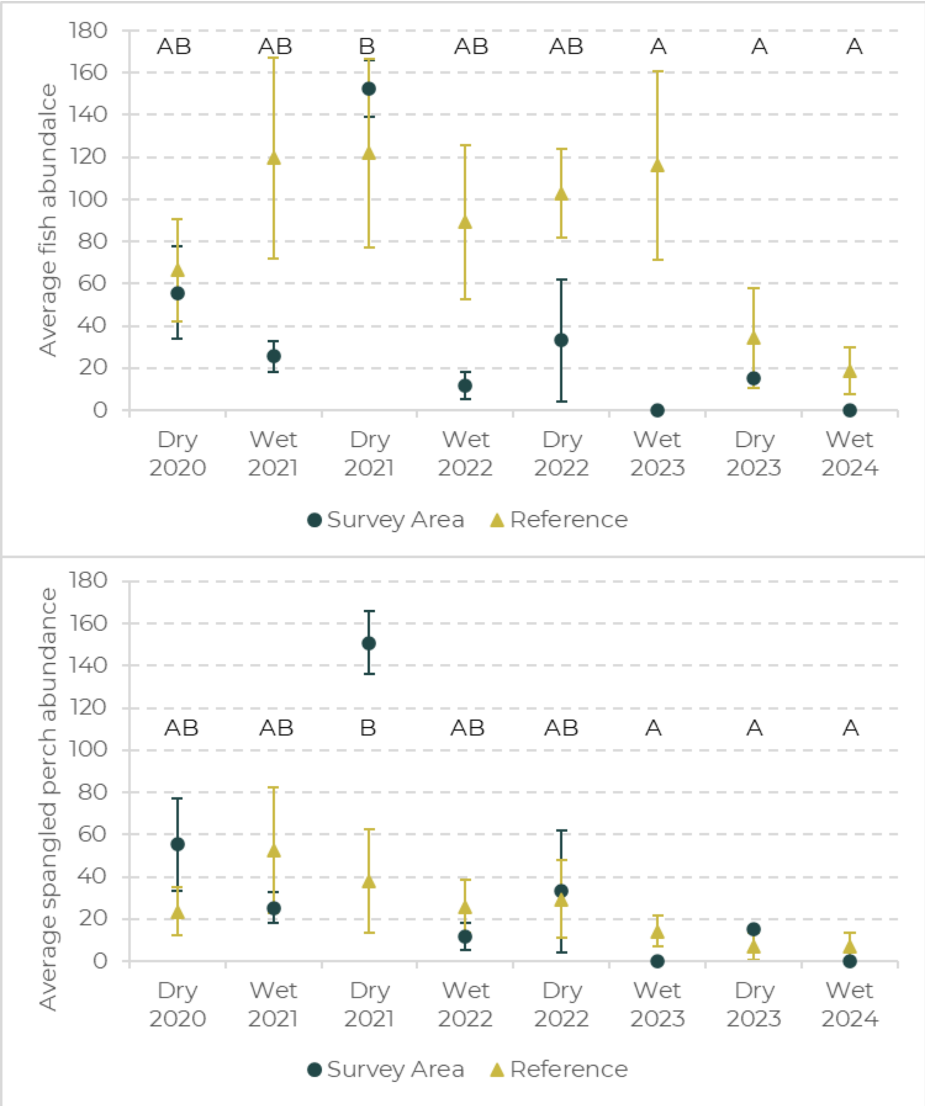

Figure 4.26: Average abundance of all fish (bottom) (± se) and spangled perch(± se) (top) recorded in each sampling event

Dry 2021 and Dry 2023 fish are based on f two replicates, not six. In the Wet 2023 and 2024, water was present in the Survey Area, but no fish were recorded. Letters denote equal means (Tukey's post-hoc results)

Spangled perch

Across all sampling events, total spangled perch abundance in the Survey Area (1,136 spangled perch) was similar to Reference sites (1,022; Table 4.15). Within a sampling event, the greatest abundance of total spangled perch was recorded from the Survey Area (332 individuals recorded in Dry 2020), as was the lowest abundance (no individuals in the Wet 2024; Figure 4.27). Spangled perch have not been recorded from MarC1, MarC2 or MarC4 since the Dry 2021, when these sites were all dry at time of sampling (Figure 4.27; Table 4.15). The lack of spangled perch recorded from these sites in the Wet 2022 (and since that time) is of concern as they were able to recolonise MarC3 following the drying in the Dry 2021, and were also recorded from MarC3a (Figure 4.27). Generally, average spangled perch abundance has declined over time at both Survey Area and Reference sites, though this is more apparent in the Survey Area (Figure 4.26; Table 4.15)

There was no significant difference in average spangled perch abundance between site types (Table 4.14). However, there was a significant difference in spangled perch abundance between sampling events. Similar to all fish, the highest abundance of spangled perch was recorded in the Dry 2021, and lowest abundance recorded in the Wet 2024 and Dry 2023 (Figure 4.26). There was also a significant interaction (df = 7, p = 0.038), indicating that the change over time was not consistent between site types(Table 4.14).

Pilbara tandan

Pilbara tandan have been recorded in the Survey Area infrequently and in low abundances (Table 4.15). They have not been recorded in the Survey Area since the Dry 2021 (Table 4.15; Figure 4.28). Overall, Pilbara tandan abundance was significantly lower in the Survey Area compared to Reference sites (Table 4.14). However, there was no significant difference between sampling events, nor was there any significant interaction between these two factors (Table 4.14).

Table 4.14: Two-way ANOVA results comparing fish abundance(all), as well as spangled perch and Pilbara tandan between sampling event and site type

Source	df	F	*p*-value*
All fish abundance			
Sampling event	7	2.98	0.009
Site type	1	9.93	0.002
Sampling event* Site type	7	1.27	0.280
Spangled perch abundance			
Sampling event	7	4.02	0.001
Site type	1	2.17	0.145
Sampling event* Site type	7	2.30	0.038
Pilbara tandan abundance			
Sampling event	7	0.85	0.552
Site type	1	7.21	0.009
Sampling event* Site type	7	0.85	0.550

*Significant *p*-values in red

Table 4.15: Total spangled perch and Pilbara tandan abundance recorded over the years

		Dry 2020		Wet 2021		Dry 2021		Wet 2022		Dry 2022		Wet 2023		Dry 2023		Wet 2024		Total - all events	
Site Type	Fish species	n	Total	n	Total	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	2	30	6	0	**39**	**1,136**
	Pilbara tandan	6	2	6	1	2	3	6	0	6	0	5	0	2	0	6	0	**39**	**6**
Reference	Spangled perch	5	118	5	263	5	190	5	129	5	147	5	61	6	79	6	35	**42**	**1,022**
	Pilbara tandan	5	12	5	83	5	30	5	60	5	21	5	29	6	12	6	5	**42**	**252**

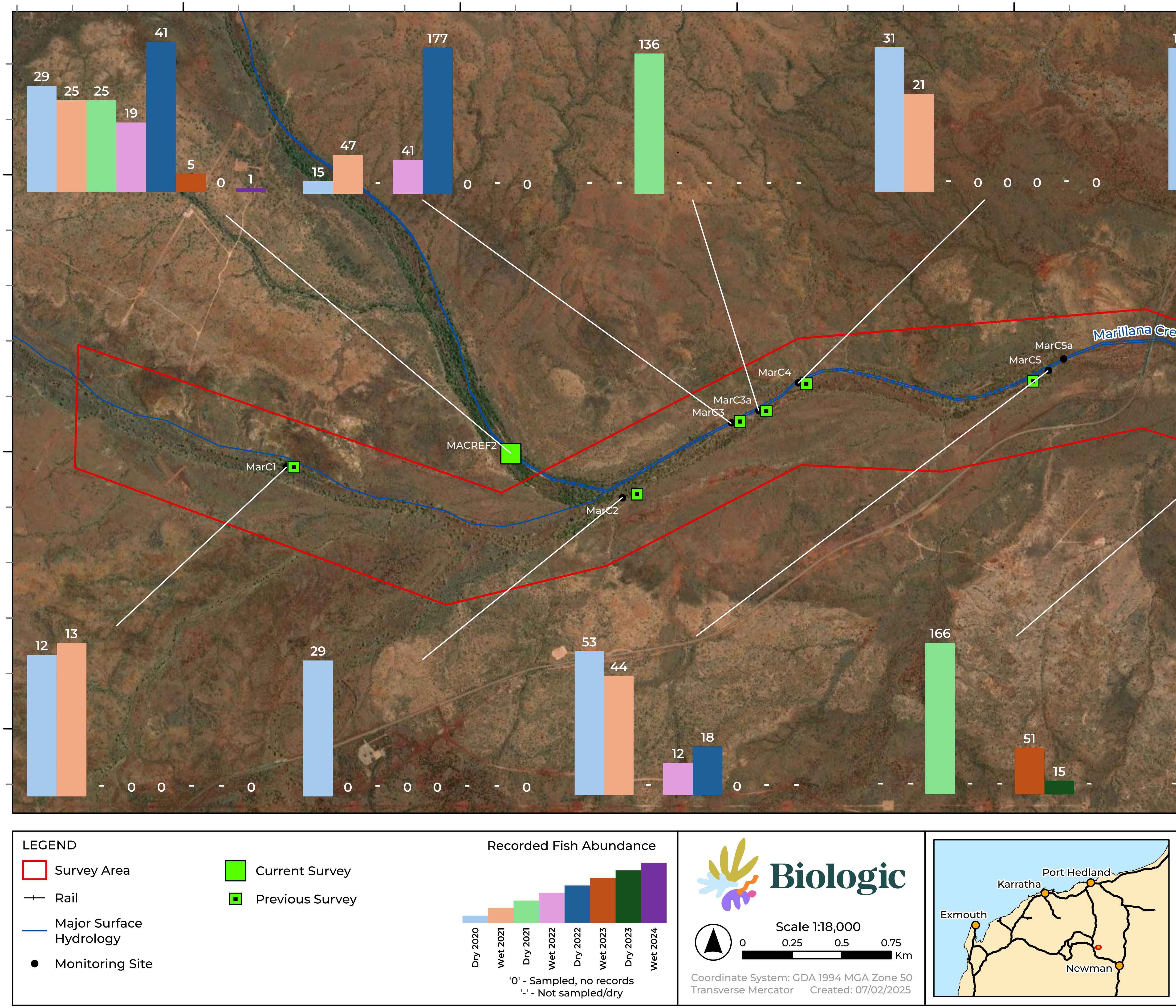

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Figure 4.27: *Leipotherapon unicolor* records from the Survey Area

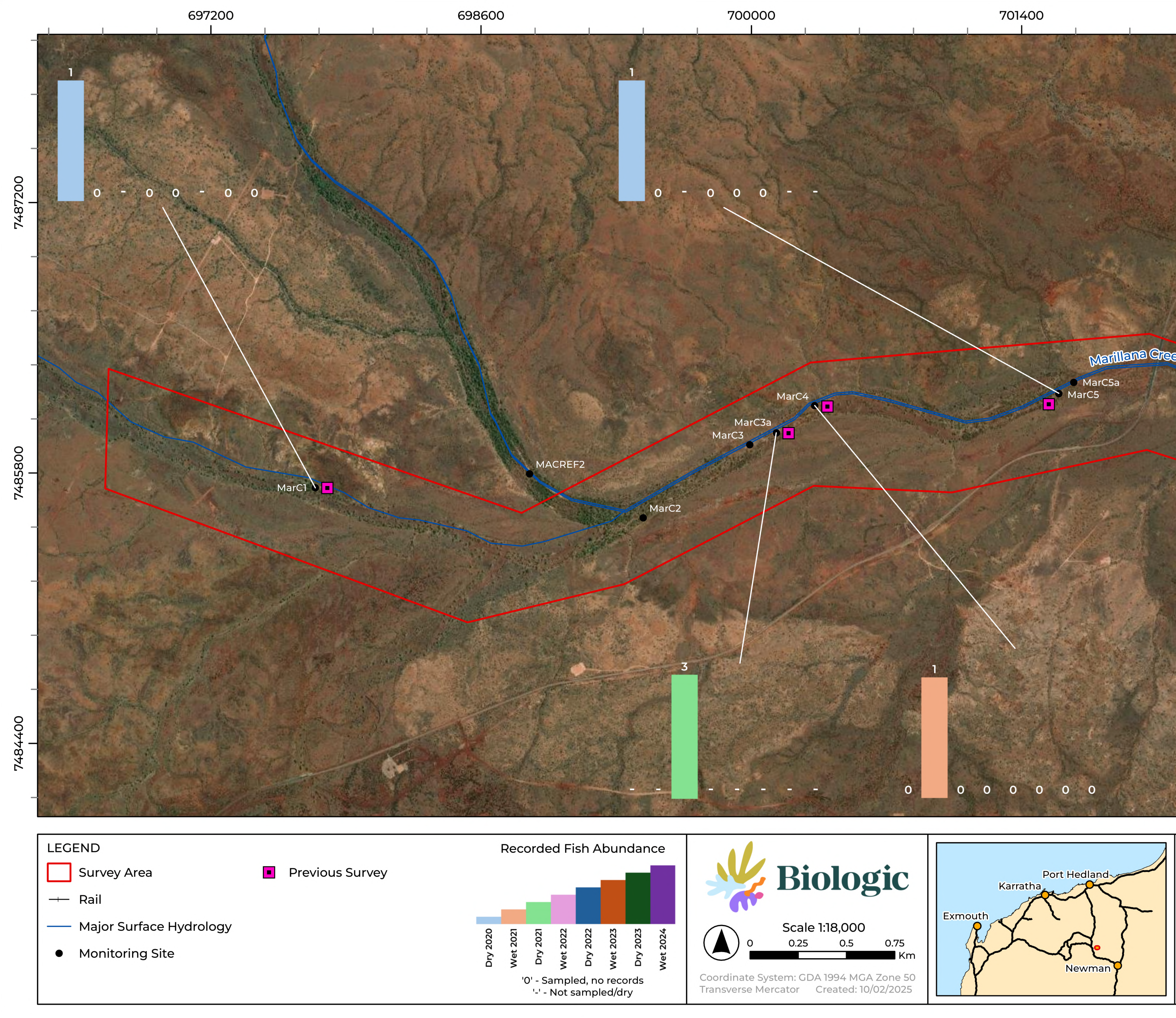

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Figure 4.28: *Neosilurus* sp. records in the Survey Area

4.8 Other Aquatic Fauna

4.8.1 Frogs

Tadpoles were observed at all Survey Area sites in the Wet 2024. While these were not able to be identified to species level in the field, tadpoles of the desert tree frog (*Litoria rubella*) have previously been recorded from the Survey Area (Biologic, 2024b). Abundance of tadpoles was relatively high at some sites, with over 300 individuals observed at MarC3, and more than 100 individuals recorded at MarC2 and MarC4. The tadpoles were of two distinct sizes and showed broad morphological variation, likely representing at least two species. One adult Main's frog (*Cyclorana maini*) was recorded at MarC1 in the Wet 2024 (Plate 4.1).

Plate 4.1: *Cyclorana maini* recorded from MarC1 in the Wet 2024 (photo by Biologic ©).

4.8.2 Other vertebrate fauna

No flat-shelled turtles (*Chelodina steindachneri*) or Pilbara olive python (*Liasis olivaceus barroni*) were recorded from the Survey Area in either the Dry 2023 or Wet 2024. This is consistent with previous baseline sampling in the Survey Area.

5 Discussion

5.1 Habitat Assessment

Although the pools within the Survey Area were thought to be relatively persistent, especially in the upper reaches (MarC2) where a high-level GDE was previously identified, all long-term monitoring locations in the Marillana Creek Survey Area (MarC1 to MarC6) were dry at the time of the Dry 2023 survey. Drying of the creek has been observed since the Dry 2021, and while surface water has been present in subsequent surveys to varying degrees, submerged and emergent macrophyte cover has markedly declined, with obvious signs of senescence in sedges and other riparian vegetation (Table 6.1). This suggests surface water within Marillana Creek is not currently being maintained by groundwater intersecting the surface, to the same extent that it was in the recent past.

The reduction and loss of submerged and emergent macrophytes translates to a reduction in available habitat for aquatic fauna, as does the reduced persistence of surface water. These impacts, coupled with the fire in January 2024, has resulted in notable habitat loss for aquatic fauna across the Survey Area. Impacts from the fire included a loss of trailing vegetation, LWD, detritus, as well as mid-storey shrubs and overstorey canopy cover (Table 6.1). The loss of shade may also exacerbate drying conditions, due to accelerated evaporation of surface water. Other impacts following fire include higher sediment load due to destabilisation of banks from loss of vegetation, influencing water clarity and light penetration (Jackson *et al.*, 2024; Smith *et al.*, 2011), as was observed at MarC5a in particular, where extremely high turbidity was recorded in the Wet 2024. Reference site MACREF2, located on Marillana Creek upstream of the Survey Area, also showed impacts from the January fire, including loss of canopy cover and layers of ash on the banks. Unlike the Survey Area, surface water at MACREF2 has maintained its permanence, and has persisted over time even despite areas downstream completely drying.

Similarly, sites MarC6a and MarC6b, located downstream of MarC6, persist even when the rest of the Survey Area is dry. While not sampled in the Wet 2024, the impact from the fire at these sites would not be immediately obvious, as these sites are not as vegetated and are naturally more exposed. There may be short-term impacts to water quality at these sites from ash and debris flowing downstream. The persistence of these pools is likely to provide a refuge for aquatic fauna in Marillana Creek.

5.2 Water Quality

Surface waters across the Survey Area were typical of Pilbara riverine pools, ranging from fresh to brackish, with circum-neutral to slightly basic pH, low DO, and generally low concentrations of nutrients and dissolved metals. Nearly all sites recorded EC in excess of the ANZG (2018) DGV, with the exception of MarC5 and MarC6 in the Wet 2024. The fresh EC at these sites suggested a higher contribution of rainwater to these surface pools at the time they were sampled. EC values at MarC2 were greater than 1,500 µS/cm, representing brackish waters as defined by (Mayer *et al.*, 2005). 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. Across all 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 data in the analysis, EC was significantly higher in the Survey Area than Reference sites. Sites MarC5a and MarC6 were very fresh in the Wet 2024 (< 185 µS/cm), indicating that rainwater made a greater contribution to surface pools in this part of the Survey Area than groundwater (ANZG, 2018).

Dissolved oxygen concentrations were high in the Survey Area in the Dry 2023 (90.1% at MarC6a and 98.9% at MarC6b), while all sites in the Wet 2024 recorded DO below the lower ANZG (2018) DGV. Dissolved oxygen concentrations were notably low at MarC4 (15.6%, Wet 2024) and Reference site MACREF1 (24.0%, Wet 2024). 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, Wet 2022 and Wet 2023), and in general has been highly variable over time. DO can be influenced by several factors, including diel daytime fluctuations due to photosynthesis from submerged plants during the day and respiration by fauna overnight (Andersen *et al.*, 2017). The decline in submerged and emergent macrophytes over time may be contributing to lower DO in the Survey Area, due to fewer plants for oxygen accumulation and CO_2 depletion through photosynthesis (Andersen *et al.*, 2017).

In both seasons, nitrogen nutrient concentrations (N_NOx and total N) within the Survey Area were generally high in comparison to Reference sites, and eutrophication DGVs. Total P was also high and exceeded the eutrophication DGV at all sites, both in the Survey Area and at References, in both seasons. Overall, total N and total P concentrations were both significantly higher in the Survey Area than at Reference sites. There were also significantly higher concentrations of these nutrients in the Wet 2024 compared to preceding sampling events. 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 (Ryding & Rast, 1989). The relationship between nitrate-enrichment and enhanced algal growth in freshwaters is well documented, often resulting in very high density and abundance, but low species richness (Camargo & Alonso, 2006; Wagenhoff *et al.*, 2011). In the Survey Area, algae blooms were not obvious in either season.

Dissolved metals concentrations in surface waters of the Survey Area generally were low and below 95% toxicity DGVs, with the exception of:

- dAl – the 95% toxicity DGV was exceeded at Survey Area sites MarC5 and MarC6, and Reference site MACREF1 in the Wet 2024
- dCr – was recorded in excess of the 95% toxicity DGV at MarC5 and MarC6 in the Wet 2024
- dCu – the 95% toxicity DGV was exceeded at all Survey Area sites, and at Reference sites MACREF1 and BENS in the Wet 2024.

Spot exceedances are relatively common in Pilbara waterbodies, especially for dAl and dCu (Biologic, unpub. data). 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. 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).

Many water quality analytes were recorded in significantly higher concentration in the Wet 2024, including turbidity, N_NOx, TN, and TP, as well as concentrations of several dissolved metals (dAl, dAs, dCo, dCu, dFe, dMo, dSe, dV and dZn). These differences were largely due to higher concentrations recorded in the Survey Area at the time. Fire can have a detrimental impact on water quality, due to sediment and ash shock loads (Jackson *et al.*, 2024). Elevated turbidity was found to be of concern following the 2019 bushfires in New South Wales, where the turbidity in raw water samples exceeded 195 NTU (Jackson *et al.*, 2024). During the Survey, turbidity at MarC5a and MarC6 were both highly elevated (>290 NTU) in the Wet 2024. Release of toxins such as metals and nutrients can also occur as a result of fire. Though studies are limited, a desktop review by Smith *et al.* (2011) found reports of elevated dFe, dCu, dZn, dCr, dAs and dPb in north-eastern Victorian streams after intense summer storm events which followed bushfires.

5.3 Macrophytes

Previous baseline surveys reported that the Survey Area supports several potential GDEs, characterised by numerous GDV/GDE indicator taxa (Biologic, 2024b). The current Survey recorded a total of nine Moderate-High GDV/GDE indicator taxa from the Survey Area, which was generally lower than recorded during previous surveys, with the key indicator of mature and abundant *Melaleuca argentea* missing during the Survey. Overall, the richness of mesophytic and hydrophytic indicator flora appears to be declining over time, as well as losses of emergent macrophytes such as *Typha domingensis* and *Schoenoplectus subulatus*. Most notable has been the near loss of *Melaleuca argentea* trees at MarC3 and MarC4 (located within the high significance GDE), the deterioration of which was previously observed in the Dry 2022/Wet 2023 survey period (Biologic, 2024b). Tree health monitoring undertaken by Biologic's botany team, which overlaps with the current Survey Area, has recorded a decline in mean crown and foliage cover for *M. argentea* since October 2020 (Biologic, 2022c, 2025a). At least 13 trees, including seven *M. argentea*, five *Eucalyptus camaldulensis* and one *E. victrix* were considered dead following the fire, at monitoring sites MPT-01 and MPT-02 (located within 250 m of MarC5 and MarC2, respectively) (Biologic, 2025a). *M. argentea* are highly susceptible to changes in groundwater level, especially declines occurring at a rapid rate (McLean, 2014). The fire obviously contributed to these deaths, but the continued drying of the Survey Area remains a considerable threat to the GDV/GDE indicator taxa and other riparian flora.

Previously identified potential GDEs include:

- potential High significance GDE –an approximate 1.2 km stretch of creek from upstream of the Marillana confluence with the tributary (including MACREF2) to MarC2
- potential Moderate significance GDE – located ~1.45 km downstream of MarC3 and including MarC5
- potential Moderate significance GDE – located ~250 m on the upstream tributary encompassing MarC1.

General tree health (foliage cover, canopy cover and tree death) in these areas has changed since the original Dry 2020/Wet 2021 survey, largely due to drying conditions, but also because of the recent fire (Table 5.2). The decline in richness and tree health has been observed prior to the January 2024 fire, though considerable burning of the understorey and dominant trees was also evident and likely compounded impacts in the area (Plate 5.1). In the Wet 2024, post-fire recruitment and epicormic growth was observed throughout the Survey Area, indicating some trees (such as *Eucalyptus camaldulensis*, *E. victrix* and *Melaleuca bracteata*) were able to survive the fire. However, given the drying conditions in the Survey Area, it is not known whether this recovery will be short-lived and extend beyond the period where wet season surface water is available.

Table 5.1: Summary of current condition of potential GDEs within the Survey Area

Type	Current condition/ observable impacts
High significance GDE (MACREF2 to MarC2)	Dying *M. argentea* and *E. camaldulensis* trees, particularly around the confluence. Declining canopy health such as lower foliage density and tip die-off (Biologic, 2025a). Observable loss of understorey was evident post-fire, from MACREF2 as far downstream as MarC2 (Plate 5.1). Loss of emergent macrophytes at MarC2, as well as surface water becoming more ephemeral. Macrophytes were still present at MACREF2 post-fire, and water is still permanent (see Table 5.1).
Moderate significance GDE (MarC3 to MarC5)	Dying *M. argentea* and *E. camaldulensis*, with many trees having been burnt by the fire (Plate 5.1). The fire intensity was such that numerous

Type	Current condition/ observable impacts
	mature trees were dead, and one of the *M. argentea* used in the tree health monitoring program had fallen (Biologic, 2025a). Vegetation condition in this area has been declining since before the fire, with obvious death of macrophytes, particularly *Typha domingensis* and *Schoenoplectus subulatus*.
Moderate significance GDE (MarC1)	Prior to the fire, many of the sedges and other macrophytes were dead or dying, with surface water seemingly becoming more ephemeral (see Table 5.1), After the fire, burnt trees and bare ground from loss of understorey was noticeable.

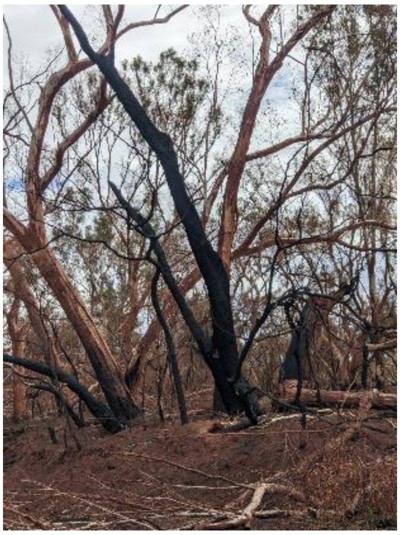

Plate 5.1: Impacts of the January 2024 fire, including loss of understorey at MACREF2 (left) and burning of mature trees at MarC5 (right)

5.4 Hyporheos Fauna

A total of 32 taxa from 11 taxonomic orders was recorded from hyporheic zones of the Survey Area, all of which were recorded in the Wet 2024. Groundwater dependent taxa (stygobites and permanent hyporheos stygophiles) represented 19% of the overall hyporheic taxa richness from the Survey Area, compared to 13% at Reference sites. The percentage contribution of stygobites in both the Survey Area (12%) and at Reference sites (8%) was greater than the percentage of stygobites previously recorded elsewhere in the Pilbara, with Halse *et al.* (2002) reporting that 5% of taxa from hyporheic zones of Pilbara springs were stygobites.

Five taxa recorded from hyporheic zones of the Survey Area were potentially significant, and were either locally restricted or rarely collected. These included the water mite *Rutacarus* `sp. Biologic-ACAR007`, syncarid *Atopobathynella* `sp. Biologic-PBAT019`, and copepods *Fierscyclops* `sp. Biologic-CYCL034`, *Fierscyclops* `sp. Biologic-CYCL039` and Canthocamptidae `sp. Biologic-

HARP059` (see Table 6.1: Photographs showing aquatic habitat changes within the Survey Area between the Dry 2020 and Wet 2024

Dry 2020	Wet 2021	Dry 2021	Wet 2022
MarC1			
			
Max depth: 0.2 m	**Max depth: 0.2 m**	**Max depth: Dry**	**Max depth: 0.4 m**
MarC2			
			
Max depth: 0.3 m	**Max depth: 0.4 m**	**Max depth: Dry**	**Max depth: 0.5 m**

Dry 2020	Wet 2021	Dry 2021	Wet 2022
MarC3			
			
Max depth: 0.6 m	**Max depth: 0.6 m**	**Max depth: Dry**	**Max depth: 1.0 m**
MarC4			
			
Max depth: 0.7 m	**Max depth: 0.4 m**	**Max depth: Dry**	**Max depth: 1.2 m**

Dry 2020	Wet 2021	Dry 2021	Wet 2022
MarC5			
			
Max depth: 0.3 m	**Max depth: 1.8 m**	**Max depth: Dry**	**Max depth: 1.5 m**
MarC6			
			
Max depth: 0.15 m	**Max depth: 1.5 m**	**Max depth: Dry**	**Max depth: 1.5 m**

Table 6.2).

Hyporheic zones of the Survey Area could only be sampled in the Wet 2024, as during the Dry 2023, sites were either too dry (no water in the sub-surface) or located on bedrock. The relatively high richness of groundwater taxa in the Survey Area in the Wet 2024, once re-inundated, suggests that these taxa are able to follow the groundwater as groundwater levels recede, and then move back up into the hyporheic zone following re-introduction of sub-surface flows and availability of hyporheic habitats. The hyporheic zone is known to represent an ecotone between the surface and groundwater, and provides several ecosystem services to both habitats (Boulton, 2001; Dole-Olivier & Marmonier, 1992; Edwards, 1998). Invertebrates are known to be able to migrate vertically through the hydrological profile to exploit the different habitats during different life history stages, but also during times of flood and drought (Bruno *et al.*, 2012; Coe, 2001; Hose *et al.*, 2005; Palmer *et al.*, 1992). It appears that the invertebrates of the Survey Area have been doing this over time.

Overall, taking all sampling events into account, there was no significant difference in the number of groundwater dependent taxa recorded between sampling events or site types. Relatively high richness of groundwater dependent taxa was recorded from MarC2, which was comparable to Reference springs such as WWS and SS, indicating that hyporheic habitat was not lost entirely in this area when the creek dried, and that the connectivity between the groundwater and surface water is still there, once surface flow returns. However, the continued persistence of groundwater dependent taxa in the hyporheic zone is likely to be threatened if groundwater levels continue to decline to a point where that connectivity is lost.

5.5 Macroinvertebrates

A total of 156 macroinvertebrate taxa from 20 taxonomic orders was recorded from the Survey Area, across both seasons. 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). Notably high richness was recorded from the two Survey Area sites sampled in the Dry 2023 (MarC6a and MarC6b), comparable to MUNJS and not much lower than SS, the latter of which is a wetland of subregional significance known for its high richness of aquatic invertebrates (Kendrick & McKenzie, 2003).

While most aquatic macroinvertebrates recorded from the Survey Area during the Survey were common, widespread species, three were of note and/or were of significance. These were Anostraca sp. and *Branchinella wellardi* (*Branchinella* `sp. Biologic-ANOS002`), and the clam shrimp *Limnadopsis pilbarensis* (see Table 6.1: Photographs showing aquatic habitat changes within the Survey Area between the Dry 2020 and Wet 2024

Dry 2020	Wet 2021	Dry 2021	Wet 2022
MarC1			

Dry 2020	Wet 2021	Dry 2021	Wet 2022
			
Max depth: 0.2 m	**Max depth: 0.2 m**	**Max depth: Dry**	**Max depth: 0.4 m**
MarC2			
			
Max depth: 0.3 m	**Max depth: 0.4 m**	**Max depth: Dry**	**Max depth: 0.5 m**

Dry 2020	Wet 2021	Dry 2021	Wet 2022
MarC3			
			
Max depth: 0.6 m	**Max depth: 0.6 m**	**Max depth: Dry**	**Max depth: 1.0 m**
MarC4			
			
Max depth: 0.7 m	**Max depth: 0.4 m**	**Max depth: Dry**	**Max depth: 1.2 m**

Dry 2020	Wet 2021	Dry 2021	Wet 2022
MarC5			
			
Max depth: 0.3 m	**Max depth: 1.8 m**	**Max depth: Dry**	**Max depth: 1.5 m**
MarC6			
			
Max depth: 0.15 m	**Max depth: 1.5 m**	**Max depth: Dry**	**Max depth: 1.5 m**

Table 6.2). In particular, *Branchinella wellardi* is listed as a Priority 3 species by DBCA (2025) and Vulnerable on the IUCN (2025) Red List of Threatened Species.

Including all macroinvertebrate data from all sampling events into the analysis, there was a significant difference in richness between sampling events, with lowest richness recorded in the Wet 2024. Average richness in the earlier sampling events was relatively steady until the Wet 2023, and has been more variable since. Macroinvertebrate taxa richness was notably low in the Wet 2024. The more recent fluctuations in macroinvertebrate richness (as well as assemblage composition), likely reflects the changes in surface water availability occurring within the Survey Area as well as the January 2024 fire. Drying can have a stronger influence on assemblage composition and community stability than magnitude of rainfall, due to altering habitat availability and intensity of biotic interactions as surface water volume shrinks (Boulton *et al.*, 1992). Changes in habitat and water quality likely associated with the fire were also found to influence macroinvertebrates of the Survey Area, with the higher concentrations of several dissolved metals and N_NOx found to be significantly correlated with assemblages (BVStep results).

Interestingly, MACREF2 showed little seasonal change in taxa richness (42 taxa in the Dry 2023 compared to 40 taxa in the Wet 2024), despite the vicinity of this site to the Survey Area and obvious impact from the fire between the two surveys. The fact MACREF2 has held persistent surface water across all sampling events might explain the site's capacity to support aquatic fauna, even following a major disturbance such as fire. The significantly lower richness from sites within the Survey Area suggests that length between inundation, as well as shorter inundation periods, are strongly influencing recovery of macroinvertebrate taxa between dry periods. 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.

Similar to the richness and water quality results, macroinvertebrate assemblage composition in the Wet 2023 and Wet 2024 was markedly different to other sampling events, separating from all others in the ordination space. This has been accompanied by impacts to some of the more sensitive taxa, including odonates, within the Survey Area. While it is not known if these changes are long-term, the decline in odonate richness during recent sampling event is of concern, as the Survey Area has previously supported considerably high richness, including IUCN-listed species (Biologic, 2022a, 2023a). The loss of abundance and diversity of submerged and emergent macrophytes as a result of continued drying of Survey Area has likely contributed to this decline because the diversity and composition of odonate assemblages is known to be related to the abundance and richness of littoral zone wetland flora and extent of riparian disturbance (Butler & deMaynadier, 2007), as well as benthic substrate granularity and in-stream productivity. Aerial and mobile invertebrates such as dragonflies and damselflies have some ability to seek refuge in more permanent water sources (such as MarC6a and MarC6b, and Reference MACREF2); however, this is highly dependent on a species' dispersal ability, connectivity between such pools, and presence of wetland flora/intact riparian vegetation in the pools to which they are dispersing.

In the Dry 2023, macroinvertebrate richness at MarC6a and MarC6b was notably higher than most Reference sites in that season, except MUNJS and SS. These sites also supported a high richness of odonate taxa. These results indicate that these lower pools are acting as refuges for aquatic fauna, while elsewhere in the Survey Area is impacted by drying conditions. 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). Conservation of permanent and semi-permanent pools in the Pilbara is considered critical to protecting threatened odonates under climate change pressures (Bush *et al.*, 2014).

5.6 Rehydrates

While limited rehydration studies in the Pilbara are publicly available, the Survey trials were considered productive, yielding 26 invertebrate taxa from the six Survey Area samples. Water quality parameters were mostly within the range recorded in the field, and conditions of the trial were considered conducive to fauna and flora emergence. Of the six sites included in the trials, greatest richness was recorded from MarC6, with 15 taxa emerging or germinating (including one "macrophyte" taxon). In comparison, previous rehydration trials on sediments collected from the Survey Area have been relatively low in productivity, yielding a maximum richness of four invertebrate taxa from an individual site (Biologic, 2024b). The low richness of emergences recorded previously was considered likely to be associated with the semi-permanent to permanent nature of the pools present, which would not favour temporary wetland specialist taxa that produce desiccation-resistant eggs and resting stages. Strategies such as diapause or having dormant life history stages (typically eggs) are adaptations typically found in aquatic invertebrates which inhabit the harsh and unstable environments of ephemeral pools (Radzikowski, 2013).

The greater productivity recorded the most recent rehydration trial may indicate that the fauna are responding to the shift from semi-permanent and permanent surface water to more ephemeral conditions. 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, it is possible that a shift in taxa to those with greater resistance strategies may occur in systems experiencing drying, though this response and the timing of such a response remains largely unknown. The highest richness in emergences was recorded from MarC6, a site that has been dry on numerous occasions over many years, with the next highest richness from MarC4. Two clam shrimp taxa, *Limnadopsis pilbarensis* (from MarC5 and MarC6) and *Ozestheria* `sp. Biologic-BRAN002` (from MarC6) were also recorded, both of which represent taxa which typically occur in temporary pools (Timms, 2018).

5.7 Fish

Of the two species of fish previously known from the Survey Area, only one was recorded during the Survey (spangled perch *Leiopotherapon unicolor*). In the Dry 2023, spangled perch were only recorded from the additional downstream Survey Area sites (MarC6a and MarC6b). At MarC6a, a single juvenile was recorded amongst the population at this time, indicating that conditions had been suitable for recruitment prior to the Survey. No fish were recorded in the Survey Area during the Wet 2024, despite the inundation of pools throughout the creek. Spawning in spangled perch coincides with flooding events, and several spawning events will occur each wet season (Beesley, 2006; Morgan *et al.*, 2002). Therefore, recruitment would have been expected following the above average rainfall (106.8 mm) in January 2024 (DWER, 2024).

The absence of fish in the Survey Area over recent sampling events may be due to the reduced persistence of surface water within this reach of Marillana Creek, preventing recruitment from occurring. Since the drying of the creek was first observed in the Dry 2021, spangled perch distribution has retracted, and they are no longer found in the upper reaches (MarC1 and MarC2), despite their presence at upstream Reference site MACREF2, albeit in low abundance (Table 5.2). They were last recorded from MarC1 and MarC2 in the Wet 2021, and have not dispersed back into this area since. 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), suggesting that it is not water quality that is preventing them re-establishing, and that perhaps the pools have not been connected for a sufficient length of time to allow dispersal. Although the additional downstream sites MarC6a and MarC6b were not sampled in the Wet 2024, these permanent pools undoubtedly act as important refuges for spangled perch in upper Marillana Creek, as the rest of the Survey Area has become increasingly ephemeral.

Table 5.2: Presence/absence of spangled perch in the Survey Area recorded in each sampling event

Survey	MACREF2	MarC1	MarC2	MarC3	MarC3a	MarC4	MarC5	MarC5a	MarC6	MarC6a	MarC6b
Dry 2020	✓	✓	✓	✓	n/s	✓	✓	n/s	✓	n/s	n/s
Wet 2021	✓	✓	×	✓	n/s	✓	✓	n/s	✓	n/s	n/s
Dry 2021	✓				✓			n/s		✓	n/s
Wet 2022	✓	×	×	✓	n/s	×	✓	n/s	✓	n/s	n/s
Dry 2022	✓	×	×	✓	n/s	×	✓	n/s	✓	n/s	n/s
Wet 2023	✓			×	n/s	×	×	n/s	×	n/s	n/s
Dry 2023	×				n/s			n/s		✓	✓
Wet 2024	✓	×	×	×	n/s	×		×	×	n/s	n/s

■ = site was dry at the time of sampling, ■ = spangled perch recorded, ■ = not recorded, n/s = not sampled

In addition to a retraction in distribution throughout the Survey Area, spangled perch abundance has also declined over time, with abundance of spangled perch in the Wet 2024 significantly lower than other sampling events. This pattern of declining abundance and recruitment has also been observed more broadly across the Marillana/Weeli Wolli Creek catchment, including Reference site MACREF1, sampled in this monitoring program. At this site, spangled perch have not been recorded since the Dry 2022. The pool completely dried in the Wet 2023, though water was present in the Dry 2023. MACREF1 is located on a tributary of Jugaricoogina Creek, where prolonged and continued drying of the creek has been observed further downstream (Biologic, 2023b). A significant decline in spangled perch abundance and a lack of recruitment has also been recorded from Weeli Wolli Creek, likely associated with the considerable hydrological and ecological changes that have occurred in this area over time, including increased flow velocities associated with Rio Tinto's discharge, calcification of the creek bed, introduction of redclaw, reduction in zooplankton richness and abundance, and reduction in macrophyte cover (Biologic, 2025b). There is now a complete lack of spangled perch new recruits and juveniles within the population[6] (Biologic, 2025b). Irrespective of the cause, the adverse changes noted to spangled perch throughout the catchment are of concern, especially given the number of mines and cumulative impacts across the catchment. Further work is required to understand the spangled perch populations (and freshwater fish more broadly) across the catchment, and ensure recruitment is still occurring within the catchment.

Pilbara tandan (*Neosilurus* sp.) have not been recorded from the Survey Area since the Dry 2021. It is possible that Pilbara tandan have not been able to re-establish since the creek dried, although this species has previously only occurred in low abundances across the Survey Area. In previous baseline years, the maximum number of Pilbara tandan recorded in a single site was three, from MarC3a in the Dry 2021 (Biologic, 2024b). During the Survey, Pilbara tandan was recorded from Reference sites WWS and SS in both seasons.

5.8 Other Aquatic Fauna

Several tadpoles of at least two species (likely *Litoria rubella* desert tree frog and *Cyclorana maini* Main's frog) were recorded across the Survey Area in the Wet 2024, as well as one adult Main's frog. Both species are common, and neither is listed as being of significance.

[6] between historic sampling undertaken in 2011 and 2012 (WRM, 2013) and more recent monitoring between 2021 and 2024

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 current ecological values and health of aquatic systems in the Survey Area, as well as change over time. To-date, bi-annual sampling has been undertaken over four consecutive years. The Survey Area supports a number of GDEs of moderate to high levels of significance. However, as previously reported (Biologic, 2024b), the Survey Area appears to be experiencing considerable decline, with continued drying resulting in a loss of GDV/GDE indicator taxa and macrophytes, and subsequently a decline in available habitat for aquatic fauna (Table 6.2). These habitat declines have resulted in a corresponding and significant change to invertebrate fauna and fish populations. The fact that all of the long-term monitoring sites completely dried in the Dry 2023 and negative impacts to GDVs are being observed is of concern, particularly in combination with the high intensity fire that occurred through the Survey Area in January 2024 which exacerbated the adverse changes which were already occurring. The main findings from the Survey, with respect to change over time within the Survey Area include:

- Significant changes in water quality in the Wet 2024, with higher concentrations of nutrients such as TN and TP, and dissolved metals dAl, dAs, dCo, dCr, dCu, dFe, dSe, dV and dZn
- Significantly lower GDV/GDE indicator taxa richness in the Survey Area compared to Reference sites, and significantly lower macrophyte richness in the Wet 2024 compared to all other sampling events
- Richness of groundwater dependent taxa within hyporheic zones of the Survey Area have shown some changes over time (although this was not significant), but importantly the Survey Area still supports groundwater dependent taxa within the remaining hyporheic habitat, including restricted species, despite the creek drying
- Macroinvertebrate and odonate richness were significantly lowest in the Wet 2024 compared to all other sampling events, which was due to the low richness recorded from the Survey Area at this time. Importantly, richness was notably high at Marc6a and MarC6b in the Dry 2023. These permanent pools are important refuges for aquatic fauna when the reach upstream is affected by drying
- Significantly lowest abundance of freshwater fish (all fish species combined) and spangled perch was recorded in the Dry 2023 and Wet 2024. In this case, this was due to low abundance in both the Survey Area and at Reference sites. However, of importance is the fact that spangled perch have not recolonised inundated areas in Marillana Creek, and that adverse changes to abundance and recruitment of spangled perch has been observed across the Marillana/Weeli Wolli Creek catchment. Given the

number and extent of mines and mining impacts throughout the catchment, further work should be undertaken to understand the spangled perch populations across the catchment.

Despite these changes, the Survey Area still supports a number of aquatic fauna, including restricted and listed invertebrate species, freshwater fish, and frogs. A summary of the significant flora and fauna recorded from the Survey Area is provided in Table 6.2. The continued presence of such taxa within the Survey Area indicates some degree of resilience, even following a major disturbance event such as fire in an already drying area.

Table 6.1: Photographs showing aquatic habitat changes within the Survey Area between the Dry 2020 and Wet 2024

Dry 2020	Wet 2021	Dry 2021	Wet 2022	Dry 2022	Wet 2023	Dry 2023	Wet 2024
MarC1							
							
Max depth: 0.2 m	**Max depth: 0.2 m**	**Max depth: Dry**	**Max depth: 0.4 m**	**Max depth: 0.4 m**	**Max depth: Dry**	**Max depth: Dry**	**Max depth: 0.5 m**
MarC2							
							
Max depth: 0.3 m	**Max depth: 0.4 m**	**Max depth: Dry**	**Max depth: 0.5 m**	**Max depth: 0.3 m**	**Max depth: Dry**	**Max depth: Dry**	**Max depth: 0.6 m**

Dry 2020	Wet 2021	Dry 2021	Wet 2022	Dry 2022	Wet 2023	Dry 2023	Wet 2024
MarC3							
							
Max depth: 0.6 m	**Max depth: 0.6 m**	**Max depth: Dry**	**Max depth: 1.0 m**	**Max depth: 1.2 m**	**Max depth: 0.8 m**	**Max depth: Dry**	**Max depth: 0.8 m**
MarC4							
							
Max depth: 0.7 m	**Max depth: 0.4 m**	**Max depth: Dry**	**Max depth: 1.2 m**	**Max depth: 1.6**	**Max depth: 1.0 m**	**Max depth: Dry**	**Max depth: 1.3 m**

Dry 2020	Wet 2021	Dry 2021	Wet 2022	Dry 2022	Wet 2023	Dry 2023	Wet 2024
MarC5							
							
Max depth: 0.3 m	**Max depth: 1.8 m**	**Max depth: Dry**	**Max depth: 1.5 m**	**Max depth: 1.5 m**	**Max depth: 0.9 m**	**Max depth: Dry**	**Max depth: Dry**
MarC6							
							
Max depth: 0.15 m	**Max depth: 1.5 m**	**Max depth: Dry**	**Max depth: 1.5 m**	**Max depth: 1.1 m**	**Max depth: 1.0 m**	**Max depth: Dry**	**Max depth: 1.5 m**

Table 6.2: Significant taxa recorded from the Survey Area

Type	Species	Survey Area		Reference Site	Significance (includes locally restricted taxa and those known from few records)
		Current Survey	Previous MAC Surveys		
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)		Known only from a few records with a linear range of 208 km
	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`	MarC1, MarC2 (hyporheos)	MarC4, MarC5 (hyporheos)	BENS	OTU with a linear range of 144.9 km. Disjunct distribution including the Survey Area, BENS, Fortescue River catchment and the Ashburton River catchment (Biologic unpub. data)
	Rutacarus `sp. Biologic-ACAR022`		MarC4 (hyporheos)		Currently the only 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, Jugaricoogina Creek, lower Weeli Wolli Creek, and groundwater bores at Jugari
	Bennelongia `sp. Biologic-OSTR026`		MarC1 (surface water)		Known only from the Survey Area and Gingianna Pool
Cyclopoida	*Fierscyclops* `sp. Biologic-CYCL034`	MarC6 (hyporheos)			One other record 46.2 km at Wonmunna Gorge (Biologic unpub. data)
	Fierscyclops `sp. Biologic-CYCL039`	MarC5 (hyporheos)			OTU with a linear range of 86.4 km (Biologic unpub. data)
Harpacticoida	Canthocamptidae `sp. Biologic-HARP059	MarC2 (hyporheos), MACREF2 (surface water)	MarC2, MarC4 (hyporheos)	MACREF2 (surface water)	Currently known only from Marillana Creek
	Elaphoidella sp.		MarC4 (hyporheos)	SS (hyporheos)	Undescribed and maybe new to science
	Kinnecaris `sp. Biologic-HARP037`		MarC2 (hyporheos)		Currently known from only the Survey Area and Jugaricoogina 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)		Currently the only record of this taxon
Stygal amphipod	*Chydaekata* sp. MJ1-UM1		MarC4 (hyporheos)		Known to have a restricted range, recorded from upper Marillana Creek only
Syncarids	*Atopobathynella* `sp. Biologic-PBAT019`	MarC6 (hyporheos)	MarC4 (hyporheos)	MACREF2, BENS (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

Type	Species	Survey Area		Reference Site	Significance (includes locally restricted taxa and those known from few records)
		Current Survey	Previous MAC Surveys		
Syncarids	*Atopobathynella* `sp. Biologic-PBAT019`	MarC6 (hyporheos)	MarC4 (hyporheos)	MACREF2, BENS (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*	MarC5 (rehydrates), MarC6 (surface waters and rehydrates)	MarC4, MarC5, MarC6 (surface waters)		Pilbara endemic, relatively uncommon. Previously recorded from Burrup Rockhole, Beabea Creek, Ratty Spring (Pirraburdu Creek) and Glen Ross Creek.
	Ozestheria `sp. Biologic-BRAN002`	MarC6 (rehydrates)			Fragmented distribution with a linear range of 371 km, previously recorded from the Harding River, Red Hill Creek, Cane River, and minor drainages of Weeli Wolli Creek
Fairy shrimp	Anostraca sp.	MarC5 (surface waters)			Immature nauplii that may represent taxa with a restricted distribution
	Branchinella wellardi	MarC6 (surface waters)			Priority 3 DBCA Vulnerable, IUCN Red List
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
Pseudoscorpions*	*Indolpium* `sp. Biologic-PSEU241`	MarC1 (surface waters)			Only known records of this taxon. Potential SRE
	Indolpium `sp. Biologic-PSEU242`	MarC2 (surface waters)			Only known records of this taxon. Potential SRE
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

* terrestrial invertebrate taxa recorded using aquatic ecology sampling methods

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.

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Appendix A: Detailed Sampling Methods

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

Water Quality

Water quality variables were recorded in situ with a portable YSI Pro Plus multimeter (see Plate 3.1). 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 measured were:

- In situ – pH, dissolved oxygen (DO; % and mg/L), electrical conductivity (EC; µS/cm), water temperature (°C) and redox potential (mV)
- General ions and others - calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), bicarbonate (HCO_3), chloride (Cl), sulfate (SO_4), sulfur (S), carbonate (CO_3), alkalinity and hardness (all mg/L)
- Water clarity – turbidity (NTU) and total suspended solids (TSS; mg/L)
- Nutrients – nitrogen nitrate (N_NO_3), nitrogen oxides (N_NOx), nitrogen 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 quality. All water samples were kept on ice in an esky whilst in the field, and either refrigerated (ions, dissolved metals, nutrients, general water), or frozen (total nutrients) as soon as possible for subsequent transport to the ALS laboratory.

Macrophytes and Dominant Riparian Vegetation

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.

Hyporheic Fauna

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

Hyporheic samples were preserved in 95% ethanol in the field and returned to the Biologic laboratory where they were stored in the freezer prior to processing. Hyporheos[7] fauna were removed by sorting under a low power dissecting microscope. Specimens were identified in-house to the lowest possible level (genus or species level) and enumerated to $\log_{10}$ scale abunance 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. Molecular analysis methodology is provided in the accompanying Molecular Report (Biologic, 2025a).

Macroinvertebrates

Macroinvertebrate sampling was conducted with a 250 µm mesh D-net across as many habitats as possible, including open water, macrophyte beds, large woody debris (LWD), leaf

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

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 and leaf litter was removed by hand (see Plate 3.2). Micro-crustacea (ostracods, Cladocera and copepods) were sampled by gentle sweeping over an approximate 15 m distance with a 53 μm mesh pond net. This collection was then combined with the macroinvertebrate sample and preserved in 95% ethanol in the field before being transported to the Biologic laboratory for processing. The sieve and both nets were thoroughly cleaned between sites to avoid cross contamination.

In the laboratory, 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.

Rehydrate Emergence Trials

Sediments were collected from dry sites to enable rehydration and emergence trials to be conducted in the Biologic laboratory. This included six sites in the Dry 2023 (MarC1, MarC2, MarC3, MarC4, MarC5 and MarC6). The aim of these trials was to obtain information on the types of resident fauna the Survey Area pools support by identifying those which emerge from desiccation-resistant resting stages following inundation and rehydration. This provides information on aquatic ecology values in the absence of surface water.

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

In the Biologic laboratory, each sediment sample was rehydrated in tanks flooded with 7 L of dechlorinated filtered water (see Plate 3.3). Rehydration was undertaken in a controlled temperature room maintained at a temperature comparable to conditions in the field at the time of collection, with a 12-hour light/12-hour dark cycle. Samples were examined every 24 to 48 hours for emergent fauna for up to 58 days after rehydration, or until no new fauna emerged. As cues for emergence and colonisation rates are different for different species, samples were allowed to dry after 28 days and re-wetted, to simulate a second flooding event. Animals were fed algal pellets for the duration of the emergence trials. 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.

Emergent fauna was identified to species level (where possible) under high-powered magnification, and abundance recorded on the $\log_{10}$ abundance scale. The conservation status of emergent taxa was determined. Macrophytes which germinated did not grow to sufficient size to allow identification before the rehydration trials were complete, and therefore were recorded as Macrophyte sp.

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) 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. Reference sites WWS and SS also included use of a Smith Root LR-24 backpack electrofisher. When used correctly, the backpack electrofisher draws fauna towards the anode pole (from within macrophytes, under large woody debris, and undercuts in banks) and results in minimal impact to fish (DSEWPaC, 2011).

Fish were identified in the field and standard length (SL[8]) measured. All fish were released alive to the site where they were collected. Any introduced redclaw caught using these fishing methods were processed in the field, including the recording of sex and carapace length (CL) measurements. As per DPIRD licencing exemption conditions, all introduced species were anaesthetised using AQUI-S® (AQUI-S New Zealand Ltd.), before being euthanised humanely in an ice slurry. Locations of introduced redclaw were reported to DPIRD in accordance with licence conditions.

Other Aquatic Fauna

Other vertebrate fauna (i.e., turtles, olive pythons, frogs) recorded using any of the methods above, or observed over the course of the Survey, were recorded for each site.

[8] 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).

Appendix B: 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).

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			0.34	0.94[C]	1.50 [C]	2.50[C]
Cadmium		H	0.00006	0.0002	0.0004	0.0008[C]
Chromium (Cr III)		H	ID	ID	ID	ID
Chromium (Cr VI)			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 (Se IV)		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 C: Biologic GDV Assessment Framework

Table 1: Site considerations for GDV rating assessment

Rating	General site features	Key/most common indicator species and density		
		Phreatophytic/Riparian	Mesophytic	Hydrophytic
High	Presence of mature obligate phreatophytes (i.e., *Melaleuca argentea*) with permanent to semi-permanent water bodies present. A high diversity and density of mesophytic and hydrophytic taxa. Pooling present; evidence of seepage	**Abundant:** • *Eucalyptus camaldulensis* • *Melaleuca argentea* **Present:** • *Sesbania formosa*	**Abundant to Common:** • *Melaleuca* species • *Ficus aculeata* **Present:** • *Acacia ampliceps* • *Cullen leucanthum* • *Ficus virens* • *Imperata cylindrica* • *Myoporum monatanum* • *Samolus* species	**Abundant to Common:** • *Potamogeton* species • *Sonchus hydrophyllus* **Present:** • *Juncus krausii* • *Livistona alfredii* • *Lobelia arnhemiaca* • *Samolus* sp. Millstream
Moderate	Presence of mature facultative phreatophytes (with potential for semi-mature to young obligate phreatophytes). Semi-permanent water bodies may be present. A moderate diversity and density of mesophytic and hydrophytic taxa. +/- Pooling present or evidence of pools; +/- evidence of seepage	**Abundant:** • *Eucalyptus victrix* • *Sesbania cannabina* **Common:** • *Eucalyptus camaldulensis* • *Melaleuca argentea*	**Abundant:** • *Melaleuca glomerata* **Common to Present:** • *Melaleuca* species • *Ficus aculeata* • *Plumbago zeylanica* • *Atalaya hemiglauca* • *Dodonaea lanceolata* • *Gymnanthera cunninghamii* • *Adriana tomentosa* • *Tinospora smilacina*	**Abundant:** • *Ammannia baccifera* • *Chara* species • *Najas* species • *Typha domingensis* **Present:** • *Cyperus* species • *Potamogeton* species • *Samolus repens* • *Schenkia* species • *Schoenoplectus subulatus* • *Sonchus hydrophyllus*
Low	Scattered presence of facultative and/or presence of	**Abundant to Common:** • *Acacia citrinoviridis*	**Abundant to Common:** • *Cyprus vaginatus*	**Present:** • *Ammannia baccifera*

Rating	General site features	Key/most common indicator species and density		
		Phreatophytic/Riparian	Mesophytic	Hydrophytic
	mature vadophytic (i.e. *Eucalyptus victrix*). Ephemeral to semi-permanent water bodies may be present. Low diversity and density of mesophytic and hydrophytic taxa.	• *Acacia coriacea subsp. pendens* • *Eucalyptus victrix* • *Stylobasium spathulatum* **Present:** • *Acacia sclerosperma* • *Eucalyptus camaldulensis* • *Eucalyptus xerothermica* • *Melaleuca argentea* • *Sesbania cannabina* • *Terminalia circumalata*	• *Eulalia aurea* • *Stemodia grossa* **Present:** • *Abutlion amplum* • *Melaleuca glomerata* • *Plumbago zeylanica* • *Atalaya hemiglauca*	• *Chara species* • *Fimbristylis microcarya* • *Marsilea exarata* • *Marsilea hirsuta* • *Myriophyllum species* • *Najas species* • *Schoenoplectiella laevis* • *Typha domingensis* • *Wahlenbergia tumidifructa*
Negligible	Minor to medium flowlines and drainage areas. Mostly inflow dependent species. Riparian species (i.e., *Acacia tumida* var. *pilbarensis*) are prevalent and dominant.	No groundwater indicator species present or not present at the density that would indicate presence of soil moisture. Mostly mature vadophytic taxa, with riparian tree species (i.e., *Eucalyptus xerothermica*, *Corymbia hamersleyana*). High diversity of Riparian species abundant and common.		
None	Minor flowlines. Occurs on upland habitats (i.e., hummock grassland on stony hills and slopes) that are highly unlikely to have to access to or be reliant on groundwater presence.	None present. Riparian species may be abundant, common and present.		

Please Note: 'Present' refers to any cover density, though is usually 0.1%; 'Common' is cover density from 0.2% to 10%; 'Abundant' is 11% cover density and higher.

Table 2: Comprehensive list of riparian taxa and their GDV rating for assessment

Family	*Taxon*	Classification	High	Moderate	Low	Negligible
Amarantaceae	*Alternanthera denticulata*	Riparian				Present
	Alternanthera nana	Riparian				Present
	Alternanthera nodiflora	Riparian				Present
	Amaranthus cuspidifolius	Riparian				Present
Apocynaceae	*Gymnanthera cunninghamii*	Mesophyte		Common/Present		
Arecaceae	*Livistona alfredii*	Hydrophyte	Present			
Asteraceae	*Centipeda minima*	Riparian				Present
	Centipeda minima subsp. *minima*	Riparian				Common
	Flaveria trinervia	Riparian				Present
	Pluchea dentex	Riparian				Present
	Pluchea rubelliflora	Riparian				Present
	Sonchus hydrophyllus	Hydrophyte	Common	Present		
Boraginaceae	*Ehretia saligna* var. *saligna*	Riparian				Present
Campanulaceae	*Lobelia arnhemiaca*	Hydrophyte	Present			
	Wahlenbergia tumidifructa	Hydrophyte			Present	
Caryophyllaceae	*Polycarpaea longiflora*	Riparian				Present
Characeae	*Chara* species	Hydrophyte		Abundant	Present	
Combretaceae	*Terminalia circumalata*	Phreatophyte			Present	Present
Convolvulaceae	*Ipomoea muelleri*	Riparian				Present
	Polymeria ambigua	Riparian				Present
Cyperaceae	*Cladium procerum*	Hydrophyte	Present			

Family	Taxon	Classification	High	Moderate	Low	Negligible
	Cyperus leptocarpus	Hydrophyte			Present	
	Cyperus polystachyos	Hydrophyte		Present		
	Cyperus species	Hydrophyte		Present		
	Cyperus vaginatus	Mesophyte		Abundant/Common	Common/Present	
	Eleocharis dulcis	Hydrophyte	Present			
	Eleocharis geniculata	Hydrophyte		Present		
	Eleocharis pallens	Hydrophyte		Present		
	Eleocharis sphacelata	Hydrophyte	Present			
	Eleocharis spiralis	Hydrophyte	Present			
	Fimbristylis cephalophora	Hydrophyte	Present			
	Fimbristylis feruginea	Hydrophyte	Present			
	Fimbristylis littoralis	Hydrophyte	Present			
	Fimbristylis microcarya	Hydrophyte			Present	
	Fimbristylis sieberiana	Hydrophyte	Present			
	Fuirena ciliaris	Hydrophyte		Present		
	Machaerina juncea	Hydrophyte	Present			
	Machaerina rubiginosa	Hydrophyte	Present			
	Schoenoplectiella laevis	Hydrophyte			Present	
	Schoenoplectus subulatus	Hydrophyte		Present		
	Schoenus falcatus	Hydrophyte	Abundant	Common		
	Schoenus punctatus	Hydrophyte	Present			

Family	*Taxon*	Classification	High	Moderate	Low	Negligible
Elatinaceae	*Bergia ammannioides*	Riparian				Present
Eriocaulaceae	*Eriocaulon cinereum*	Hydrophyte	Present			
Euphorbiaceae	*Adriana tomentosa*	Mesophyte		Present		
Fabaceae	*Acacia ampliceps*	Mesophyte	Present			
	Acacia citrinoviridis	Phreatophyte			Abundant/Common	
	Acacia colei var. *ileocarpa*	Riparian				Common
	Acacia coriacea subsp. *pendens*	Phreatophyte			Common	
	Acacia monticola	Riparian				Present
	Acacia monticola	Riparian				Common
	Acacia pyrifolia	Riparian				Common
	Acacia pyrifolia var. *pyrifolia*	Riparian				Common
	Acacia sclerosperma	Phreatophyte			Present	
	Acacia sericophylla	Phreatophyte			Present	
	Acacia tumida	Riparian				Present
	Acacia tumida var. *pilbarensis*	Riparian				Common
	Afrohybanthus aurantiacus	Riparian				Present
	Cajanus pubescens	Riparian				Present
	Crotalaria medicaginea var. *neglecta*	Riparian				Present
	Crotalaria novae-hollandiae	Riparian				Present
	Cullen leucanthum	Mesophyte	Present			
	Petalostylis labicheoides	Riparian				Common

Family	*Taxon*	Classification	High	Moderate	Low	Negligible
	Rhynchosia bungarensis	Mesophyte			Present	
	Sesbania cannabina	Phreatophyte		Abundant	Present	
	Sesbania formosa	Phreatophyte	Present			
	Tephrosia rosea var. Fortescue creeks (M.I.H. Brooker 2186)	Riparian				Present
	Vigna lanceolata var. *lanceolata*	Riparian				Present
Gentianaceae	*Schenkia australis*	Hydrophyte		Present		
	Schenkia clementii	Hydrophyte		Present		
Haloragaceae	*Myriophyllum* species	Hydrophyte			Present	
Hydrocharitaceae	*Najas* species	Hydrophyte		Abundant	Present	
Juncaceae	*Juncus krausii*	Hydrophyte	Present			
Lamiaceae	*Clerodendrum floribundum* var. *angustifolium*	Riparian				Present
Lythraceae	*Ammannia baccifera*	Hydrophyte		Abundant	Present	
	Ammannia multiflora	Hydrophyte			Present	
Malvaceae	*Abutilon amplum*	Mesophyte		Common	Present	
	Abutilon sp. Dioicum (A.A. Mitchell PRP 1618)	Riparian				Common
	Gossypium sturtianum	Mesophyte		Present		
	Lawrencia glomerata	Mesophyte		Present		
Marsileaceae	*Marsilea exarata*	Hydrophyte			Present	
	Marsilea hirsuta	Hydrophyte			Present	

Family	*Taxon*	Classification	High	Moderate	Low	Negligible
Menispermaceae	*Tinospora smilacina*	Mesophyte		Present		
Moracea	*Ficus aculeata*	Mesophyte	Common	Present		
	Ficus brachypoda	Riparian				Present
	Ficus geniculata	Mesophyte	Present			
	Ficus virens	Mesophyte	Present			
	Ficus virens var. *dasycarpa*	Mesophyte	Present			
Myrtaceae	*Eucalyptus camaldulensis*	Phreatophyte	Abundant	Common	Present	
	Eucalyptus camaldulensis subsp. *refulgens*	Phreatophyte	Abundant	Common	Present	
	Eucalyptus victrix	Phreatophyte		Abundant	Common	
	Eucalyptus xerothermica	Riparian			Present	Present
	Melaleuca alsophila	Mesophyte	Abundant	Present		
	Melaleuca argentea	Phreatophyte	Abundant	Common	Present	
	Melaleuca bracteata	Mesophyte		Present		
	Melaleuca glomerata	Mesophyte		Abundant	Present	
	Melaleuca lasiandra	Mesophyte		Present		
	Melaleuca linophylla	Mesophyte		Abundant/present		
	Melaleuca nervosa	Mesophyte	Abundant			
	Melaleuca xerophila	Mesophyte		Common		
Nyctaginaceae	*Commicarpus australis*	Mesophyte		Present		
Nymphaea	*Nymphaea pubescens*	Hydrophyte	Present			
	Nymphaeaceae species.	Hydrophyte	Present			

Family	*Taxon*	Classification	High	Moderate	Low	Negligible
	Nymphoides indica	Hydrophyte	Present			
Orobanchaceae	*Striga curviflora*	Hydrophyte		Present		
Papaveraceae	*Argemone ochroleuca* subsp. *ochroleuca*	Riparian				Present
Passifloraceae	*Passiflora foetida var. hispida*	Riparian				Present
Phyllanthaceae	*Fleuggea virosa* subsp. *melanthesoides*	Mesophyte		Present		
	Kirganelia baccata	Mesophyte		Common/Present		
	Nellica maderaspatensis	Riparian				Present
	Notoleptopus decaisnei var. *orbicularis* (A.B. Craig 428)	Riparian				Present
Plantaginaceae	*Stemodia grossa*	Mesophyte			Abundant	
Plumbaginaceae	*Muellerolimon salicorniaceum*	Mesophyte		Present		
	Plumbago zeylanica	Mesophyte		Common	Present	
Poaceae	*Cenchrus ciliaris*	Riparian				Common
	Cenchrus setiger	Riparian				Common
	Chrysopogon fallax	Riparian				Present
	Cymbopogon ambiguus	Riparian				Present
	Cymbopogon obtectus	Riparian				Present
	Cynodon dactylon	Riparian				Present
	Eragrostis tenellula	Riparian				Present
	Eriachne mucronata	Riparian				Common

Family	*Taxon*	Classification	High	Moderate	Low	Negligible
	Arundo donax	Hydrophyte	Present			
	Elytrophorus spicatus	Hydrophyte			Present	
	Eragrostis surreyana	Mesophyte		Present		
	Eulalia aurea	Mesophyte			Abundant	
	Imperata cylindrica	Mesophyte	Present			
	Leptochloa digitata	Riparian				Present
	Phragmites karka	Hydrophyte	Present			
	Pseudoraphis spinescens	Hydrophyte		Present		
	Sporobolis virginicus	Hydrophyte	Present			
	Themeda triandra	Riparian				Common
Polygonaceae	*Duma florulenta*	Mesophyte		Present		
Potamogetonaceae	*Potamogeton* species	Hydrophyte	Abundant	Present		
	Potamogeton tepperi	Hydrophyte	Abundant	Present		
Primulaceae	*Samolus repens*	Hydrophyte		Present		
	Samolus sp. Millstream	Hydrophyte	Present			
	Samolus species.	Mesophyte	Present			
Pteridaceae	*Acrostichum speciosum*	Hydrophyte	Present			
	Adiantum capillus-veneris	Hydrophyte	Present			
	Ceratopteris thalictroides	Hydrophyte	Present			
	Pteris vittata	Hydrophyte	Present			
Ruppiaceae	*Ruppia polycarpa*	Hydrophyte		Present		

Family	*Taxon*	Classification	High	Moderate	Low	Negligible
Sapindaceae	*Atalaya hemiglauca*	Mesophyte		Common	Present	
	Dodonaea lanceolata	Mesophyte		Common		
Scrophulariaceae	*Myoporum montanum*	Mesophyte	Present			
Solanaceae	*Physalis angulata*	Riparian				Present
Stylidiaceae	*Stylidium fluminense*	Hydrophyte		Present		
	Stylidium weeliwolli	Hydrophyte	Present			
Surianaceae	*Stylobasium spathulatum*	Phreatophyte			Common	Present
Thelypteridaceae	*Ampelopteris prolifera*	Hydrophyte	Present			
Typhaceae	*Typha domingensis*	Hydrophyte		Abundant	Present	

Please Note: 'Present' refers to any cover density, though is usually 0.1%; 'Common' is cover density from 0.2% to 10%; 'Abundant' is 11% cover density and higher.

Appendix D: 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 Attractions Priority codes

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

Appendix E: Habitat results

Percentage cover by each of the in-stream substrate types

Dry 2023

	Site	Inorganic seds.	Sub. mac.	Emerg. mac.	Algae	LWD	Detritus	Roots	Trailing veg.
Survey Area	**MarC6a**	59	24	10	2	1	3	0	1
	MarC6b	61	18	12	2	1	4	0	2
Reference	**MACREF2**	16	7	11	41	4	18	1	2
	MACREF1	47	2	6	18	6	11	6	4
	WWS	75	0	3	5	2	10	3	2
	BENS	67	0	0	0	2	20	10	1
	MUNJS	85	3	4	3	2	3	0	0
	SS	6	1	4	66	2	10	8	3

Wet 2024

	Site	Inorganic seds.	Sub. mac.	Emerg. mac.	Algae	LWD	Detritus	Roots	Trailing veg.
Survey Area	**MarC1**	60	0	5	0	4	18	10	3
	MarC2	86	0	0	0	2	6	5	1
	MarC3	84	0	0	8	1	3	2	2
	MarC4	95	0	0	0	2	2	0	1
	MarC5a	82	0	0	2	2	11	2	1
	MarC6	86	0	0	0	2	12	0	0
Reference	**MACREF2**	82	0	8	2	2	5	0	1
	MACREF1	61	0	3	0	5	20	5	6
	WWS	65	0	1	5	2	6	18	3
	BENS	96	0	0	0	1	0	2	1
	MUNJS	88	5	2	0	1	1	2	1
	SS	20	11	2	46	5	9	6	1

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

Dry 2023

	Site	Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt	Clay
Survey Area	**MarC6a**	54	8	2	8	22	2	3	1
	MarC6b	57	8	4	2	18	4	2	5
Reference	**MACREF2**	5	0	2	4	10	1	11	67
	MACREF1	40	2	0	0	2	4	13	39
	WWS	6	1	6	32	43	10	2	0
	BENS	1	1	3	40	38	15	0	2
	MUNJS	87	0	3	3	2	1	4	0
	SS	1	2	2	32	45	15	2	1

Wet 2024

	Site	Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt	Clay
Survey Area	**MarC1**	2	0	4	36	40	12	6	0
	MarC2	0	0	2	12	41	2	13	30
	MarC3	74	2	4	2	8	1	5	4
	MarC4	1	0	0	2	9	12	12	64
	MarC5a	55	0	6	7	7	2	15	8
	MarC6	12	2	6	8	15	15	12	30
Reference	**MACREF2**	12	1	2	3	2	4	22	54
	MACREF1	70	0	2	3	6	2	10	7
	WWS	5	3	2	43	30	12	5	0
	BENS	1	1	5	35	45	13	0	0
	MUNJS	91	1	1	0	5	2	0	0
	SS	2	1	6	30	35	24	2	0

Appendix F: Water quality results

Dry 2023 - Highlighted cells refer to the values which are in excess of: ■ > the 99% ANZG DGV and the ■ > the 95% DGV

		ANZG DGV		Survey Area		Reference					
Analyte	**Units**	**99% DGV**	**95% DGV**	**MarC6a**	**MarC6b**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
Temperature	°C			20.3	22.8	14.2	14.8	26.7	17.4	16.2	21.8
Conductivity (EC)	µS/cm		250	551	591	1471	656	1003	817	843	561
pH	pH units		6-8	8.5	8.4	8.1	7.2	7.2	7.7	7.6	7.6
Redox	mV			-30.4	-27.4	-104.7	-114.4	55.5	212.0	198.1	275.0
DO	%		85-120	90.1	98.9	102.9	52.8	40.7	48.3	79.4	54.8
Turbidity	NTU		15	2.2	2.4	0.8	0.6	0.4	3.6	0.9	1.4
TSS	mg/L			5	5	7	<1	<1	4	<1	1
Alkalinity	mg/L			225	232	528	209	371	421	155	253
Hardness	mg/L			203	212	600	204	414	410	241	202
Na	mg/L			35.2	35.8	148	68.3	50.2	28.7	94	36
Ca	mg/L			26.7	28.6	72.2	25.8	68.7	63.4	29.2	37.6
Mg	mg/L			33.2	34.1	102	33.9	58.8	61.1	40.8	26.2
K	mg/L			8.4	8.5	20.4	5.9	10.3	5.1	10.2	4.2
HCO_3	mg/L			212	220	507	209	371	421	155	253
Cl	mg/L			50	51	301	96	86	61	210	38
S_SO_4	mg/L			11.2	12.1	32.7	14.5	21.7	11	24.3	6.7
CO_3	mg/L			13.0	12	20	<1	<1	<1	<1	<1
dAl	mg/L	0.027	0.055	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
dAs	mg/L	0.001	0.024	0.0006	0.0006	0.0004	0.0004	0.0004	0.0004	0.0002	<0.0002
dB	mg/L	0.340	0.940	0.225	0.24	0.366	0.163	0.339	0.102	0.166	0.088
dBa	mg/L			0.0576	0.0576	0.134	0.0279	0.0123	0.0966	0.0527	0.125
dCd	mg/L	0.00006	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
dCo	mg/L			<0.0001	<0.0001	<0.0001	0.0001	<0.0001	0.0006	<0.0001	<0.0001
dCr	mg/L	0.00001	0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
dCu	mg/L	0.0010	0.0014	0.00046	0.0004	0.00023	0.00054	0.00012	0.00037	0.0001	0.00008
dFe	mg/L	0.300*		0.092	0.073	0.021	0.087	<0.002	0.046	0.152	0.014
dMn	mg/L	1.20	1.90	0.0063	0.0039	0.0043	0.0134	<0.0005	0.669	0.0116	0.0182
dMo	mg/L			0.0002	0.0001	0.0002	0.0003	0.0002	0.0002	<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
dPb	mg/L	0.001	0.0034	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
dS	mg/L			11.8	12.3	36.7	14.7	18.1	11.4	26.4	6.7
dSe	mg/L	0.005	0.011	<0.0002	<0.0002	0.001	<0.0002	<0.0002	<0.0002	<0.0002	0.0005
dU	mg/L			0.0006	0.00064	0.00259	0.00038	0.00056	0.0004	<0.00005	0.0006
dV	mg/L			0.0005	0.0006	0.0026	0.0046	0.0029	0.0007	0.0003	0.0011
dZn	mg/L	0.0024	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N_NH_3	mg/L	0.32	0.90	0.02	0.02	0.02	0.01	<0.01	0.06	<0.01	<0.01
N_NO_3	mg/L	1.00	2.40	<0.01	0.01	0.04	<0.01	0.01	0.01	<0.01	0.51
N_NOx	mg/L		0.01	<0.01	0.01	0.04	<0.01	0.01	0.01	<0.01	0.51
Total N	mg/L		0.30	0.8000	0.83	0.15	0.22	<0.01	0.17	0.11	0.56
Total P	mg/L		0.01	0.019	0.021	0.027	0.028	0.01	0.019	0.02	0.012

Wet 2024 - Highlighted cells refer to the values which are in excess of: ■ > the 99% ANZG DGV and the ■ > the 95% DGV

		ANZG DGV		Survey Area						Reference					
Analyte	**Units**	**99% DGV**	**95% DGV**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5a**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
Temperature	ºC			30.9	35.1	31.5	31.4	35.8	36.1	31.8	26.8	25.1	28.2	27.2	25.7
Conductivity (EC)	µS/cm		250	1415	1967	474.9	1485	135.1	181.6	3540	515	932	92.1	2829	570
pH	pH units		6-8	7.4	7.5	7.3	7.3	7.5	7.4	7.7	6.9	7.5	7.1	7.1	7.8
Redox	mV			183.6	120.8	124.2	53.3	93.2	96.0	145.8	166.3	168.5	109.9	107.9	138.1
DO	%		85-120	48.1	49.9	42.9	15.6	57.0	40.4	68.4	24.0	61.6	86.4	48.5	80.8
Turbidity	NTU		15	5.9	30.0	11.7	5.8	497.0	293.0	1.8	39.3	<0.1	49.0	2.2	0.2
TSS	mg/L			4	51	11	8	89	57	3	12	<1	<1	<1	<1
Alkalinity	mg/L			122	211	156	215	45	63	542	111	343	188	89	224
Hardness	mg/L			492	332	512	226	42	59	992	146	414	212	946	224
Na	mg/L			118	113	119	71.6	1.1	2.2	235	37.1	50	13	204	33.6
Ca	mg/L			91.7	45.6	75.6	39.2	12.6	16.7	130	20.2	71.2	35.6	128	44.8
Mg	mg/L			63.8	53	78.4	31.2	2.6	4.3	162	23.2	57.5	29.9	152	27.2
K	mg/L			14.6	19.1	24.6	17.2	5.7	5.9	37.6	7.9	9.4	3.9	38.9	4.4
HCO_3	mg/L			122	211	156	215	45	63	542	111	343	188	89	224
Cl	mg/L			332	225	272	94	3	3	609	42	84	15	500	37
S_SO_4	mg/L			69.7	41	92.3	15.3	0.553	0.787	87	18.8	18.5	6.9	205	7.37
CO_3	mg/L			<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
dAl	mg/L	0.027	0.055	0.008	0.008	0.034	0.051	1.57	1.38	<0.005	0.162	<0.005	0.019	0.005	<0.005
dAs	mg/L	0.001	0.024	0.0006	0.001	0.002	0.0013	0.0009	0.0009	0.0012	0.001	0.0003	0.0005	0.0008	<0.0002
dB	mg/L	0.340	0.940	0.286	0.468	0.482	0.288	0.057	0.064	0.665	0.246	0.375	0.115	0.338	0.135
dBa	mg/L			0.104	0.0918	0.0992	0.0603	0.0386	0.0382	0.259	0.0279	0.0101	0.0192	0.161	0.158
dCd	mg/L	0.00006	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
dCo	mg/L			0.0002	0.0004	0.0016	0.0006	0.0008	0.0007	0.0003	0.0009	<0.0001	0.0004	0.0021	<0.0001
dCr	mg/L	0.00001	0.001	<0.0002	0.0002	0.0005	0.0002	0.0012	0.001	<0.0002	0.0004	<0.0002	<0.0002	0.0002	<0.0002
dCu	mg/L	0.0010	0.0014	0.00155	0.00286	0.00677	0.0021	0.00256	0.00211	0.00034	0.00148	<0.00005	0.00233	0.00076	<0.00005
dFe	mg/L	0.300*		0.007	0.006	0.057	0.066	1.14	1.09	0.102	0.384	<0.002	0.034	0.667	0.02
dMn	mg/L	1.20	1.90	0.0079	0.0382	0.0486	0.0364	0.0385	0.0444	0.133	0.138	<0.0005	0.0495	0.611	0.0092
dMo	mg/L			0.0003	0.0006	0.001	0.0004	0.0002	0.0003	0.0004	0.0006	0.0002	0.0003	0.0002	0.0002
dNi	mg/L	0.008	0.011	<0.0005	0.0006	0.0018	<0.0005	0.0012	0.0011	<0.0005	0.0009	<0.0005	<0.0005	0.0029	<0.0005
dPb	mg/L	0.001	0.0034	<0.0001	<0.0001	<0.0001	<0.0001	0.0005	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
dS	mg/L			73.5	40.8	101	16.7	0.7	0.9	88.8	18.7	17.8	6.4	220	6.2
dSe	mg/L	0.005	0.011	0.0019	0.0101	0.0077	0.0012	0.0002	0.0005	0.0004	0.0002	<0.0002	<0.0002	0.0004	0.0005
dU	mg/L			0.00026	0.00097	0.00192	0.00034	0.00008	0.00012	0.00289	0.00022	0.00067	0.00026	<0.00005	0.00051
dV	mg/L			0.0048	0.0155	0.0448	0.0095	0.0075	0.0069	0.0024	0.0027	0.0024	0.0021	0.0025	0.0017
dZn	mg/L	0.0024	0.008	0.002	0.002	<0.001	0.001	0.002	0.002	<0.001	0.001	<0.001	<0.001	0.001	<0.001
N_NH_3	mg/L	0.32	0.90	0.28	0.2	1.26	<0.01	0.36	0.16	0.08	0.08	0.01	0.16	0.47	0.01
N_NO_3	mg/L	1.00	2.40	0.8	0.93	3.86	3.17	0.77	0.5	<0.01	<0.01	0.02	0.03	<0.01	0.35
N_NOx	mg/L		0.01	0.84	1	4.13	3.43	0.81	0.53	<0.01	<0.01	0.02	0.03	<0.01	0.35
Total N	mg/L		0.30	1.3	1.22	5.54	4.6	2.26	1.38	0.29	0.72	0.03	0.16	0.92	0.09
Total P	mg/L		0.01	0.054	0.047	0.127	0.076	0.275	0.147	0.032	0.054	0.012	0.013	0.03	0.01

Appendix G: Dominant riparian flora list

			Survey Area								Reference					
Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MarC6a**	**MarC6b**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
CHAROPHYTA																
CHAROPHYCEAE																
Charales	**Characeae**	*Chara* sp.^↓							X		X					
		Chara fibrosa^↓														X
PLANTAE																
MAGNOLIOPSIDA																
Asterales	**Asteraceae**	**Bidens bipinnata*										X				
		Centipeda minima														X
		**Erigeron bonariensis*										X				X
		**Flaveria trinervia*				X										
		**Lactuca serriola*										X	X			
		Pluchea dentex^	X	X	X	X	X	X	X	X	X	X	X			X
		Pluchea rubelliflora^	X								X			X		
		Pterocaulon sphacelatum														X
		Rhodanthe margarethae													X	
		**Sigesbeckia orientalis*												X		
		**Sonchus oleraceus*				X	X	X		X		X				
	Campanulaceae	*Lobelia arnhemiaca*^^											X			X
	Goodeniaceae	*Goodenia lamprosperma*				X										
	Stylidiaceae	*Stylidium fluminense*^^													X	
		Stylidium weeliwolli^^ (P3)											X	X		
Boraginales	**Boraginaceae**	*Trichodesma zeylanicum* var. *zeylanicum*										X				
Brassicales	**Brassicaceae**	**Lepidium didymum*				X										
		**Sisymbrium orientale*						X								
	Capparaceae	*Capparis lasiantha*													X	
		Capparis spinosa subsp. *nummularia*											X	X	X	X
	Cleomaceae	*Arivela viscosa*	X	X	X	X	X	X				X	X	X	X	X
Caryophyllales	**Amaranthaceae**	*Alternanthera nodiflora*				X										
	Plumbaginaceae	*Plumbago zeylanica*										X				
Cucurbitales	**Cucurbitaceae**	*Cucumis variabilis*										X				
Fabales	**Fabaceae**	*Acacia* sp.				X										
		Acacia ampliceps^^	X	X	X		X	X		X	X	X				X
		Acacia bivenosa		X								X	X		X	
		Acacia citrinoviridis											X			
		Acacia coriacea subsp. *pendens*^	X	X		X	X	X		X	X	X	X	X	X	X
		Acacia maitlandii		X												
		Acacia pyrifolia var. *pyrifolia*	X	X			X				X	X			X	X
		Acacia tumida var. *pilbarensis*	X								X	X				
		Acacia tumida var. *tumida*													X	
		Crotalaria medicaginea var. *neglecta*												X		
		Cullen leucanthum^^														X
		Erythrina vespertilio														X
		Glycine canescens											X	X		
		Isotropis iophyta										X				
		Lotus australis										X				
		Petalostylis labicheoides											X	X		X

			Survey Area								Reference					
Class/Order	Family	Lowest taxon	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MarC6a	MarC6b	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
		Rhynchosia minima		X			X					X	X			
		Senna sp. indet	X													
		Senna artemisioides subsp. x *artemisioides*				X										
		Senna notabilis		X		X										
		Sesbania cannabina^		X									X			X
		Swainsona formosa														X
		Tephrosia rosea var. Fortescue creeks (M.I.H. Brooker 2186)	X	X									X			
		**Vachellia farnesiana*	X	X			X							X		
		Vigna ?lanceolata										X				
		Vigna lanceolata														X
	Surianaceae	*Stylobasium spathulatum*^										X				
Gentianales	**Apocynaceae**	**Calotropis gigantea*														X
		Cynanchum viminale subsp. *australe*													X	
	Gentianaceae	*Schenkia clementii*^^				X				X						
Lamiales	**Lamiaceae**	*Clerodendrum tomentosum* var. *tomentosum*											X			
	Plantaginaceae	*Stemodia grossa*^	X	X		X	X		X	X		X	X	X		X
		Stemodia viscosa													X	X
Laurales	**Lauraceae**	*Cassytha capillaris*											X			
Malpighiales	**Elatinaceae**	*Bergia trimera*														X
	Euphorbiaceae	*Euphorbia biconvexa*				X	X				X	X				
		**Euphorbia hirta*											X			
	Pyllanthaceae	*Nellica maderaspatensis*		X	X	X	X					X				X
Malvales	**Malvaceae**	Malvaceae sp. indet	X				X									
		Androcalva luteiflora									X					
		Corchorus sp. indet									X					
		Corchorus crozophorifolius^	X	X			X						X			
		Corchorus tridens				X	X									
		Gossypium robinsonii	X	X			X					X	X	X	X	X
		Gossypium sturtianum var. *sturtianum*^	X	X		X							X	X		
		**Malvastrum americanum*														X
		Waltheria indica			X											
Myrtales	**Lythraceae**	*Ammannia baccifera*^^														X
	Myrtaceae	*Eucalyptus* sp.		X		X					X					
		Eucalyptus camaldulensis^^	X	X	X		X	X	X		X	X	X	X	X	X
		Eucalyptus victrix^^	X		X						X	X	X			
		Melaleuca argentea^^	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		
Ranunculales	**Papaveraceae**	**Argemone ochroleuca*														X
Rosales	**Moraceae**	*Ficus brachypoda*													X	
Sapindales	**Sapindaceae**	*Atalaya hemiglauca*^											X		X	X
		Dodonaea lanceolata var. *lanceolata*^										X				
		Dodonaea viscosa subsp. *mucronata*												X		
Solanales	**Convolvulaceae**	*Evolvulus alsinoides* var. *villosicalyx*													X	
		Ipomoea muelleri					X									X
		Operculina aequisepala											X			

Class/Order	Family	Lowest taxon	Survey Area								Reference					
			MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MarC6a	MarC6b	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
		Polymeria ambigua		X										X		
	Solanaceae	*Solanum diversiflorum*														X
		**Solanum nigrum*										X				
		Solanum phlomoides												X		
LILIOPSIDA																
Alismatales	**Hydrocharitaceae**	*Najas marina*^^↓								X						
		Potamegeton cf. *tricarinatus*^^↓														X
		Potamogeton tepperi^^↓							X	X	X				X	X
		Vallisneria sp.^^↓										X				
		Vallisneria nana^^↓									X					
Poales	**Cyperaceae**	*Cyperus* sp.		X		X					X	X				
		Cyperus cunninghamii subsp. *cunninghamii*^↑													X	
		Cyperus difformis^↑														X
		Cyperus vaginatus^↑	X	X	X		X	X			X	X	X	X	X	X
		Eleocharis geniculata^^↑											X			X
		Fimbristylis sieberiana^^↑ (P3)											X			
		Machaerina rubiginosa^^↑													X	
		Schoenoplectus subulatus^↑							X	X	X	X	X	X	X	X
		Schoenus falcatus^^↑													X	
	Poaceae	Poaceae sp. indet					X	X			X					
		**Cenchrus ciliaris*	X				X					X	X			X
		Chloris barbata														X
		Cymbopogon sp.									X					
		Cymbopogon ambiguus										X	X	X	X	
		Eragrostis tenellula								X						
		Eriachne mucronata												X	X	
		Eulalia aurea^										X	X		X	
		Imperata cylindrica^^↑										X				
		Leptochloa digitata														X
		Sorghum timorense													X	
		Themeda triandra		X								X	X		X	
		Triodia sp.			X	X			X						X	
	Typhaceae	*Typha domingensis*^↑		X					X	X	X		X		X	X
		Taxa richness	**22**	**27**	**11**	**21**	**23**	**11**	**9**	**12**	**24**	**39**	**35**	**23**	**31**	**41**

^^High to Moderate GDE indicator species

^Moderate to Low GDE indicator and/or riparian associated species

*introduced species

↓submerged macrophyte

↑emergent macrophyte

P2 - Priority 2 species (DBCA)

P3 - Priority 3 species (DBCA)

Appendix H: Hyporheic fauna taxonomic list

Dry 2023

		Survey Area	Reference			
Phylum/Class/Order	**Family**	**Lowest taxon**	**MACREF1**	**WWS**	**BENS**	**SS**
ANNELIDA						
Oligochaeta						
Tubificida	**Naididae**	Naididae sp.	1	0	0	0
		Aulophorus furcatus	0	0	2	0
		Dero pectinata	0	0	3	0
		Pristina aequiseta	0	3	0	0
		Pristina longiseta	0	0	0	1
		Pristina nr. *osborni*	3	2	0	0
		Pristina sima	0	2	0	0
	Phreodrilidae	Phreodrilidae sp.	0	0	0	2
Polychaeta	**Aeolosomatidae**	Aeolosomatidae sp.	0	0	2	0
NEMATODA		Nematoda sp.	3	0	0	0
MOLLUSCA						
Gastropoda						
Hygrophila	**Planorbidae**	*Ferrissia petterdi*	0	0	1	0
ARTHROPODA						
Arachnida						
Mesostigmata		Mesostigmata sp.	1	2	0	0
Sarcoptiformes		Oribatida sp.	0	2	0	1
Acari		Acari sp.	1	2	0	0
Trombidiformes	**Anisitsiellidae**	*Rutacarus* `sp. Biologic-ACAR006`	0	1	0	0
	Arrenuridae	*Arrenurus* `sp. Biologic-ACAR034`	0	2	0	0
	Hydryphantidae	Hydryphantes sp.	0	0	1	0
	Limnesiidae	*Limnesia* sp. `solida group`	0	0	1	0
	Mideopsidae	*Gretacarus* sp.	0	1	0	0
		Guineaxonopsis sp.	0	0	0	1
Maxillopoda						
Cyclopoida	**Cyclopidae**	*Ectocyclops phaleratus*	0	3	0	0
		Microcyclops varicans	3	3	0	2
		Thermocyclops sp.	2	0	3	0
Harpacticoida	**Canthocamptidae**	*Australocamptus* `sp. Biologic-HARP090`	0	0	0	1
Malacostraca						
Amphipoda	**Paramelitidae**	*Chydaekata* sp. E `TLF-2008`	0	2	1	0
		Maarrka weeliwolli	0	1	0	0
Bathynellacea	**Parabathynellidae**	*Atopobathynella* `sp. Biologic-PBAT043`	0	0	0	3
Ostracoda						
Podocopida						
	Candonidae	*Candonopsis* cf. *tenuis* (`sp. Biologic-OSTR009`)	1	0	0	0
		Meridiescandona facies (`sp. Biologic-OSTR057`)	0	0	1	0
		Notacandona boultoni (`sp. Biologic-OSTR010`)	0	1	0	0

		Survey Area	Reference			
Phylum/Class/Order	**Family**	**Lowest taxon**	**MACREF1**	**WWS**	**BENS**	**SS**
	Cyprididae	*Cypridopsis* sp.	0	1	0	0
Collembola						
Symphypleona		Symphypleona sp.	2	0	0	0
Insecta						
Coleoptera	**Dytiscidae**	Bidessini sp. (L)	0	0	1	1
		Allodessus bistrigatus	0	0	2	0
		Hydroglyphus grammopterus	0	0	0	1
		Hydroglyphus orthogrammus	0	0	1	0
		Limbodessus compactus	0	0	2	0
	Hydraenidae	Hydraenidae sp. (L)	1	0	0	0
		Hydraena sp.	0	0	3	0
	Hydrophilidae	Hydrophilidae sp. (L)	0	2	0	0
		Chaetarthria nigerrima	0	1	0	0
		Helochares sp. (L)	0	0	2	0
	Scirtidae	Scirtidae sp. (L)	0	2	3	0
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	2	0	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	0	0	2	2
		Ceratopogoninae sp.	3	0	0	0
		Dasyhelea sp.	0	2	0	1
	Chironomidae					
	Chironominae					
	Chironomini	*Chironomus* aff. *alternans*	0	0	2	0
		Paratendipes sp. K1	0	0	0	2
	Tanytarsini	*Tanytarsus* sp.	0	0	3	0
	Orthocladiinae	Orthocladiinae sp.	0	1	0	0
	Tanypodinae	?*Australopelopia* sp.	0	0	0	1
		Paramerina sp. 1	0	2	3	0
		Procladius sp.	0	0	2	0
	Dolichopodidae	Dolichopodidae sp.	2	0	0	0
	Empididae	Empididae sp.	2	0	0	0
	Ephydridae	Ephydridae sp.	0	2	0	1
	Psychodidae	Psychodidae sp.	1	0	0	0
Ephemeroptera	**Caenidae**	Caenidae sp.	0	0	1	0
		Taxa richness	**15**	**22**	**22**	**14**

Wet 2024

			Survey Area					Reference		
ANNELIDA										
Oligochaeta										
Tubificida	**Naididae**	*Pristina leidyi*	0	0	0	0	0	0	0	4
		Pristina longiseta	0	0	0	1	0	0	2	4
		Pristina nr. *osborni*	0	3	0	0	0	0	0	0
CNIDARIA										
Hydrozoa										
Anthoathecata	**Hydridae**	Hydra sp.	0	0	0	0	0	0	0	2
PLATYHELMINTHES		Turbellaria sp.	0	0	2	0	0	0	0	2
NEMATODA		Nematoda sp.	0	2	2	2	3	0	2	4
MOLLUSCA										
Gastropoda										
Hypsogastropoda	**?Tateidae**	?Tateidae sp.	1	0	0	0	0	0	0	0
ARTHROPODA										
Arachnida		Acari sp.	2	2	3	3	0	0	2	4
Mesostigmata		Mesostigmata sp.	0	0	1	2	0	0	0	0
Sarcoptiformes		Oribatida sp.	0	0	2	0	0	0	2	4
Trombidiformes		Trombidioidea sp.	1	1	2	0	0	0	0	2
	Anisitsiellidae	*Rutacarus* `sp. Biologic-ACAR007`	0	2	0	0	0	0	0	0
	Halacaridae	Halacaridae sp.	0	0	0	0	0	1	0	3
	Hydryphantidae	*Wandesia* sp.	0	0	0	0	0	0	0	3
		Wandesia `sp. Biologic-ACAR008`	0	0	1	0	0	0	0	0
	Unionicolidae	*Neumania* sp.	0	0	0	1	0	0	0	0
Ostracoda										
Podocopida	**Candonidae**	*Candonopsis* cf. *tenuis* (`sp. Biologic-OSTR009`)	0	0	0	2	2	0	0	0
	Cyprididae	*Cypridopsis* sp.	0	0	0	0	0	1	0	0
		Stenocypris major	0	0	0	0	0	1	0	0
	Darwinulidae	*Vestalenula marmonieri*	0	0	0	0	0	2	0	2
Maxillopoda										
Cyclopoida	**Cyclopidae**	*Fierscyclops* `sp. Biologic-CYCL034`	0	0	0	0	3	0	0	0
		Fierscyclops `sp. Biologic-CYCL039`	0	0	0	3	0	0	0	0
		Mesocyclops notius	0	0	0	0	0	0	2	0
		Microcyclops varicans	0	2	1	0	4	2	3	4
		Pescecyclops `sp. WAM-CYLP001`	2	3	3	3	0	0	0	0
		Thermocyclops sp.	0	0	0	0	0	0	2	0
Harpacticoida	**Canthocamptidae**	*Australocamptus* sp.	0	0	0	0	0	0	0	1
		Canthocamptidae `sp. Biologic-HARP059`	0	2	0	0	0	0	0	0

			Survey Area					Reference		
Malacostraca										
Amphipoda	**Paramelitidae**	Paramelitidae `sp. Biologic-AMPH024`	0	0	0	0	0	1	0	0
Bathynellacea	**Parabathynellidae**	*Atopobathynella* `sp. Biologic-PBAT019`	0	0	0	0	1	0	2	0
Collembola										
Symphypleona		Symphypleona sp.	1	0	2	2	0	0	0	2
Insecta										
Coleoptera	**Carabidae**	Carabidae sp. (L)	1	0	0	0	0	0	0	0
	Dytiscidae	Dytiscidae sp. (L)	0	0	0	0	1	0	0	0
		Bidessini sp. (L)	0	0	0	0	1	0	0	0
	Elmidae	*Austrolimnius* sp. (L)	0	0	0	0	0	0	0	2
	Georissidae	*Georissus* sp.	0	0	0	0	0	0	0	1
	Hydraenidae	Hydraenidae sp. (L)	0	0	0	1	1	0	0	1
	Hydrophilidae	Hydrophilidae sp. (L)	0	0	0	0	0	0	0	2
		Agraphydrus coomani (L)	0	0	0	0	0	0	2	2
		Paracymus sp. (L)	0	0	0	0	0	0	0	2
	Ptiliidae	Ptiliidae sp.	0	0	0	0	0	0	0	2
	Scirtidae	Scirtidae sp. (L)	0	0	0	0	0	0	3	2
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	0	2	0	2	0	0	1	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	0	0	0	0	0	0	3	2
		Ceratopogoninae sp.	0	0	0	2	3	0	2	0
		Dasyhelea sp.	0	0	0	0	0	2	0	0
		Forcipomyiinae sp.	1	0	0	0	0	0	0	2
	Chironomidae									
	Chironominae									
	Chironomini	*Chironomus* aff. *alternans*	0	0	0	1	0	0	0	0
		Polypedilum nubifer	0	0	1	2	0	0	1	0
	Tanytarsini	*Tanytarsus* sp.	0	2	0	2	0	0	0	2
	Orthocladiinae	nr. *Gymnometriocnemus* sp.	0	0	0	0	0	0	1	0
	Tanypodinae	Tanypodinae sp.	0	0	0	0	0	0	0	3
		?*Australopelopia* sp.	0	0	0	0	0	0	0	2
		Larsia ?albiceps	0	0	0	0	0	0	2	3
		Nilotanypus sp.	0	0	0	0	0	0	0	3
		Paramerina sp. 1	0	0	0	0	0	0	0	2
	Culicidae	Culicidae sp.	0	0	0	0	2	0	0	0
	Ephydridae	Ephydridae sp.	0	0	0	0	0	0	0	1
	Muscidae	Muscidae sp.	0	0	0	0	0	0	1	0
Ephemeroptera	**Caenidae**	Ephemeroptera sp.	0	0	0	0	1	0	0	0
		Caenidae sp.	0	0	0	0	0	0	1	0
		Tasmanocoenis sp. P/*arcuata*	0	0	0	0	0	0	0	2
Odonata		Anisoptera sp.	0	0	0	0	0	1	0	0
		Taxa richness	**7**	**10**	**11**	**15**	**11**	**8**	**18**	**32**

Appendix I: Macroinvertebrate taxonomic list

Dry 2023

			Survey Area		Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC6a	MarC6b	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
ANNELIDA										
Hirudinida		Hirudinea sp.	0	2	0	0	0	0	1	0
Oligochaeta										
Tubificida	**Naididae**	Naididae sp.	0	0	0	2	0	0	0	0
		Allonais paraguayensis	0	0	0	0	0	0	2	0
		Allonais pectinata	0	0	0	0	0	0	2	3
		Chaetogaster sp.	0	2	0	0	0	0	0	0
		Dero nivea	0	0	0	0	0	2	0	0
		Nais communis	3	0	0	0	0	0	0	0
		Nais variabilis	0	0	0	0	0	0	0	4
		Pristina leidyi	2	0	0	0	2	0	0	0
		Pristina longiseta	4	0	1	2	0	1	3	4
	Phreodrilidae	Phreodrilidae sp.	0	0	0	1	2	0	0	4
CNIDARIA										
Hydrozoa										
Anthoathecata	**Hydridae**	*Hydra* sp.	4	3	0	0	0	0	1	1
TARDIGRADA		Tardigrada sp.	0	0	0	0	0	0	0	2
PLATYHELMINTHES										
Turbellaria		Turbellaria sp.	0	2	0	0	0	0	0	2
NEMATODA		Nematoda sp.	2	0	0	0	0	1	1	1
MOLLUSCA										
Gastropoda										
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	3	3	2	2	0	0	3	2
	Planorbidae	*Ferrissia petterdi*	0	0	0	0	2	3	1	2
		Gyraulus sp.	4	3	3	0	0	3	3	0
ARTHROPODA										
Arachnida										
Araneae	**Pisauridae**	*Dolomedes* sp.	0	1	0	0	0	0	1	0
Acari		Acarina sp.	2	3	2	2	2	3	0	4
Mesostigmata		Mesostigmata sp.	0	0	0	1	0	0	0	0
Sarcoptiformes		Oribatida sp.	0	0	0	0	4	0	0	3
Trombidiformes	**Arrenuridae**	*Arrenurus* sp.	0	3	0	0	0	0	0	0
		Arrenurus (*Brevicadaturus*) sp.	0	0	0	0	0	0	2	0
		Arrenurus (*Megaluracarus*) sp.	2	0	0	0	0	0	0	0
		Arrenurus (*Truncaturus*) sp.	2	2	0	0	0	0	0	0
	Aturidae	*Albia* sp.	0	0	0	0	0	0	0	3
		Austraturus sp.	0	0	0	0	1	0	0	0
		Axonopsella sp.	2	0	0	0	0	0	0	0

			Survey Area		Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC6a	MarC6b	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
	Hydrachnidae	*Hydrachna* sp.	0	0	0	0	0	0	2	0
	Hydrodromidae	*Hydrodroma* sp.	3	3	0	0	0	0	1	3
	Hydryphantidae	*Pseudohydryphantes* sp.	2	2	0	0	0	0	0	0
	Hygrobatidae	*Aspidiobates* `sp. Biologic-ACAR037`	0	0	0	0	1	0	0	0
		Australiobates sp.	0	0	0	0	0	0	0	4
		Coaustraliobates minor	3	3	2	0	0	2	1	3
		Gondwanabates `sp. Biologic-ACAR016`	0	0	0	0	1	0	0	0
	Limnesiidae	*Limnesia maceripalpis*	3	2	0	0	0	0	0	0
		Limnesia parasolida	2	2	2	0	0	0	0	0
		Limnesia sp. `solida group`	3	0	2	1	2	3	3	3
	Limnocharidae	*Limnochares* sp.	0	0	3	0	0	0	0	0
	Mideopsidae	*Gretacarus* sp.	0	0	0	0	0	0	0	3
	Oxidae	*Oxus* sp.	3	2	0	0	0	3	0	3
	Pionidae	*Piona* sp.	0	0	0	2	0	0	0	0
		Piona cumberlandensis	3	2	0	0	0	0	0	0
	Unionicolidae	*Unionicola* sp.	0	0	0	0	0	0	1	0
		Neumania sp.	0	0	0	0	0	4	0	0
		Recifella sp.	0	3	0	0	0	0	0	0
Branchiopoda										
Diplostraca	**Chydoridae**	*Alona* sp.	0	0	0	0	3	0	0	0
		Dunhevedia crassa	0	0	0	0	1	0	0	0
		Leberis sp.	0	0	0	1	0	0	2	0
	Daphniidae	*Ceriodaphnia quadrangula*	0	0	0	4	0	0	0	0
		Simocephalus sp.	4	5	0	0	0	0	0	0
		Simocephalus latirostris	0	0	0	0	0	0	2	0
Ostracoda		Ostracoda sp.	0	0	0	0	0	0	2	2
Podocopida	**Candonidae**	*Candonopsis* cf. *tenuis* (`sp. Biologic-OSTR009`)	1	0	0	3	0	0	0	0
	Cyprididae	Cyprididae sp.	1	0	0	0	0	0	0	0
		Bennelongia strellyensis	0	0	0	0	0	0	4	0
		Cypretta `sp. Biologic-OSTR015`	0	0	0	3	3	0	0	0
		Cypridopsis `sp. Biologic-OSTR011`	0	0	0	0	0	0	3	0
		Ilyodromus sp.	2	0	0	0	0	0	0	0
		Ilyodromus `sp. Biologic-OSTR014`	0	3	0	0	0	0	3	0
		Stenocypris major	0	3	0	0	0	0	3	2
	Darwinulidae	*Darwinula* sp.	0	0	0	0	1	0	0	0
		Vestalenula marmonieri	0	0	0	0	0	0	0	3
		Vestalenula matildae	0	0	2	0	0	0	0	0
Maxillopoda										
Cyclopoida	**Cyclopidae**	*Mesocyclops* sp.	0	0	1	0	0	0	0	0
		Mesocyclops brooksi	0	0	0	3	0	0	0	0
		Mesocyclops notius	3	3	0	4	0	0	0	0
		Microcyclops varicans	3	0	2	0	0	0	0	0
		Thermocyclops sp.	3	3	0	0	0	0	0	0
	Notodromadidae	*Newnhamia fenestrata*	0	0	0	0	0	1	3	0

			Survey Area		Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC6a**	**MarC6b**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
Malacostraca										
Amphipoda	**Paramelitidae**	*Chydaekata* sp. `E TLF-2008`	0	0	0	0	3	0	0	0
Decapoda	**Parastacidae**	*Cherax quadricarinatus*	0	0	0	0	2	0	0	0
Collembola										
Poduromorpha		Poduroidea sp.	0	0	0	1	0	0	0	0
Insecta										
Coleoptera	**Dytiscidae**	Dytiscidae sp. (L)	0	0	0	3	0	0	0	0
		Bidessini sp. (L)	0	2	0	2	0	1	0	2
		Allodessus bistrigatus	0	1	1	2	0	0	0	0
		Austrodytes plateni	0	0	0	0	0	1	0	0
		Cybister tripunctatus	0	0	0	0	0	0	0	1
		Hydroglyphus grammopterus	2	2	0	1	0	0	2	0
		Hydroglyphus orthogrammus	0	2	0	0	0	2	2	1
		Hydrovatus sp. (L)	0	0	0	0	0	0	1	0
		Hydrovatus opacus	0	0	0	0	0	0	0	2
		Hyphydrus sp. (L)	0	0	0	0	0	1	0	0
		Hyphydrus elegans	2	1	0	0	0	1	0	1
		Hyphydrus lyratus	2	0	0	0	0	0	0	1
		Laccophilus sp. (L)	0	0	1	0	0	0	0	0
		Laccophilus sharpi	0	0	0	0	0	2	0	0
		Limbodessus compactus	0	2	0	0	0	2	0	0
		Megaporus sp. (L)	0	0	0	0	0	3	0	0
		Necterosoma sp. (L)	2	0	2	2	0	0	0	0
		Necterosoma regulare	2	1	0	0	0	1	0	2
		Necterosoma undecimlineatum	0	0	0	0	0	2	0	0
		Platynectes sp. (L)	0	0	0	2	0	0	2	0
		Rhantaticus congestus	0	1	0	1	0	0	0	0
		Rhantus sp. (L)	0	0	0	3	0	0	0	0
		Sternopriscus sp. (L)	1	0	0	0	0	0	0	0
		Sternopriscus sp.	2	0	0	0	0	1	0	0
		Sternopriscus multimaculatus	0	1	0	0	0	0	1	0
		Tiporus sp. (L)	1	0	0	0	0	0	0	0
		Tiporus tambreyi	1	1	0	0	0	0	0	0
	Elmidae	*Austrolimnius* sp. (L)	0	0	0	0	0	0	0	3
		Austrolimnius sp.	0	0	0	0	0	0	0	2
	Gyrinidae	*Dineutus australis* (L)	0	0	0	0	0	2	2	0
		Dineutus australis	0	0	0	0	0	0	0	2
		Macrogyrus gibbosus	0	0	0	0	0	0	2	0
	Haliplidae	*Haliplus* sp. (L)	1	1	0	0	0	0	0	0
	Hydraenidae	*Hydraena* sp.	0	0	0	0	0	3	0	0
		Limnebius sp.	0	2	0	0	0	0	0	1
		Ochthebius sp.	0	1	1	0	0	0	0	0
	Hydrochidae	*Hydrochus interioris*	3	3	1	0	0	3	0	0
		Hydrochus obscuroaeneus	0	0	0	0	0	3	0	0

			Survey Area		Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC6a	MarC6b	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
	Hydrophilidae	Hydrophilidae sp. (L)	2	0	0	2	0	0	0	0
		Anacaena horni	0	0	0	0	0	3	0	0
		Berosus sp. (L)	0	0	1	2	0	0	0	2
		Berosus dallasi	3	0	0	1	0	1	0	3
		Berosus pulchellus	0	0	0	0	0	0	1	0
		Enochrus deserticola	0	0	0	0	0	2	1	0
		Enochrus elongatulus	0	1	0	0	0	0	0	0
		Helochares sp. (L)	0	1	0	0	0	0	0	2
		Helochares tatei	0	0	0	0	0	0	0	1
		Paracymus sp. (L)	0	0	0	0	0	0	1	0
		Paracymus spenceri	2	2	0	0	0	1	0	0
		Regimbartia attenuata	0	1	0	0	0	0	0	0
		Sternolophus sp. (L)	0	0	0	0	0	0	0	1
		Sternolophus australis	0	0	0	0	0	0	1	0
	Scirtidae	Scirtidae sp. (L)	0	0	2	0	3	4	1	3
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	0	0	0	1	0	0	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	0	1	2	0	1	0	3	2
		Ceratopogoninae sp.	4	3	2	3	2	2	3	4
		Dasyhelea sp.	2	3	3	0	3	0	3	3
		Forcipomyiinae sp.	0	0	1	0	2	0	2	1
	Chironomidae	Chironomidae sp. (P)	3	3	2	2	3	3	3	3
	Chironominae									
	Chironomini	*Chironomus* aff. *alternans*	0	3	2	3	0	4	2	3
		Cladopelma curtivalva	3	3	0	0	0	0	0	0
		Cryptochironomus griseidorsum	0	3	0	2	0	3	0	0
		Dicrotendipes sp. `CA1`	0	2	0	0	2	3	3	3
		Paratendipes sp. 'K1'	0	0	2	0	0	0	0	0
		Polypedilum sp. 1	0	0	0	0	0	0	0	3
		Polypedilum (*Pentapedilum*) *leei*	0	0	0	0	0	0	2	0
		Polypedilum watsoni	0	3	2	0	0	3	0	0
		Skusella subvittata	3	0	0	0	0	0	0	0
		Stenochironomus watsoni	0	0	0	0	0	0	3	3
	Tanytarsini	*Cladotanytarsus* sp.	0	0	2	0	0	3	0	0
		Paratanytarsus sp.	4	3	0	0	0	0	0	4
		Rheotanytarsus sp.	0	0	0	0	3	0	0	0
		Tanytarsus sp.	3	4	3	3	2	4	4	4
	Orthocladiinae	*Corynoneura* sp.	0	0	0	0	2	0	2	3
		Cricotopus albitarsis	0	0	0	0	3	0	0	0
		Nanocladius sp.	2	3	0	0	0	0	0	0
		nr. *Gymnometriocnemus* sp.	0	0	0	2	0	0	0	0
		Parametriocnemus sp.	0	0	0	0	0	0	2	0
		Parakiefferiella sp.	0	0	0	0	0	0	3	0
		Rheocricotopus sp.	0	0	0	0	0	0	3	4
	Tanypodinae	*Ablabesmyia hilli*	3	2	0	0	0	0	0	3
		Coelopynia pruinosa	3	0	0	0	0	0	0	0
		Larsia ?albiceps	4	3	3	0	2	0	3	4

			Survey Area		Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC6a	MarC6b	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
		Nilotanypus sp.	0	0	0	0	0	4	0	3
		Paramerina sp. 1	0	3	2	3	3	0	3	4
		Paramerina sp. 2	0	0	0	0	0	0	2	3
		Procladius sp.	4	3	3	3	0	4	2	3
		Thienemanniella sp.	0	0	0	0	3	0	1	3
	Culicidae	Culicidae sp. (P)	2	1	2	2	0	0	1	0
		Culicidae sp.	3	3	0	3	3	3	3	3
	Dolichopodidae	Dolichopodidae sp.	0	0	1	0	0	0	1	4
	Ephydridae	Ephydridae sp.	0	0	0	0	0	0	0	2
	Muscidae	Muscidae sp.	0	0	1	0	0	0	0	0
	Psychodidae	Psychodidae sp.	0	0	0	1	0	1	0	0
	Scatopsidae	Scatopsidae sp.	0	0	0	0	0	0	1	0
	Simuliidae	Simuliidae sp. (P)	0	0	0	0	0	0	2	3
		Simuliidae sp.	0	0	0	0	1	0	3	5
	Stratiomyidae	Stratiomyidae sp.	2	2	3	2	1	1	2	2
	Tabanidae	Tabanidae sp.	0	0	0	2	2	0	2	0
	Tipulidae	Tipulidae sp.	0	0	0	2	0	0	0	0
Ephemeroptera	**Baetidae**	Baetidae sp.	4	0	1	0	3	3	0	2
		Cloeon fluviatile	0	2	0	3	0	3	2	0
		Cloeon sp. Red Stripe	4	3	2	3	3	0	3	4
		Offadens G1 sp. WA2	0	0	0	0	3	0	0	4
		Pseudocloeon hypodelum	0	0	0	0	3	0	0	2
	Caenidae	Caenidae sp.	3	2	1	0	2	2	3	4
		Tasmanocoenis sp. M	0	2	0	0	0	0	0	0
		Tasmanocoenis sp. P/*arcuata*	3	3	0	0	2	2	2	4
	Leptophlebiidae	Leptophlebiidae sp.	0	0	0	0	0	0	2	0
		Atalophlebia sp. AV5	0	0	0	0	0	0	1	0
Hemiptera		Corixoidea sp.	2	0	0	2	0	0	0	0
	Belostomatidae	Belostomatidae sp.	0	0	0	0	0	0	0	2
		Diplonychus eques	0	0	0	0	0	0	2	2
	Corixidae	Corixidae sp.	0	3	0	0	0	2	0	0
	Gelastocoridae	*Nerthra* sp.	0	0	0	0	0	0	0	2
	Gerridae	Gerridae sp.	0	0	0	1	0	0	0	3
		Limnogonus fossarum gilguy	0	0	0	0	0	0	1	0
		Limnogonus luctuosus	0	0	0	0	0	2	0	1
		Rhagadotarsus anomalus	0	0	0	0	0	1	0	0
	Micronectidae	*Austronecta bartzarum*	2	2	0	0	0	0	0	0
		Micronecta sp.	0	1	0	1	0	0	0	0
		Micronecta annae	0	0	0	2	0	0	0	0
	Nepidae	*Laccotrephes tristis*	0	0	0	0	0	1	0	0
	Notonectidae	Notonectidae sp.	0	2	0	0	0	0	2	0
		Anisops sp.	0	0	0	0	0	1	2	0
		Anisops elstoni	0	0	0	0	0	0	2	0
		Anisops hackeri	0	0	0	1	0	0	0	0
		Anisops nabillus	0	0	0	0	0	0	2	0
		Anisops stali	0	0	0	0	0	1	0	0

			Survey Area		Reference					
Phylum/Class/Order	Family	Lowest taxon	MarC6a	MarC6b	MACREF2	MACREF1	WWS	BENS	MUNJS	SS
	Pleidae	*Paraplea brunni*	2	2	1	0	0	3	0	1
	Veliidae	Veliidae sp.	0	0	0	0	3	1	1	1
		Microvelia sp.	1	0	0	0	0	0	0	0
		Nesidovelia peramoena	0	0	0	0	0	2	0	0
Lepidoptera	**Crambidae**	Acentropinae sp.	2	1	0	0	2	0	0	3
		Margarosticha sp. 3	0	0	0	0	1	0	0	3
Odonata			0	0	0	0	0	0	0	0
Zygoptera		Zygoptera sp.	3	0	0	0	3	2	0	2
	Coenagrionidae	*Agriocnemis* sp.	0	3	2	0	0	0	0	0
		Argiocnemis rubescens	2	0	0	0	0	2	0	0
		Ischnura aurora	3	3	0	0	0	1	0	0
		Ischnura heterosticta	2	0	0	0	0	0	0	0
		Pseudagrion aureofrons	3	2	0	0	2	0	0	0
		Xanthagrion erythroneurum	3	2	0	0	0	0	0	0
	Isostictidae	*Eurysticta coolawanyah*	0	0	0	0	0	3	0	0
	Platycnemididae	*Nososticta pilbara*	0	0	0	0	2	0	0	0
Anisoptera		Anisoptera sp.	3	0	0	3	3	3	0	2
	Aeshnidae	*Hemianax papuensis*	0	2	0	0	0	0	0	0
	Corduliidae	*Hemicordulia koomina*	0	0	0	0	0	2	0	1
		Hemicordulia tau	1	0	0	0	0	2	0	0
	Gomphidae	*Austrogomphus* sp.	0	0	1	0	0	0	0	0
		Austrogomphus gordoni	0	0	0	0	0	0	0	2
	Libellulidae	*Diplacodes bipunctata*	0	2	0	0	0	2	0	0
		Diplacodes haematodes	2	2	0	0	1	2	0	2
		Nannophlebia injibandi	0	0	0	0	2	0	0	2
		Orthetrum caledonicum	2	0	0	0	0	0	0	0
Trichoptera	**Ecnomidae**	*Ecnomus pilbarensis*	2	0	0	0	0	0	3	0
	Hydropsychidae	*Cheumatopsyche wellsae*	0	0	0	0	4	0	0	5
	Hydroptilidae	*Hellyethira* sp.	2	0	0	0	0	1	2	2
		Orthotrichia sp.	2	2	0	0	2	0	0	4
	Leptoceridae	Leptoceridae sp.	2	0	0	0	0	0	0	2
		Oecetis sp.	0	0	2	0	0	0	2	2
		Oecetis sp. Pilbara 1	0	2	0	0	0	0	0	0
		Oecetis sp. Pilbara 4	2	2	0	0	0	0	1	1
		Triplectides ciuskus seductus	0	0	0	0	0	2	0	0
	Philopotamidae	Philopotamidae sp.	0	0	0	0	1	0	0	0
		Chimarra sp. AV17	0	0	0	0	1	0	0	5
	Polycentropodidae	*Paranyctiophylax* sp. AV5	2	0	0	0	0	0	0	0
		Taxa richness	**80**	**81**	**42**	**49**	**52**	**68**	**80**	**93**

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			Survey Area						Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5a**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
ANNELIDA														
Oligochaeta		Oligochaeta sp.	0	0	0	0	0	0	0	0	0	0	0	2
Tubificida	**Enchytraeidae**	Enchytraeidae sp.	1	0	0	0	0	0	0	1	0	0	0	0
	Naididae	Naididae sp.	0	0	0	0	0	0	2	2	0	0	0	0
		Allonais pectinata	0	0	0	0	0	0	0	1	0	0	0	0
		Aulophorus furcatus	0	0	0	0	0	0	0	0	0	0	0	2
		Nais variabilis	0	0	0	0	0	0	0	0	0	0	0	2
		Pristina aequiseta	0	0	0	0	0	0	0	0	0	0	1	0
		Pristina jenkinae	0	0	0	0	0	0	0	0	0	0	1	0
		Pristina longiseta	0	0	0	0	0	0	2	0	0	0	0	2
		Pristina nr. *osborni*	0	2	0	0	0	0	0	0	0	0	0	0
	Phreodrilidae	Phreodrilidae sp.	0	0	0	0	0	0	0	0	0	0	0	3
CNIDARIA														
Hydrozoa														
Anthoathecata	**Hydridae**	*Hydra* sp.	0	0	0	0	0	0	2	0	0	0	0	0
NEMATODA		Nematoda sp.	0	0	3	3	3	4	0	2	2	3	2	0
MOLLUSCA														
Gastropoda														
Hygrophila	**Planorbidae**	*Ferrissia petterdi*	0	0	0	0	0	0	0	0	3	0	0	1
		Gyraulus sp.	0	0	0	0	0	1	2	0	0	2	0	0
ARTHROPODA														
Arachnida														
Araneae	**Pisauridae**	*Dolomedes* sp.	0	0	0	0	0	0	0	0	2	0	0	1
Acari		Acarina sp.	2	2	0	1	1	2	2	3	3	2	1	2
Mesostigmata		Mesostigmata sp.	2	0	0	1	2	0	0	2	0	1	2	0
Sarcoptiformes		Oribatida sp.	2	0	1	0	0	0	0	0	4	0	2	0
Trombidiformes		Trombidioidea sp.	1	0	0	0	0	0	0	2	0	1	0	0
	Anisitsiellidae	*Rutacarus* `sp. Biologic-ACAR007`	1	1	0	0	0	0	0	0	0	0	0	0
	Aturidae	*Albia* sp.	0	0	0	0	0	0	0	0	2	0	0	1
		Austraturus sp.	0	0	0	0	0	0	0	0	3	0	0	0
	Eylaidae	*Eylais* sp.	0	0	0	0	0	0	0	0	0	0	1	0
	Hydryphantidae	*Wandesia* `sp. Biologic-ACAR008`	0	1	0	0	0	0	0	0	0	0	0	0
	Hygrobatidae	*Australiobates* sp.	0	0	0	0	0	0	0	0	3	0	0	1
		Coaustraliobates minor	0	0	0	0	0	0	1	0	0	0	0	0
		Procorticacarus sp.	0	0	0	0	0	0	0	0	0	0	0	2
	Limnesiidae	*Limnesia* sp. `solida group`	0	0	0	0	0	0	1	2	0	0	1	3
	Limnocharidae	*Limnochares* sp.	0	0	0	0	0	3	0	0	0	0	0	0
	Pionidae	*Piona cumberlandensis*	0	0	0	0	0	0	1	0	0	0	0	0
	Unionicolidae	Unionicolidae sp.	0	0	0	0	0	0	0	0	0	2	0	0
		Neumania sp.	0	0	0	0	2	3	0	2	0	0	0	0

			Survey Area						Reference					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5a**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
Branchiopoda														
Anostraca	**Thamnocephalidae**	Anostraca sp.	0	0	0	0	2	0	0	0	0	2	0	0
		Branchinella wellardi	0	0	0	0	0	4	0	0	0	0	0	0
Diplostraca		Cladocera sp.	0	0	0	1	1	0	0	0	0	0	0	0
	Chydoridae	Chydoridae sp.	0	0	0	0	0	0	2	0	0	0	2	2
		Chydorus sp.	0	0	0	0	0	0	0	0	1	0	0	0
		Leberis sp.	0	0	0	0	0	0	0	0	0	0	0	2
	Daphniidae	Daphniidae sp.	0	0	0	0	0	0	0	0	0	0	1	0
		Simocephalus sp.	0	0	0	0	0	0	0	4	0	0	0	0
		Simocephalus latirostris	0	0	0	0	0	0	0	0	0	0	1	0
	Limnadiidae	*Limnadopsis pilbarensis*	0	0	0	0	0	4	0	0	0	0	0	0
		Limnadopsis tatei	0	0	0	0	0	0	0	0	0	1	0	0
	Moinidae	*Moina micrura*	0	0	0	0	0	5	0	0	0	0	0	0
Ostracoda														
Podocopida	**Candonidae**	*Candonopsis* cf. *tenuis* (`sp. Biologic-OSTR009`)	0	0	0	0	0	1	0	3	0	1	3	0
	Cyprididae	Cyprididae sp.	0	0	0	0	0	0	0	0	0	0	2	0
		Bennelongia strellyensis	0	0	0	0	0	0	0	0	0	0	3	0
		Cypretta `sp. Biologic-OSTR015`	0	0	0	0	0	2	0	3	4	0	0	1
		Cyprideis cf. *australiensis*	0	0	0	0	0	0	0	0	0	1	0	0
		Cypridopsis `sp. Biologic-OSTR011`	0	0	0	0	0	0	0	0	3	0	0	0
		Riocypris fitzroyi	0	0	0	0	0	0	0	3	0	0	0	0
		Stenocypris major	0	0	0	0	0	0	0	3	3	1	2	0
	Darwinulidae	*Vestalenula marmonieri*	0	0	0	0	0	0	3	0	2	0	2	0
	Limnocytheridae	*Limnocythere dorsosicula*	0	0	0	0	0	0	3	0	0	0	0	0
	Notodromadidae	*Newnhamia fenestrata*	0	0	0	0	0	0	0	0	0	0	3	0
Maxillopoda														
Cyclopoida	**Cyclopidae**	*Eucyclops australiensis*	0	0	0	0	0	0	0	0	3	0	0	0
		Mesocyclops brooksi	0	0	0	0	0	0	0	3	0	2	0	0
		Mesocyclops darwini	0	0	0	0	0	0	0	0	0	4	0	3
		Mesocyclops notius	0	0	0	0	0	0	3	0	0	2	4	0
		Microcyclops varicans	0	0	0	3	0	0	3	0	3	3	4	0
		Thermocyclops sp.	0	1	2	0	3	4	0	3	0	0	0	0
Harpacticoida	**Canthocamptidae**	Canthocamptidae `sp. Biologic-HARP059`	0	0	0	0	0	0	1	0	0	0	0	0
	Parastenocaridae	*Kinnecaris* `sp. Biologic-HARP092`	0	0	0	0	0	0	0	0	0	2	0	0
Malacostraca														
Amphipoda	**Paramelitidae**	*Chydaekata* sp. `E TLF-2008`	0	0	0	0	0	0	0	0	4	0	0	0
		Paramelitidae `sp. Biologic-AMPH024`	0	0	0	0	0	0	0	0	2	0	0	0
Bathynellacea	**Parabathynellidae**	*Atopobathynella* `sp. Biologic-PBAT019`	0	0	0	0	0	0	0	0	0	3	0	0
Decapoda	**Parastacidae**	*Cherax quadricarinatus*	0	0	0	0	0	0	0	0	1	0	0	0
Collembola														
Poduromorpha		Poduroidea sp.	0	0	1	0	0	0	0	0	0	2	0	0
Symphypleona		Symphypleona sp.	3	0	2	2	2	1	2	3	0	2	0	0
Insecta														

			Survey Area						Reference					
Coleoptera														
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5a**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
	Carabidae	Carabidae sp. (L)	1	0	0	0	0	0	0	0	0	0	0	0
	Dytiscidae	Dytiscidae sp. (L)	0	0	0	0	0	0	0	2	0	0	0	0
		Dytiscidae sp.	0	0	1	0	0	0	0	0	0	0	0	0
		Bidessini sp. (L)	0	1	3	0	0	3	0	1	0	2	2	0
		Allodessus bistrigatus	0	0	0	0	0	0	0	0	0	2	2	0
		Cybister tripunctatus	0	0	0	0	0	0	0	0	0	1	0	0
		Eretes australis (L)	0	0	0	1	0	2	0	0	0	0	2	0
		Eretes australis	1	0	0	0	1	1	0	0	0	0	1	0
		Hydaticus sp. (L)	0	0	0	0	0	0	0	0	0	0	0	2
		Hydroglyphus grammopterus	0	0	0	0	0	1	0	0	0	2	2	0
		Hydroglyphus orthogrammus	0	2	0	0	0	0	0	0	0	1	2	0
		Hyphydrus sp. (L)	0	0	0	0	0	2	0	2	0	0	0	0
		Hyphydrus elegans	0	0	0	0	0	0	0	1	0	1	0	0
		Limbodessus compactus	0	0	0	0	0	0	0	1	0	1	0	0
		Necterosoma regulare	0	0	0	0	0	0	1	0	0	0	0	0
		Tiporus tambreyi	0	0	0	0	0	0	0	0	1	0	0	0
	Elmidae	*Austrolimnius* sp. (L)	0	0	0	0	0	0	0	0	2	0	0	3
	Gyrinidae	Gyrinidae sp.	2	0	0	0	0	0	0	0	0	0	0	0
		Dineutus australis (L)	0	0	1	0	0	1	0	0	0	0	0	0
		Dineutus australis	1	1	0	0	1	0	0	0	2	1	0	0
		Macrogyrus paradoxus	0	0	0	0	0	0	0	0	2	0	0	0
	Haliplidae	*Haliplus pilbaraensis*	0	0	0	0	0	1	0	0	0	0	0	0
	Hydraenidae	*Hydraena* sp.	0	0	0	0	0	0	0	0	0	2	0	0
		Limnebius sp.	0	0	0	0	0	0	0	0	0	2	0	0
		Ochthebius sp.	0	0	0	0	0	0	0	0	0	2	0	0
	Hydrochidae	*Hydrochus interioris*	0	0	0	0	0	0	0	0	0	1	0	0
		Hydrochus obscuroaeneus	0	0	0	0	0	0	0	0	0	2	0	0
	Hydrophilidae	Hydrophilidae sp. (L)	0	0	0	0	0	0	0	2	0	0	0	0
		Agraphydrus coomani	0	0	0	0	0	0	0	0	0	1	0	0
		Berosus approximans	0	0	0	0	0	0	0	0	0	1	0	0
		Berosus dallasi	0	0	0	0	0	0	0	0	0	0	0	2
		Enochrus sp. (L)	0	0	0	0	0	0	0	2	0	0	1	0
		Helochares sp. (L)	0	0	0	0	0	0	0	0	0	1	1	0
		Hydrophilus sp.	0	0	0	0	0	1	0	0	0	0	0	0
		Paracymus sp. (L)	0	0	0	0	0	0	0	0	0	1	0	0
		Paracymus spenceri	0	0	1	0	0	0	0	0	0	1	1	0
		Sternolophus sp. (L)	0	0	2	0	0	0	0	0	0	0	0	0
	Psephenidae	Psephenidae sp. (L)	1	0	0	0	0	0	0	0	0	0	0	0
		Sclerocyphon sp. (L)	0	0	0	0	0	0	0	2	0	0	0	0
	Ptilodactylidae	Ptilodactylidae sp. (L)	2	0	0	0	0	0	0	0	1	0	0	0
	Scirtidae	Scirtidae sp. (L)	0	2	0	0	0	0	0	4	3	2	1	0
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	2	2	0	0	2	0	1	0	0	2	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	0	0	0	0	0	0	3	2	2	2	2	0
		Ceratopogoninae sp.	2	1	2	2	3	3	3	4	3	3	1	3
		Dasyhelea sp.	0	0	0	0	0	0	0	2	1	2	0	0

			Survey Area						Reference					
	Chironomidae	Chironomidae sp. (P)	0	0	0	0	1	0	3	2	2	2	0	2
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5a**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
	Chironominae													
	Chironomini	*Chironomus* aff. *alternans*	0	2	4	1	3	3	3	3	0	0	4	0
		Dicrotendipes sp. `CA1`	0	0	0	0	0	0	0	0	0	0	0	2
		Paratendipes sp. 'K1'	0	0	0	0	0	0	0	0	0	2	0	0
		Polypedilum sp.	0	0	0	2	0	0	0	0	0	0	0	0
		Polypedilum (*Pentapedilum*) *leei*	0	0	0	0	0	0	3	0	0	0	0	0
		Polypedilum nubifer	0	0	0	0	0	0	3	3	0	3	0	0
		Polypedilum watsoni	1	1	0	0	0	0	0	0	0	0	0	0
	Tanytarsini	*Rheotanytarsus* sp.	0	0	0	0	0	0	0	0	0	0	0	3
		Tanytarsus sp.	0	0	0	0	0	0	4	4	0	0	3	2
	Orthocladiinae	*Corynoneura* sp.	0	0	0	0	0	0	0	0	2	0	0	2
		Nanocladius sp.	0	0	0	0	0	0	0	0	0	0	0	2
		nr. *Gymnometriocnemus* sp.	0	0	0	0	0	0	0	0	0	1	0	0
		Parametriocnemus sp.	0	0	0	0	0	0	0	0	0	0	0	2
		Rheocricotopus sp.	0	0	0	0	0	0	0	0	3	0	0	2
		Thienemanniella sp.	0	0	0	0	0	0	0	0	4	0	0	2
	Tanypodinae	*Ablabesmyia hilli*	0	0	0	0	0	0	0	0	2	1	0	0
		Larsia ?albiceps	2	0	0	0	0	0	2	2	3	2	1	1
		Paramerina sp. 1	0	0	0	0	0	0	0	0	4	2	2	2
		Paramerina sp. 2	2	0	0	0	0	0	0	1	3	0	0	0
		Procladius sp.	0	0	2	0	1	2	4	2	0	0	0	0
	Culicidae	Culicidae sp. (P)	0	0	2	0	0	0	0	1	0	0	1	0
		Culicidae sp.	0	2	3	0	2	0	3	3	2	2	3	3
	Dolichopodidae	Dolichopodidae sp.	0	0	0	0	0	0	0	1	1	1	0	3
	Empididae	Empididae sp.	2	2	0	0	0	0	0	0	0	0	0	0
	Ephydridae	Ephydridae sp.	0	0	0	0	1	0	2	0	0	2	0	0
	Muscidae	Muscidae sp.	0	0	0	0	0	0	2	0	0	0	0	0
	Psychodidae	Psychodidae sp.	0	0	1	0	0	0	0	0	0	0	0	0
	Simuliidae	Simuliidae sp.	0	0	0	0	0	0	0	0	0	0	0	3
	Stratiomyidae	Stratiomyidae sp.	0	0	0	0	0	0	0	2	0	0	0	1
	Tabanidae	Tabanidae sp.	0	0	0	0	0	0	0	2	0	0	0	0
	Tipulidae	Tipulidae sp.	0	0	0	0	0	0	0	2	0	0	0	0
Ephemeroptera	**Baetidae**	Baetidae sp.	0	0	2	0	0	0	0	0	4	1	2	3
		Cloeon sp.	0	0	0	0	2	2	0	0	0	0	0	0
		Cloeon fluviatile	0	0	0	0	0	0	0	3	0	0	0	0
		Cloeon sp. Red Stripe	0	0	2	0	0	0	2	3	4	0	0	1
		Offadens G1 sp. WA2	0	0	0	0	0	0	0	0	4	0	0	2
		Pseudocloeon hypodelum	0	0	0	0	0	0	0	0	0	0	0	3
	Caenidae	Caenidae sp.	0	0	0	0	0	0	0	0	3	0	0	2
		Tasmanocoenis sp.	0	0	0	0	0	0	0	0	0	2	0	0
		Tasmanocoenis sp. P/*arcuata*	0	0	0	0	0	0	0	0	3	0	0	1
Hemiptera		Corixoidea sp.	0	0	0	0	0	0	0	3	2	0	0	0
	Belostomatidae	*Diplonychus eques*	0	0	0	0	0	0	0	0	0	0	2	0
	Corixidae	Corixidae sp.	0	0	0	0	0	0	0	0	0	1	0	0
		Agraptocorixa eurynome	0	0	0	0	1	0	0	0	0	0	0	0

			Survey Area						Reference					
	Gerridae	Gerridae sp.	0	2	0	0	1	0	1	0	0	0	0	0
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5a**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**MUNJS**	**SS**
		Limnogonus fossarum gilguy	0	0	0	0	0	0	1	0	0	0	0	0
	Hebridae	Hebridae sp.	0	0	0	0	0	0	0	2	0	0	0	0
		Merragata hackeri	0	0	0	0	0	0	0	0	0	0	1	0
	Micronectidae	*Micronecta* sp.	0	0	2	1	1	2	0	2	0	2	2	0
		Micronecta annae	0	0	0	0	0	0	0	2	0	2	0	0
		Micronecta robusta	0	0	0	0	0	1	0	0	0	0	0	0
	Notonectidae	Notonectidae sp.	1	0	0	0	0	0	0	3	0	2	0	2
		Anisops sp.	0	0	0	0	1	0	0	0	0	2	0	1
		Anisops hackeri	0	0	0	0	0	0	0	0	0	2	0	2
		Anisops nasutus	0	0	0	0	0	1	0	0	0	0	0	0
	Pleidae	*Paraplea brunni*	0	0	0	0	0	0	0	2	0	2	0	0
	Veliidae	Veliidae sp.	0	0	0	0	0	0	0	2	0	1	0	2
		Nesidovelia sp.	0	0	0	0	0	0	0	1	0	0	0	0
		Nesidovelia peramoena	0	0	0	0	0	0	0	0	0	0	0	1
Lepidoptera	**Crambidae**	Acentropinae sp.	0	0	0	0	0	0	0	0	2	0	0	0
		Margarosticha sp. 3	0	0	0	0	0	0	0	0	0	0	0	2
Odonata			0	0	0	0	0	0	0	0	0	0	0	0
Zygoptera		Zygoptera sp.	0	0	0	0	0	0	1	2	3	1	0	2
	Coenagrionidae	*Argiocnemis rubescens*	0	0	0	0	0	0	0	0	0	0	0	2
		Ischnura aurora	0	0	0	0	0	0	0	2	0	0	0	0
		Pseudagrion aureofrons	0	0	0	0	0	0	0	0	1	0	0	0
		Xanthagrion erythroneurum	0	0	0	0	0	0	1	0	0	0	0	0
	Isostictidae	*Austrosticta fieldi*	0	0	0	0	0	0	0	0	0	1	0	0
	Platycnemididae	*Nososticta* sp.	0	0	0	0	0	0	0	0	2	0	0	0
Anisoptera		Anisoptera sp.	0	0	0	1	0	0	2	3	4	2	1	3
	Aeshnidae	*Hemianax papuensis*	0	0	0	0	0	0	1	1	0	0	0	0
	Corduliidae	*Hemicordulia tau*	0	0	0	0	0	0	2	0	0	0	0	0
	Gomphidae	*Austrogomphus gordoni*	0	0	0	0	0	0	1	0	0	0	0	0
	Libellulidae	*Diplacodes haematodes*	0	0	0	0	0	0	2	0	2	2	0	0
		Nannophlebia injibandi	0	0	0	0	0	0	0	0	1	0	0	0
		Orthetrum caledonicum	0	0	0	0	0	0	3	2	1	0	0	0
Trichoptera	**Ecnomidae**	*Ecnomus pilbarensis*	0	0	0	0	0	0	0	0	0	0	0	2
	Hydropsychidae	*Cheumatopsyche wellsae*	0	0	0	0	0	0	0	0	4	0	0	3
	Hydroptilidae	*Hellyethira* sp.	0	0	0	0	0	0	0	0	0	0	0	1
		Orthotrichia sp.	0	0	0	0	0	0	0	0	2	0	0	1
	Leptoceridae	Leptoceridae sp.	0	0	0	0	0	0	0	0	0	0	0	2
		Oecetis sp.	0	0	0	0	0	1	0	0	0	0	0	0
		Triplectides sp.	0	0	0	0	0	0	0	0	0	0	0	1
	Philopotamidae	*Chimarra* sp. AV17	0	0	0	0	0	0	0	0	3	0	0	3
		Taxa richness	**20**	**16**	**19**	**12**	**22**	**28**	**40**	**57**	**54**	**66**	**42**	**57**

Appendix J: Rehydration trial water quality summary data

Dry 2023 - Highlighted cells refer to the values which are in excess of: ■ > the 95% DGV

Site	Statistic	Temp. °C		pH		EC µS/cm		DO%	
		W1	W2	W1	W2	W1	W2	W1	W2
MarC1	Min.	22.50	22.60	7.81	8.12	3012.0	1234.0	76.6	79.2
	Max.	22.70	23.40	8.89	8.55	3975.0	1430.0	92.5	97.5
	Mean	19.86	22.86	8.25	8.38	3618.4	1345.9	74.7	89.8
	se	2.52	0.07	0.12	0.05	129.6	18.5	12.0	2.7
MarC2	Min.	22.00	22.60	7.38	7.96	943.0	846.0	16.5	81.5
	Max.	22.60	23.50	8.69	8.40	1288.0	1004.0	88.2	95.6
	Mean	22.29	22.94	8.04	8.24	1157.5	933.9	58.7	90.1
	se	0.06	0.09	0.15	0.05	46.1	15.2	12.9	2.0
MarC3	Min.	21.80	23.00	7.40	7.70	1924.0	1553.0	49.6	71.9
	Max.	22.50	23.70	9.02	8.11	2189.0	1860.0	82.0	87.1
	Mean	22.08	23.21	8.05	7.90	2066.6	1792.1	59.0	79.3
	se	0.08	0.07	0.17	0.04	32.0	29.2	9.8	2.2
MarC4	Min.	21.80	22.80	7.74	8.03	1143.0	1070.0	59.6	81.4
	Max.	22.40	23.50	9.04	8.43	1661.0	1315.0	87.7	95.5
	Mean	22.08	23.00	8.17	8.27	1468.9	1224.0	69.0	89.7
	se	0.06	0.07	0.15	0.05	72.3	24.4	11.2	2.0
MarC5	Min.	21.80	22.70	7.13	7.89	918.0	963.0	54.0	84.0
	Max.	22.60	23.30	9.02	8.44	1125.0	1139.0	84.7	96.8
	Mean	22.16	22.92	7.94	8.24	1043.3	1077.4	64.4	91.4
	se	0.08	0.06	0.20	0.06	26.8	15.9	10.6	1.9
MarC6	Min.	21.70	22.50	7.67	7.86	771.0	841.0	58.3	83.2
	Max.	22.50	23.40	9.02	8.45	1010.0	1044.0	85.3	95.5
	Mean	22.10	22.73	8.10	8.21	919.9	960.8	68.2	90.2
	se	0.08	0.10	0.15	0.06	30.8	17.9	10.6	1.9

Appendix K: Rehydration trial taxa list

Dry 2023

			MarC1		MarC2		MarC3		MarC4		MarC5		MarC6	
Phylum/Class/Order	**Family**	**Lowest taxon**	**W1**	**W2**	**W1**	**W2**	**W1**	**W2**	**W1**	**W2**	**W1**	**W2**	**W1**	**W2**
PLANTAE		"Macrophyte" sp.	3	3	4	3	2	2	1	3	4	4	3	3
PLATYHELMINTHES														
Turbellaria		Turbellaria sp.	0	0	0	0	0	0	0	0	3	0	3	2
ROTIFERA		Rotifera sp.	3	0	0	0	0	0	4	4	0	0	0	0
NEMATODA		Nematoda sp.	3	0	2	0	2	0	3	4	0	0	2	2
ARTHROPODA														
Branchiopoda														
Diplostraca														
Cladocera	**Chydoridae**	*Alona quadrangularis*	0	0	0	0	0	0	0	0	0	0	0	4
		Chydorus sp.	0	0	0	1	0	0	0	4	0	3	0	0
		Leberis sp.	5	4	0	2	0	0	5	4	0	3	5	4
	Daphniidae	*Ceriodaphnia* sp.	3	0	0	0	0	0	4	0	0	0	0	0
		Simocephalus sp.	0	0	0	0	0	0	0	0	5	4	4	0
	Ilyocryptidae	*Ilyocryptus* sp.	0	0	0	0	0	0	0	0	0	0	1	4
	Macrothrichidae	*Macrothrix* sp.	4	0	0	0	0	0	0	0	0	0	0	0
	Sididae	*Latonopsis* sp.	0	0	0	0	0	0	0	2	0	0	0	0
		Latonopsis australis	0	0	0	0	0	0	0	0	0	0	3	1
Spinicaudata	**Cyzicidae**	*Ozestheria* `sp. Biologic-BRAN002`	0	0	0	0	0	0	0	0	0	0	2	0
	Limnadiidae	*Limnadopsis occidentalis*	0	0	0	0	0	0	2	3	0	0	0	0
		Limnadopsis pilbarensis	0	0	0	0	0	0	2	0	0	0	1	0
Ostracoda														
Podocopida	**Cyprididae**	*Bennelongia tirigie*	2	3	0	0	0	0	0	0	0	0	0	0
		Cypretta `sp. Biologic-OSTR015`	2	3	0	0	0	0	0	2	2	3	1	3
		Cypretta `sp. Biologic-OSTR016`	0	0	0	0	0	0	0	0	2	3	0	0
		Ilyodromus sp.	0	0	0	0	0	0	0	0	0	0	0	2
		Ilyodromus `sp. Biologic-OSTR014`	0	0	0	0	0	0	0	0	0	3	1	0
		Riocypris cf. *fitzroyi*	0	0	0	0	0	0	0	0	0	3	0	0
		Stenocypris major	3	4	0	0	0	0	0	2	0	0	0	2
	Ilyocyprididae	*Ilyocypris australiensis*	0	0	0	0	0	0	0	2	0	0	1	2
	Limnocytheridae	*Limnocythere dorsosicula*	3	2	0	0	0	0	1	0	0	0	0	0
Collembola														
Symphypleona		Symphypleona sp.	2	0	0	0	0	0	0	0	0	0	0	0
Insecta														
Diptera	**Psychodidae**	Psychodidae sp.	0	0	0	0	0	1	0	0	0	0	0	0
		Taxa richness	**11**	**6**	**2**	**3**	**2**	**2**	**8**	**10**	**5**	**8**	**12**	**11**