Alcoa Willowdale (Larego Region)

Targeted Carter's Freshwater Mussel Survey

Report to Alcoa of Australia Limited

19 April 2024

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Executive Summary

Alcoa commissioned Biologic Environmental Survey (Biologic) to conduct a targeted survey for *Westralunio carteri* (Carter's freshwater mussel; CFM) in the Larego region (the Survey Area). This species is currently listed as Vulnerable under State (WA *Biodiversity Conservation Act 2016*), Federal (*Environment Protection and Biodiversity Conservation Act 1999*), and international conservation lists (IUCN Red List of Threatened Species).

A targeted CFM survey was conducted in November 2023. Eight sites, including three Haul Road sites (HR1, HR2 and HR3) and five Turbidity Monitoring sites (Conveyor, TM2, TM3, TM4 and TM5) were proposed for the survey. However, only one of the haul road sites was accessible (HR3) at the time of survey due to dense vegetation impeding access at HR1 and HR2. An alternate, accessible location (HR1a) was sampled approximately 660 m downstream of HR1, resulting in a total of two haul road sites and five Turbidity Monitoring sites being successfully sampled.

Survey methods included foraging with mussel rakes, hand searching, intensive searching within quadrats, and sieving of sediments to locate juveniles. Substrate assessments were also undertaken at each site, along with measurements of water quality (including in situ analytes at all sites and laboratory analyses of ionic composition, nutrients and dissolved metals at sites where mussels were found), to evaluate the suitability of in-stream habitat for CFM.

A total of nine CFM was recorded from the Survey Area. Eight individuals between 37 mm and 47 mm in length were recorded from TM3, all of which were deceased at the time of survey, while a single live CFM was recorded during an opportunistic search at TM4 (55 mm). Water quality and habitat data from TM3 found conditions were suitable for CFM at the time of survey, and therefore did not provide any insight into the cause of deaths. However, this assessment was based on spot measurements at the time of sampling, with no indication of whether there were any previous spikes in analyte concentrations or contamination events which may have impacted CFM in this area. There were moderate flows at TM3 at the time of sampling, so it is also possible the deaths could have occurred upstream.

Following the targeted survey and re-assessment of likelihood of occurrence, HR3 was deemed 'Highly Unlikely' to support CFM due to the ephemeral nature of this pool, coupled with the highly compacted sediment in this area, while Conveyor was considered 'Unlikely' to support CFM due to the limited availability of suitable habitat. Sites HR1a, TM2 and TM5 were all considered 'Possible', as favourable habitat was present despite no CFM being found during the survey. The lack of CFM may be due to physical barriers preventing freshwater fish from dispersing the parasitic mussel larvae (glochidia) to these areas. Alternatively, the

absence of CFM at TM5 may have been a result of sampling effort, given the overgrown vegetation at this site made surveying for mussels difficult.

Based on the results of the targeted survey, TM3 and TM4 are the only sites in the Survey Area that support CFM, although it is possible that the population at TM3 is no longer extant. The conservation status of CFM is currently under review due to recent redescription of *Westralunio carteri* and reduction in range as a result. As a species currently experiencing population decline, this reduction has implications for the conservation status of CFM. The importance of existing populations of CFM is likely to become more significant following any reassessment of the species. The mortality event at TM3 should be investigated further, and a repeat targeted survey undertaken in the vicinity to assess whether the area supports any live mussels in future.

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1 Introduction

1.1 Background

Alcoa of Australia Limited's (Alcoa) Western Australian (WA) mining operations comprise the Huntly and Willowdale bauxite mines, which occur in Alcoa's Mining Lease 1SA (ML1SA), located approximately 63 km southeast of Perth in the Northern Jarrah Forest IBRA subregion (Figure 1.1). Alcoa has approval to mine within ML1SA subject to submitting draft five-year mine plans and associated environmental management programs, known as the Mining and Management Program (MMP). The MMP is submitted to the State's Mining and Management Program Liaison Group (MMPLG) on an annual basis.

Alcoa has committed to undertaking ecological surveys for the Huntly Mine (Myara region) and Willowdale Mine (Larego region) as part of its MMP assessment by the MMPLG (Figure 1.1). This includes baseline desktop studies and targeted surveys, which will be used to:

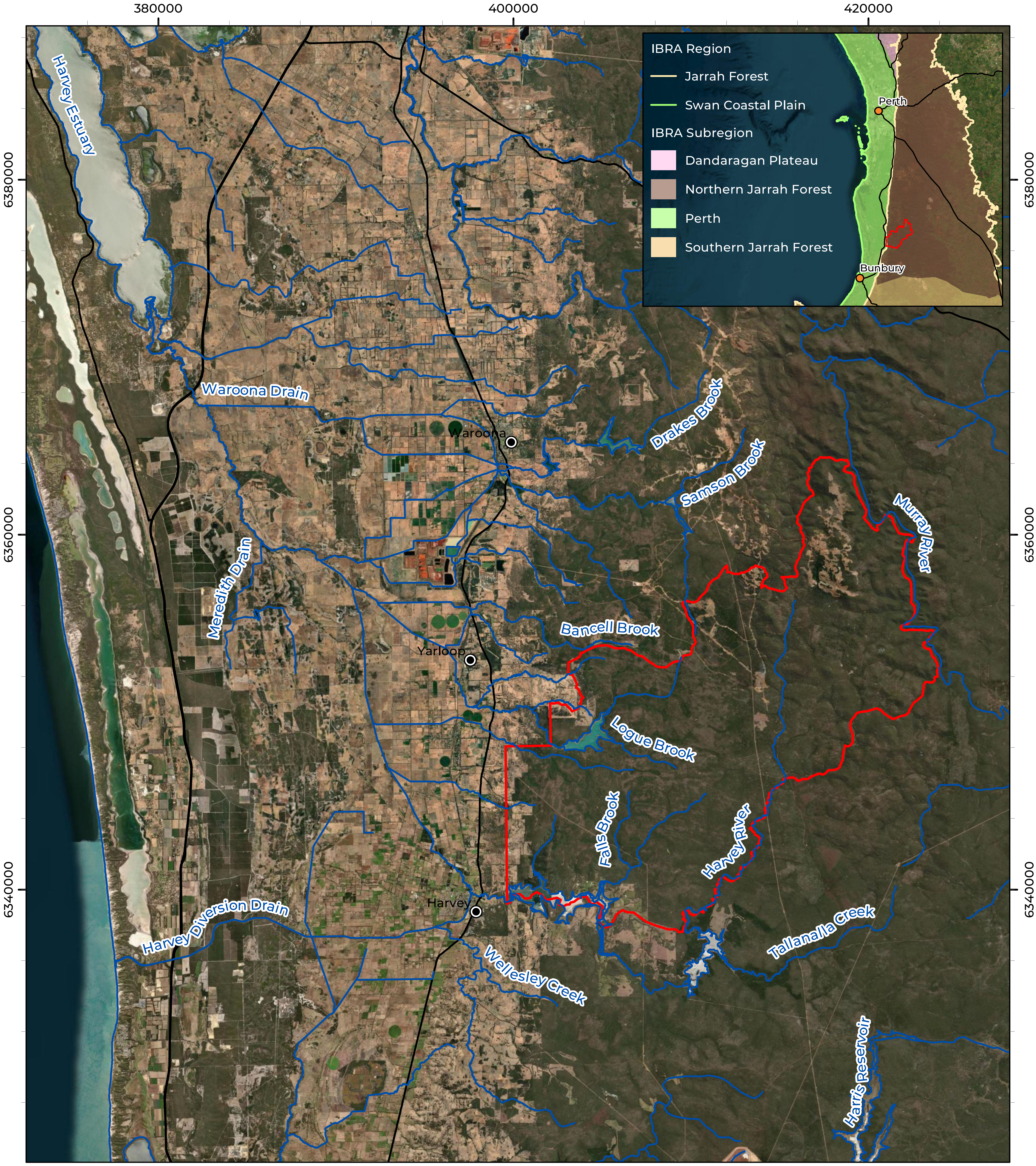
- Amend the conceptual alignment to avoid significant fauna
- Realign waterway crossings to avoid significant fauna
- Inform translocation and environmental management plans as required
- Develop mining avoidance zones for significant fauna
- Assist Alcoa in preparing MMP submission to the MMPLG.

Therefore, Alcoa commissioned Biologic Environmental Survey (Biologic) to conduct a targeted survey for *Westralunio carteri* (Carter's freshwater mussel; CFM) in stream zone areas within the Larego region (hereafter referred to as the Survey Area; Figure 1.1). This species is currently listed as Vulnerable under the State *Biodiversity Conservation Act 2016* (BC Act) and Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). It is also listed as Vulnerable on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2024) (see Appendix A for a description of conservation codes).

1.2 Scope and Objectives

The overarching objective of the targeted survey was to search for and record occurrence of CFM within the Survey Area. This was achieved via:

- Desktop assessment – identify CFM records within a 20 km of the Survey Area. This included a likelihood of occurrence assessment for mussels within the Survey Area.
- Targeted field survey – undertake extensive searches for CFM within the Survey Area at eight locations in 2023 (three Haul Road Crossing sites and five Turbidity Monitoring Points).



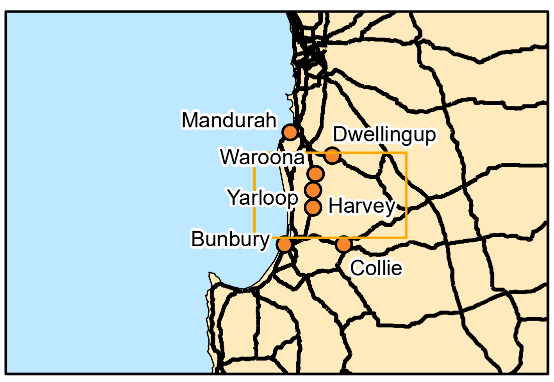
LEGEND

- Survey Area
- State Road
- Major Creek

Scale 1:200,000

0 2 4 6 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 19/03/2024



Biologic

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Figure 1.1: Survey Area and regional context

1.3 Compliance

There is currently no technical guidance for targeted CFM surveys. However, freshwater mussels are included, along with all aquatic fauna, under the Western Australian Environmental Protection Authority's (EPA) Terrestrial Fauna environmental factor. Therefore, this targeted survey employed sampling design, methods, and general approaches consistent with the following:

- Technical Guidance, Terrestrial Fauna Surveys (EPA, 2016)
- Environmental Factor Guideline, Inland Waters (EPA, 2018)
- New Zealand Regional Guidelines for Adult Freshwater Mussel Monitoring (Catlin *et al.*, 2017)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)
- Best practice, following similar targeted CFM surveys undertaken in the South West, including Klunzinger et al. (2012a), Klunzinger et al. (2012b), Biologic (2020), Biologic (2021), Biologic (2022a), Biologic (2022b), Biologic (2023a), Biologic (2023b) and WRM (2020).

1.4 Carter's Freshwater Mussel

CFM is endemic to South West Western Australia. Until recently, it was considered the only species of native freshwater mussel in this region, and the only member of the genus *Westralunio* to occur in Australia. Molecular and morphometric analyses has since found three evolutionary significant units (Klunzinger *et al.*, 2022). As a result, two species of freshwater mussel are currently known, *Westralunio carteri* and *Westralunio inbisi*, the latter of which represents two subspecies. *Westralunio carteri* is now known to be restricted to western coastal drainages, while *Westralunio inbisi inbisi* occurs in southern coastal drainages, and *Westralunio inbisi meridiemus* is found in the Margaret River and Blackwood River catchments only (Klunzinger *et al.*, 2022).

Historically, the distribution of CFM extended from the Moore River in the north, inland to the Avon and Blackwood Rivers, and south to the Bow River (Klunzinger, 2012). This historic range has reduced by approximately 49%, with its distribution lying between Gingin Brook in the north and the Kent River in the south (Klunzinger *et al.*, 2015), with two outlying populations in the Goodga and Waychincup Rivers. The redescription of CFM reduces this range further, with the current distribution for CFM lying between Gingin and to the north and west of the Blackwood River, within 150 km of the coast (Klunzinger *et al.*, 2022). The reduction in range and continuing population decline led to its conservation listing as Vulnerable on State, Federal and International conservation lists (Klunzinger & Walker, 2014). However, it is expected this conservation listing will require reassessment considering the recent taxonomic changes and further reductions in range for CFM as a result.

Like other freshwater bivalves, CFM is a slow-growing, long-lived species. Maximum age range among populations are 36 to 52 years and sexual maturity is reached at approximately four to six years (and ~27 mm in length). Maximum size has been reported to be 72.9 to 82.8 mm in some populations (Klunzinger *et al.*, 2014).

CFM are typically dioecious, though hermaphrodites have occasionally been recorded (Klunzinger *et al.*, 2014). They have an obligate parasitic larval stage (glochidia), which attach to suitable host fish and are transported and deposited into suitable sediment as post-parasitic juvenile mussels. As such, juvenile mussels are only recorded where suitable host fish are present. Little is known about the juvenile stage, though they would require stable sediment to avoid being swept away by currents (Klunzinger, 2012). CFM need sediment that is firm but penetrable, such as sand. They are generally absent from sediments that are too soft or too compact, such as clay and bedrock.

The greatest threats to CFM are salinisation and drying of water systems. CFM have an acute sensitivity to salinity, with a maximum tolerance of 3.5 ppt under lab conditions and are rarely found in water greater than 1.6 ppt (Klunzinger, 2012; Klunzinger *et al.*, 2012b; Klunzinger *et al.*, 2015). CFM also cannot survive exposure to direct sunlight or heat, and do not aestivate, so rarely persist in non-perennial water systems (Klunzinger, 2012), though burrowing into sediments can protect individuals from water emersion to some extent (Lymbery *et al.*, 2020). These threatening processes also adversely impact native fish populations in the South West (Beatty *et al.*, 2011; Morgan *et al.*, 1998; Morgan *et al.*, 2003), leading to further decline in mussel populations due to loss of suitable host fish species (Klunzinger, 2012). High turbidity and suspended solids can also negatively impact the filtration ability of freshwater mussels (Klunzinger, 2012).

2 Desktop assessment

2.1 Methods

A desktop assessment, comprising database searches and a literature review, was undertaken prior to the field survey. The purpose of the desktop assessment was to identify CFM known to occur, or potentially occurring in the Survey Area.

2.1.1 Database Searches

Five databases were searched for CFM records (Table 2.1). Searches were conducted within a 20 km radius of the Survey Area, with the exception of the Index of Biodiversity Surveys for Assessments (IBSA) database, which covered the Northern Jarrah Forest region.

Table 2.1: Details of database searches conducted

Provider	Reference	Database	Parameters
Department of Climate Change, Energy, the Environment and Water (DCCEEW)	DCCEEW (2023)	Protected Matters Database Search Tool. Accessed September 2023	20 km search area around Survey Area
Atlas of Living Australia (ALA)	ALA (2023)	Atlas of Living Australia. Accessed September 2023	20 km search area around Survey Area
DBCA Dandjoo Biodiversity Data Repository (Formally Nature Map)	(DBCA, 2023)	Mollusca Database Search. Accessed September 2023	20 km search area around Survey Area
Department of Water and Environmental Regulation (DWER)	DWER (2023a)	Healthy Rivers Database: *Westralunio carteri*. Accessed September 2023	20 km search area around Survey Area
DWER Index of Biodiversity Surveys for Assessments (IBSA)	DWER (2023b)	IBSA Database Search. Accessed September 2023	All known occurrence records for the Northern Jarrah Forest

2.1.2 Literature Review

A review of relevant available literature was conducted to gather regional context and any additional records not captured in the database searches (Table 2.2). Literature in the vicinity of the Survey Area was limited. In a study investigating age and growth rate of CFM populations in different systems, Klunzinger *et al.* (2014) collected individuals from the Brunswick River, ~28 km south of the Survey Area. A total of 85 CFM from the Brunswick River were marked, and 77 recaptured after 12 months, as part of the age-growth study. No juveniles were captured from the Brunswick River (Klunzinger *et al.*, 2014). Ma *et al.* (2022)

conducted mussel surveys at 32 sites across several river systems in the South West, finding CFM at 26 of these. One site was located in the Harvey River, but no CFM were recorded (Ma *et al.*, 2022). The exact location of the site was not provided, so its proximity to the Survey Area is unknown.

Table 2.2: Summary of relevant literature reviewed

Report title	Survey type	Location
Range decline and conservation status of *Westralunio carteri* Iredale, 1934 (Bivalvia: Hyriidae) from south-western Australia (Klunzinger *et al.*, 2015)	Database search	Vasse, Brunswick and Preston Rivers – exact location not provided
Population structure and microhabitat preference of a threatened freshwater mussel, *Westralunio carteri*, in south-western Australia (Ma *et al.*, 2022)	Targeted mussel survey	Vasse, Brunswick and Preston Rivers – exact locations not provided
Age and growth in the Australian freshwater mussel, *Westralunio carteri*, with an evaluation of the fluorochrome calcein for validating the assumption of annulus formation (Klunzinger *et al.*, 2014)	Targeted mussel survey	Brunswick River – 28 km south of Survey Area

2.1.3 Likelihood of Occurrence

The likelihood of CFM occurrence within the Survey Area was assessed using a decision matrix which considers habitat suitability and the proximity of previous records (Table 2.3).

Table 2.3: Assessment of occurrence decision matrix

		Habitat Categories (within the Survey Area)			
		Core/ critical habitat present	Suitable habitat present/ within known distribution	Marginal habitat present/ adjacent to known distribution	No suitable habitat present/ outside of known distribution
Species records/ Occurrence Categories	Recorded in the Survey Area	Confirmed	Confirmed	Confirmed	Confirmed
	Recorded within <2km	Highly Likely	Likely	Possible	Possible
	Recorded within 2–5 km	Likely	Possible	Possible	Unlikely
	Recorded within 5–20 km	Possible	Possible	Unlikely	Unlikely
	Recorded >20 km	Possible	Unlikely	Unlikely	Highly Unlikely
	Taxa considered locally/regionally extinct	Unlikely	Unlikely	Highly Unlikely	Highly Unlikely

2.2 Results

2.2.1 Desktop Assessment

The desktop assessment found two CFM records from the Atlas of Living Australia (ALA) and two records from the Dandjoo Biodiversity Data Repository, which were only identified to family level (Hyriidae) (Figure 2.1). The coordinates provided by ALA (2023) were generalised to 10 km due to sensitivity concerns.

The Project Matters Database Search Tool indicated CFM habitat was likely to occur throughout the Survey Area (DCCEEW, 2023). The Healthy Rivers Database revealed CFM records at undisclosed sites including the Samson Brook (approximately 2 km south of Waroona), the creeks surrounding the town of Yarloop (approximately 16 km west of the Survey Area), and in the tributaries of the Harvey Dam (on the south west border of the Survey Area) (DWER, 2023a). These two databases do not provide exact locations of fauna records, and only indicate whether CFM have been recorded in any given area.

Three targeted CFM surveys are available on the IBSA database. These include surveys at Gingin Brook (Biologic, 2022a), Bennett Brook (WRM, 2020), and a targeted survey as part of the Byford railway extension project (Stream Environment and Water, 2021). All three surveys were located more than 70 km from the Survey Area.

2.2.2 Likelihood of Occurrence

The likelihood of occurrence at all sites within the Survey Area was assessed as 'Possible' (Table 2.4). While the Survey Area itself has not previously been surveyed for CFM, the potential for suitable habitat (i.e. permanent, fresh water) that could support this species was considered likely to occur within the area, and the nearest known record of CFM was between 5 - 20 km from each site (DCCEEW, 2023).

Table 2.4: Summary of assessment of occurrence

Site	Within current known distribution	Distance to nearest record	Core/critical habitat within Survey Area	Likelihood of Occurrence
HR1	Yes	~13.2 km northwest (DWER, 2023a)	Yes	Possible
HR1a	Yes	~12.8 km northwest (DWER, 2023a)	Yes	Possible
HR2	Yes	~13 km west DWER, 2023a)	Yes	Possible
HR3	Yes	~13.5 km west (DWER, 2023a)	Yes	Possible
Conveyor	Yes	~16.7 km west (DWER, 2023a)	Yes	Possible
TM2	Yes	~16.2 km west (DWER, 2023a)	Yes	Possible
TM3	Yes	~14.8 km south west (DWER, 2023a)	Yes	Possible
TM4	Yes	~13.3 km south west (DWER, 2023a)	Yes	Possible
TM5	Yes	~9.7 km west (DWER, 2023a)	Yes	Possible

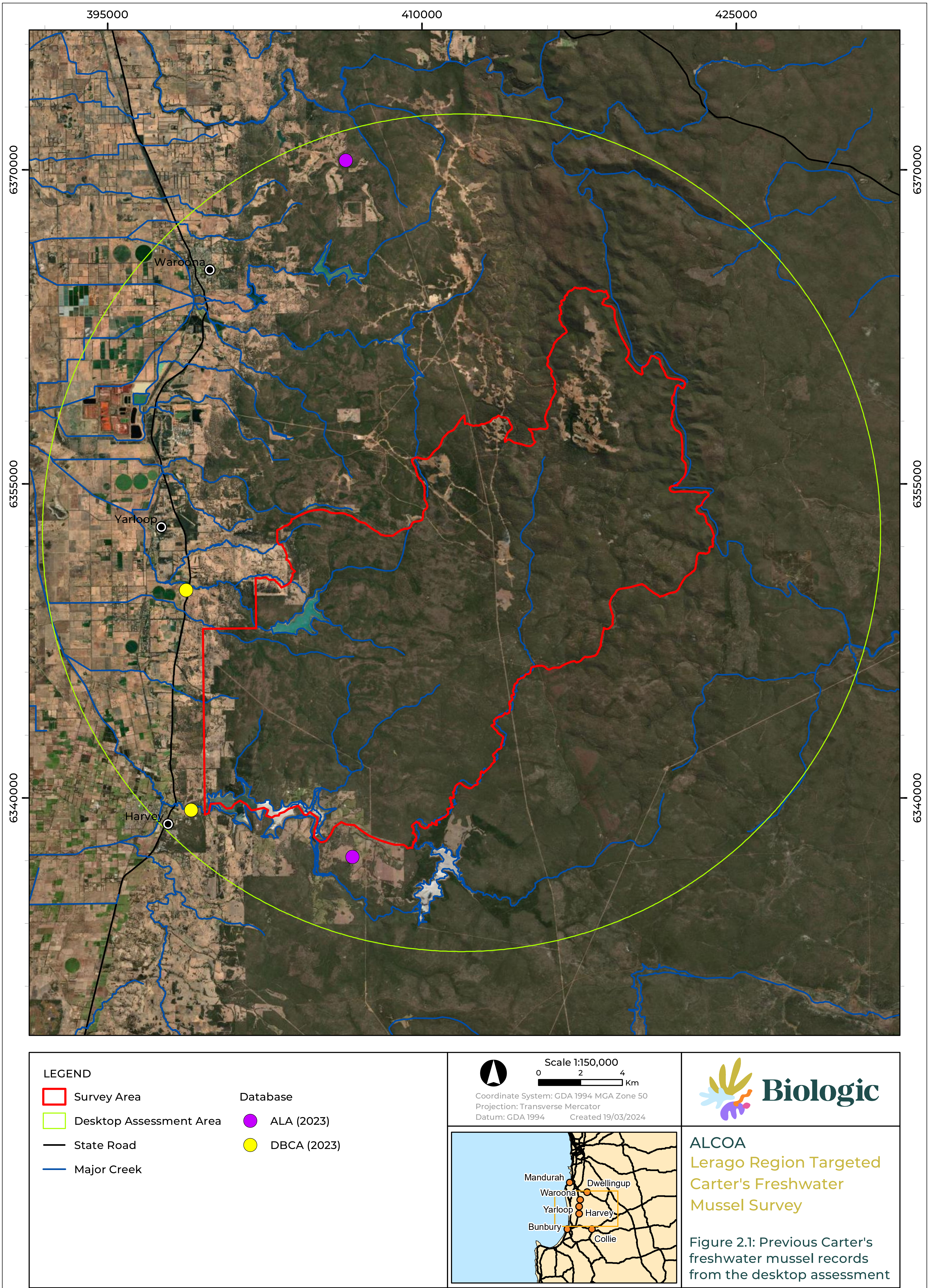

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Figure 2.1: Previous Carter's freshwater mussel records from the desktop assessment

3 Field Survey Methods

3.1 Survey Timing & Personnel

The targeted survey was undertaken over three days between the 17th and 19th of November 2023. Personnel and licence information is provided in Table 3.1.

Table 3.1: Project team & licences

Biologic Personnel	Project Involvement	Licencing	Experience
Principal Aquatic Ecologist			
Jess Delaney	Project management support, reviewer for quality assurance		22 yrs
Senior Aquatic Ecologist			
Alex Riemer	Field team lead, reporting	TFA 2324-0060 EXEM 251140923	12 yrs
Aquatic Ecologist			
Mahabubur Rahman	Field survey, data management	TFA 2324-0060 EXEM 251140923	4 yrs

3.2 Weather & Climate

There was no rainfall recorded during the survey at nearby Bureau of Meteorology (BOM) station Dwellingup (station 009538). A total of 2.8 mm of rainfall was recorded at Dwellingup in the week prior to the survey. Ambient temperatures were warm during the survey, with a maximum of 31.3 °C (BoM, 2023). River flows and water levels were low during the survey.

3.3 Sampling Sites

Eight sites were originally selected for sampling, however, two Haul Road sites (HR1 and HR2) were heavily vegetated and the team were unable to traverse the area between the track and creek to access the sites. One alternative location approximately 660 m downstream of HR1 was able to be accessed, and therefore an additional sample site was positioned here (HR1a), resulting in a total of seven sites sampled. Site details are provided in Table 3.2 and locations shown in Figure 4.1 (see section 4.1).

Table 3.2: Sampling site details

Type	System	Site Code	Latitude	Longitude	Successfully sampled
Haul Road	Un-named Creek, flowing into Samson Brook Dam	HR1	-32.923431	116.050603	×
	Un-named Creek, flowing into Samson Brook Dam	HR1a	-32.9182506	116.0502079	✓
	Tributary of Un-named Creek flowing into Samson Brook Dam	HR2	-32.925650	116.048450	×
	Tributary of the Harvey River	HR3	-32.9603083	116.05736	✓
Turbidity Monitoring	Tributary of the Harvey River	Conveyor	-32.9557617	116.0922283	✓
	Tributary of the Harvey River	TM2	-32.96022031	116.0879798	✓
	Tributary of the Harvey River	TM3	-32.9905712	116.0916774	✓
	Tributary of the Harvey River	TM4	-33.0041917	116.0860767	✓
	Tributary of Un-named Creek flowing into Logue Brook Dam	TM5	-32.9768733	116.01968	✓

3.4 Water Quality

In situ water quality was measured at each site using a YSI Pro Plus multimeter. Parameters recorded included pH (pH units), redox potential (mV), salinity (parts per thousand; ppt), electrical conductivity (EC; µS/cm), dissolved oxygen (DO; mg/L and % saturation), and water temperature (°C).

At sites where mussels were recorded, undisturbed water samples were collected for laboratory analyses of ionic composition, nutrients, dissolved metals, total suspended sediment (TSS) and turbidity. All water quality variables included:

- General ions and others – calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), bicarbonate (HCO_3), chloride (Cl), sulfur (S), sulfate (S_SO_4), carbonate (CO_3) alkalinity, and hardness (all mg/L)
- Water clarity – TSS (mg/L) and turbidity (NTU)
- Nutrients – total nitrogen (total N), total phosphorus (total P), nitrogen oxides (N_NOx), nitrogen nitrate (N_NO_3), and nitrogen ammonia (N_NH_3) (all 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 Millipore nitrocellulose filters in the field. 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. In addition, field personnel wore nitrile gloves whilst undertaking water sampling. All water samples were kept cool in an esky while in the field, and either refrigerated (ions, metals, general water), or frozen (nutrients) as soon as possible for subsequent transport to the laboratory. Water quality analyses were undertaken by ALS, a NATA accredited laboratory.

3.5 Habitat Assessment

As CFM are often found partially to fully submerged in fine sediment, details of benthic sediment characteristics were recorded at each site. Sediment data was used to assist in explaining distribution patterns and the presence/absence of CFM. Details of substrate composition included percent cover by bedrock, boulders, cobbles, pebbles, gravel, sand, silt and clay.

3.6 Mussel Sampling

At each site, CFM were targeted using several methods to increase the likelihood of recording individuals, with factors such as access, water depth and salinity considered. Sampling methods included hand searching, mussel rakes and dip nets. Sieving of sediments was undertaken to target juvenile mussels. Sampling comprised a timed survey (minimum 1 hour per team member, total minimum search time effort of 2 hours per site), checking benthic sediments, especially in and around large woody debris, for evidence of mussels. GPS track logs were recorded during the survey to attest to sampling effort expended (Figure 4.1, see section 4.1).

Where access was possible and sufficient water depth was present, up to eight 1 m^2 quadrats were deployed across the site (Plate 3.1). Dense vegetation severely impeded access to most sites and water depth was generally low. As such, the maximum of eight quadrats were deployed at three sites only; TM2, TM3 and TM4. Of the remaining sites, six quadrats were deployed at HR1a, five at Conveyor, four at HR3 and two at TM5.

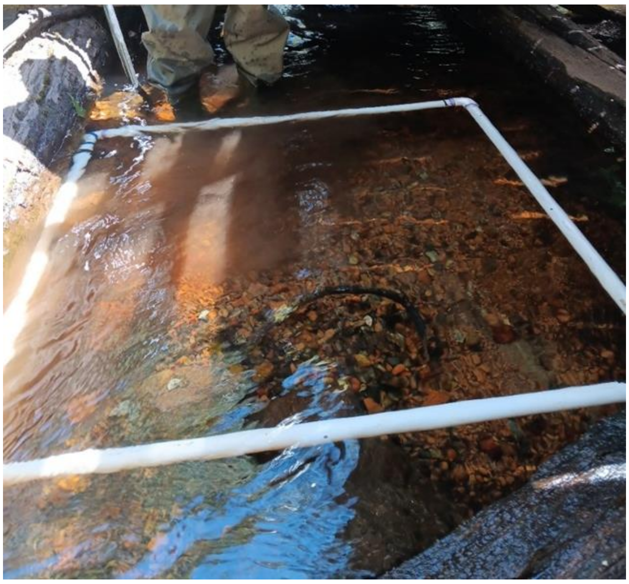


Plate 3.1: A quadrat placed at TM4, ready for hand searching

Morphometric measurements were taken of any mussels found using vernier callipers, including measurements of maximum length (ML) and maximum width (MW). All live mussels were then returned alive to the site of capture. Any dead mussels observed, as indicated by empty shells, were also recorded.

3.7 Data Analysis

3.7.1 Water Quality

Water quality data were compared against the ANZG (2018) default guideline values (DGVs) for the protection of slightly to moderately disturbed aquatic ecosystems in the South West of Western Australia (equivalent to 95% species protection DGVs) (see Appendix B). The primary objective of the guidelines is to "provide authoritative guidance on the management of water quality in Australia and New Zealand and includes setting water quality and sediment quality objectives designed to sustain current, or likely future, community values for natural and semi-natural water resources" (ANZG, 2018). DGVs are provided for a range of parameters designed to protect aquatic systems at a low level of risk. Water quality was compared against the existing DGVs for upland rivers within the South West (ANZG, 2018). Water quality data provides information on the suitability of habitats to support CFM.

3.7.2 Carter's Freshwater Mussel

While growth rates of CFM can be highly variable across populations of different river systems, field observations indicate first maturity is attained at ~27 mm ML (Klunzinger *et al.*, 2014). Therefore, individuals > 27 mm ML were classified as mature adults in this study.

3.8 Assumptions and Limitations

The targeted survey was undertaken by qualified personnel with experience in targeted CFM surveys. Potential limitations and constraints are summarised in Table 3.3.

Table 3.3: Summary of assumptions and limitations in relation to the targeted survey

Potential limitation or constraint	Constraint (Yes/No)	Applicability to this survey
Experience of personnel	No	The Senior Aquatic Ecologist who led the survey has over 12 years' experience undertaking targeted invertebrate fauna surveys, with direct and relevant experience undertaking CFM surveys in the South West region.
Scope (faunal groups sampled and whether any constraints affect this)	No	The scope was to undertake a field survey to determine the presence of CFM at specified sites within the Survey Area, which was completed.
Identification of aquatic fauna	No	CFM are easily identifiable in the field.
Sources of information (recent or historic) and availability of contextual information	No	Relevant database information was provided by Main Roads. Additional databases and literature were accessed from publicly available sources.
Proportion of the task achieved	Minor	Eight sites were originally selected, but due to heavy vegetation, only seven sites were able to be accessed. Dense vegetation and shallow water depths also impeded the number of quadrats deployed at some sites.
Disturbances (fire or flood)	No	There were no recent fires which posed a constraint to sampling effort. The survey was completed in late spring, at a time when river flows from winter rainfall had receded and water depths were wadable and appropriate for hand searching.
Intensity of survey	Yes	Search effort was sufficient at sites that were easily accessible (which included hand searches, mussel rakes and sieving of sediments as appropriate). However, access and sampling was hindered at some sites (especially TM5), and the maximum number of quadrats (8) was only able to be deployed at 3 sites.
Completeness of survey	Minor	Two of the three Haul Road sites were not able to accessed for survey due to dense vegetation. An alternate sampling location was found downstream of HR1 which was successfully sampled (HR1a). Of the seven sites sampled, thick vegetation and low water depth reduced the number of quadrats deployed at each site. Particularly sites HR3 (four quadrats) and TM5 (two quadrats).
Resources (degree of expertise available)	No	All resources required to complete the survey were available.

Potential limitation or constraint	Constraint (Yes/No)	Applicability to this survey
Remoteness or access issues	Minor	Some sites not able to accessed for survey due to dense, overgrown vegetation

4 Results

4.1 Site Descriptions

Descriptions of each site are provided in Table 4.1. Track logs of traverses from the targeted survey show the areas assessed and sampling effort expended (Figure 4.1).

4.2 Water Quality

4.2.1 In Situ

Surface waters were fresh[1] and clear at all sites. EC ranged from 114 µS/cm (at TM5) to 242 µS/cm (at Conveyor), while salinity varied between 0.07 ppt (at HR3, TM4 and TM5) and 0.14 (at Conveyer). EC values were all within the ANZG (2018) DGV for upland rivers of the South West (Table 4.2). Salinity was well below the upper tolerance limit of CFM (1.6 ppt) at all sites (Klunzinger *et al.*, 2015). At sites which supported CFM, turbidity was well below the ANZG (2018) DGV (20 NTU), with measurements of 0.3 NTU at TM3 and 0.4 NTU at TM4 (Table 4.3).

Surface water pH ranged from acidic (6.04 at Conveyor) to neutral (7.38 at HR3). Most sites recorded pH within the ANZG (2018) DGV range, with the exception of Conveyor and TM2. Both sites recorded pH slightly below the lower DGV (Table 4.2). Although no specific tolerance studies have been undertaken on CFM in relation to pH, freshwater mussels in general are considered to be sensitive to low pH (Strayer, 2008). Klunzinger *et al.* (2015) reported records of live CFM from habitats ranging from pH 4.24 to 9.7. However, long-term survival rates and the influence of low pH on different life history stages is currently unknown. Based on the live records by Klunzinger *et al.* (2015), the low pH recorded from Conveyor and TM2 in this study are within the known occurrence range for CFM.

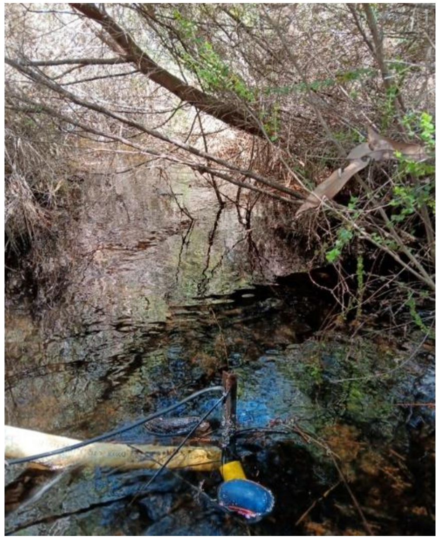
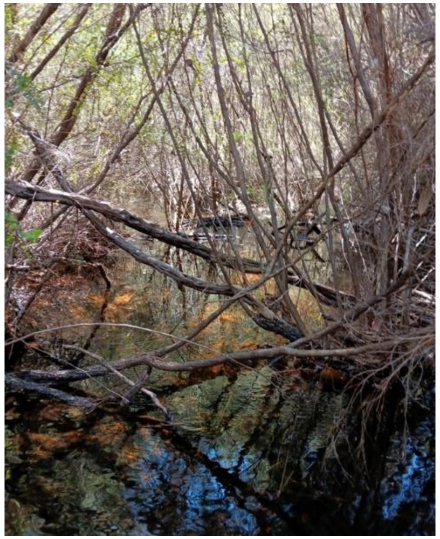
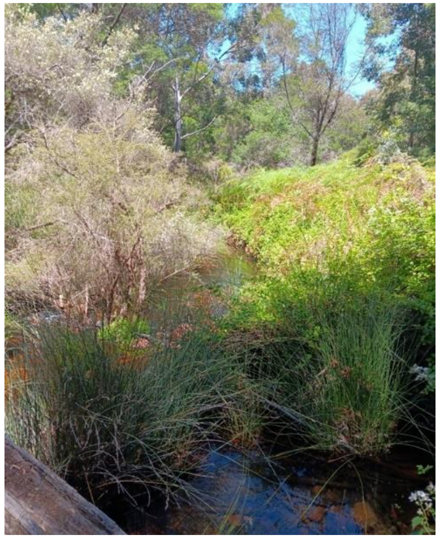
DO saturation was generally considered adequate, and varied between 80.9% (at Conveyor) and 122.8% (at TM4; Table 4.2). Two sites recorded DO levels below the lower ANZG (2018) DGV (Conveyor and TM2). Despite this, DO saturation was still relatively high, and considered adequate to support aquatic fauna, including CFM.

[1] Salinity categories are based on the DWER classification system for freshwater rivers, 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).

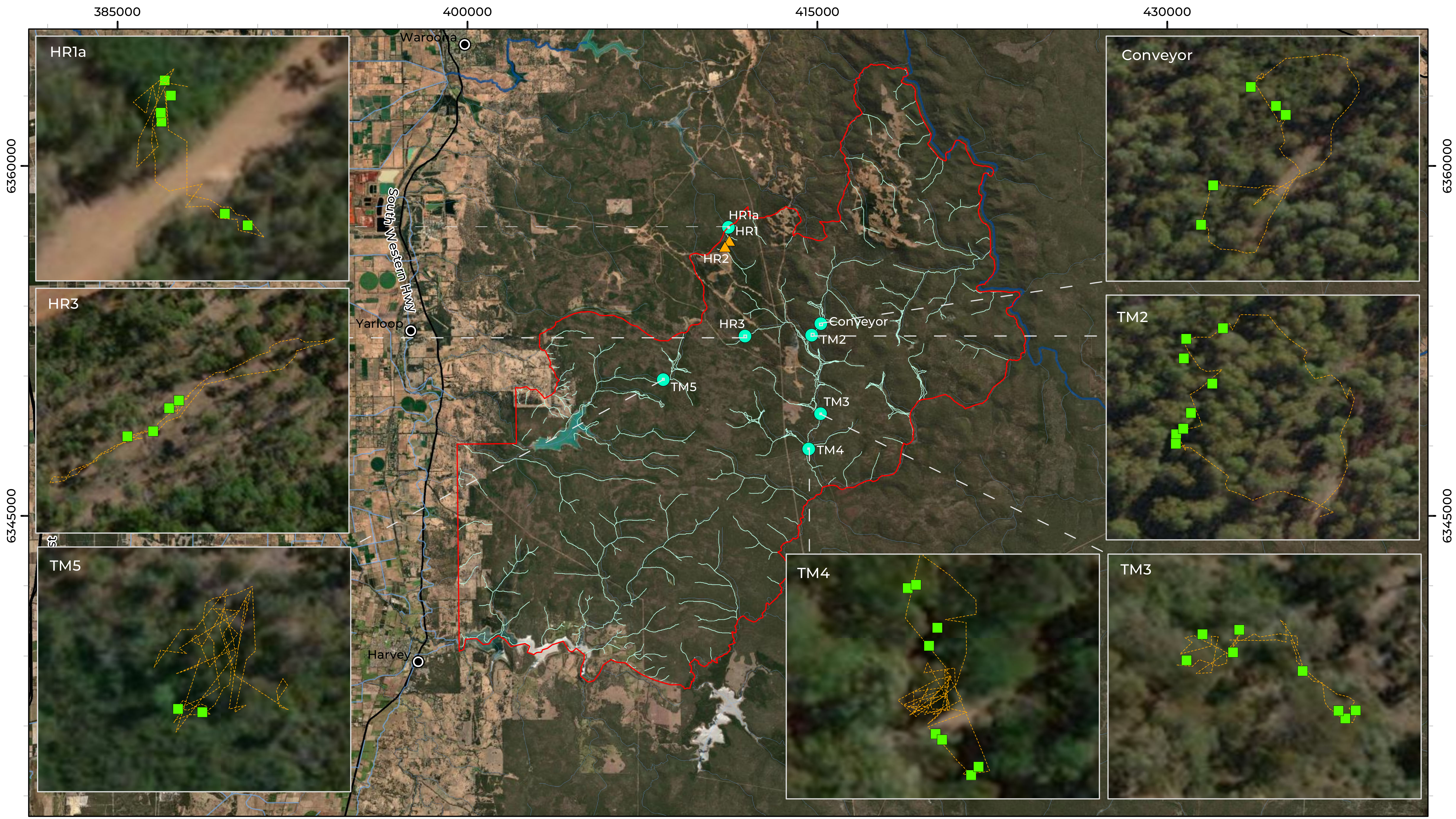
Table 4.1: Description of each sampling site

Type	Site	Description	Site Photographs	
Haul Road Crossing	HR1a	A ~50 m section of an un-named creek which flows into the Samon Brook Dam. Site located ~ 660 m downstream of the original crossing (HR1), which was not accessible due to overgrown vegetation. Dense riparian vegetation present. Max depth = 0.4 m.		
	HR3	A ~100 m section of an upper tributary flowing east to the Harvey River. Likely ephemeral. Substrate compacted. Max depth < 0.1 m.		

Type	Site	Description	Site Photographs	
Turbidity Monitoring	Conveyor	A ~100 m length of an unnamed creek, an upper tributary flowing south to the Harvey River. Rocky pool flowing into very narrow and heavily vegetated creek. Max depth = 0.4 m.		
	TM2	A ~100 m length of an unnamed creek, an upper tributary flowing south to the Harvey River. Healthy riparian vegetation with mostly open creek. Max depth = 0.5 m.		

Type	Site	Description	Site Photographs	
Turbidity Monitoring	TM3	A ~100 m length of an unnamed creek, an upper tributary flowing south to the Harvey River. Substantial flows and heavily vegetated. Max depth = 1.2 m.		
	TM4	A ~100 m length of an unnamed creek, an upper tributary flowing south to the Harvey River. Dense riparian vegetation. Max depth = 1.0 m.		

Type	Site	Description	Site Photographs	
Turbidity Monitoring	TM5	A ~50 m length of an Un-named Creek flowing into Logue Brook Dam Access impeded by dense vegetation. Max depth = 0.4 m.		



LEGEND

- Survey Area
- State Road
- Track

Surface Hydrology

- Minor
- Major
- Stream

- Sampling Site
- Not Accessed
- Quadrat

Biologic

Scale 1:150,000

0 2 4 6 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 19/03/2024

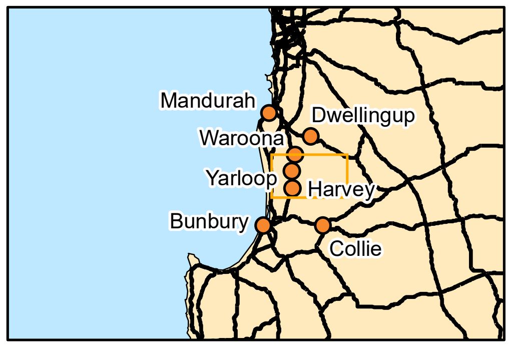


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Figure 4.1: Sampling sites and traverses

Table 4.2: In situ water quality results in comparison to ANZ (2018) DGVs

Shading indicates values are in excess of: ■ > the 95% DGV

Analyte	Units	ANZG (2018) DGV	HR1a	HR3	Conveyor	TM2	TM3	TM4	TM5
Temperature	°C		15.8	25.3	15.4	15.4	14.6	15.8	14.2
EC	µS/cm	300	178	145	242	198	139	130	114
Salinity	ppt		0.10	0.07	0.14	0.12	0.08	0.07	0.07
pH	pH units	6.5 - 8.0	6.62	7.38	6.04	6.40	6.74	6.55	6.70
DO	mg/L		10.4	7.9	7.9	7.8	10.2	11.9	10.7
DO	%	90%-na	106.7	98.7	80.9	82.1	103.0	122.8	108.2

na – no upper limit provided in ANZG (2018) for DO for upland rivers.

4.2.2 Lab Analyses

Dissolved metal concentrations at TM3 and TM4 were low and in many cases below the limit of reporting (LOR; Table 4.3). No concentrations exceeded the corresponding 95% toxicity DGV, and only one dissolved metal exceeded the 99% toxicity DGV. This was dAl, which marginally exceeded the 99% toxicity DGV (0.027 mg/L) at TM4 (0.030 mg/L).

Nutrient concentrations at TM3 and TM4 were also low. There were no exceedances of nitrogen eutrophication or toxicity DGVs, and at TM4, some concentrations were below the LOR (Table 4.3). Total P concentrations were below the LOR at both TM3 and TM4.

Alkalinity and hardness were low at TM3 and TM4, with alkalinity ranging from 4 mg/L (at TM4) to 7 mg/L (at TM3) (Table 4.3). Alkalinity measures the capacity of the water to resist sudden changes in pH, i.e., it is the buffering capacity of the water. Alkalinity of less than 20 mg/L is considered low, and the system would have limited ability to buffer against rapid changes in pH. This suggests that surface waters at both TM3 and TM4 have low buffering capacity.

Ionic composition was dominated by Na cations and Cl anions at both sites where mussels were present. Mg and S_SO_4 were sub-dominant. Ion concentrations were low, reflecting the low salinity of the surface waters at these sites.

Table 4.3: Concentrations of ions, nutrients and dissolved metals from TM3 and TM4, in comparison to ANZ (2018) DGVs

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

		ANZG (2018) DGV		Sites	
Analyte	Units	99%	95%	TM3	TM4
Turbidity	NTU		20	0.3	0.4
TSS	mg/L			3	<1
Hardness	mg/L			14	12
Alkalinity	mg/L			7	4
Ca	mg/L			1.1	0.9
Mg	mg/L			2.8	2.4
K	mg/L			1.2	1.0
Na	mg/L			27.6	25.3
HCO_3	mg/L			7	4
Cl	mg/L			41	39
S_SO_4	mg/L			4.89	4.38
CO_3	mg/L			<1	<1
S	mg/L			1.6	1.4
dAl	mg/L	0.027	0.055	0.024	0.030
dAs	mg/L	0.001	0.024	<0.0002	<0.0002
dB	mg/L	0.009	0.37	0.007	0.006
dBa	mg/L			0.0076	0.0066
dCd	mg/L	0.00006	0.0002	<0.00005	<0.00005
dCo	mg/L			0.0004	0.0002
dCr	mg/L	0.00001	0.001	<0.0002	<0.0002
dCu	mg/L	0.001	0.0014	0.00014	0.00012
dFe	mg/L	0.300*		0.098	0.084
dMn	mg/L	1.2	1.9	0.0034	0.0034
dMo	mg/L			<0.0001	<0.0001
dNi	mg/L	0.008	0.011	<0.0005	<0.0005
dSe	mg/L	0.005	0.011	<0.0002	<0.0002
dPb	mg/L	0.001	0.0034	<0.0001	<0.0001
dU	mg/L			<0.00005	<0.00005
dV	mg/L			0.0003	0.0002
dZn	mg/L	0.0024	0.008	<0.001	<0.001
N_NH_3	mg/L	0.32	0.90	0.04	0.06
N_NO_3	mg/L	1.0	2.4	0.01	<0.01
N_NOx	mg/L		0.20	0.01	<0.01
Total N	mg/L		0.45	0.05	0.06
Total P	mg/L		0.02	<0.005	<0.005

*low reliability trigger

4.3 Habitat Assessment

4.3.1 HR1a

Sediment composition of HR1a varied slightly across the site (between quadrats). Quadrats 1 (Q1) and Q2 were dominated by gravel, with some pebbles, sand and silt also present (Figure 4.2). Q1 was the only quadrat containing boulders. Quadrats Q3 and Q4 recorded an even composition of pebbles, gravel and sand, while Q3 was the only quadrat with clay. Cobbles were present in small amounts at Q1, Q2, Q5 and Q6. Quadrats Q5 to Q6, located upstream of the culvert, had sediments more evenly dispersed between pebbles, gravel, sand and silt.

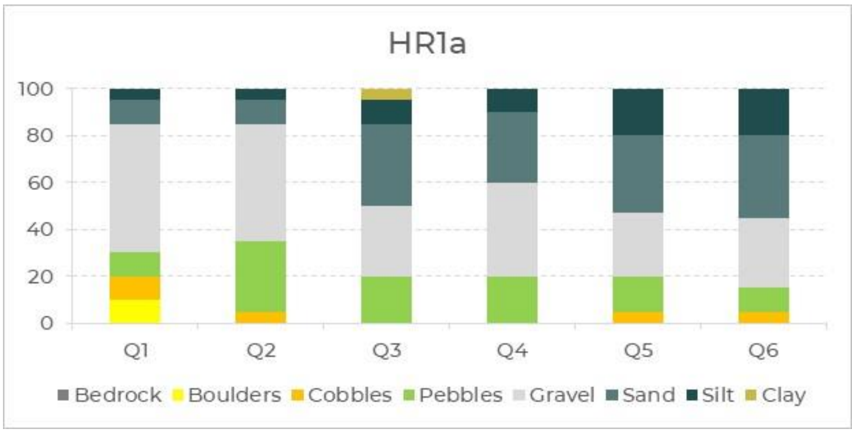


Figure 4.2: Sediment composition (%) within each quadrat at HR1a

4.3.2 HR3

The sediment composition at HR3 was homogeneous throughout the four quadrats, with a relatively even composition of pebbles, gravel, sand, silt and clay. No bedrock, boulders or cobbles were present at this site (Figure 4.3).

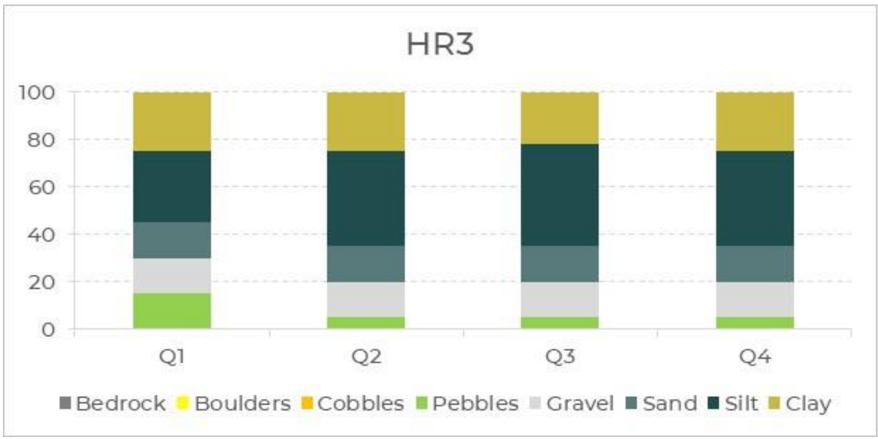


Figure 4.3: Sediment composition (%) within each quadrat at HR3

4.3.3 Conveyor

Sediment composition was variable across the Conveyor sampling site, with boulders dominating the substrate at Q1. Silt and clay were dominant at the remaining quadrats, while Q2 was the only quadrat recording pebbles. Gravel was also present in small amounts at Q1, Q4 and Q5 (Figure 4.4). No cobbles were present within any of the quadrats sampled.

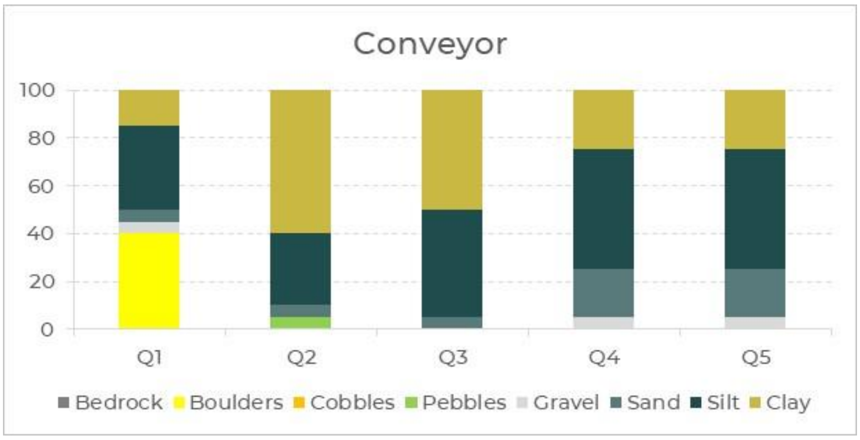


Figure 4.4: Sediment composition (%) within each quadrat at Conveyor

4.3.4 TM2

Sediment composition at TM2 was generally homogeneous with gravel, sand and silt present in all quadrats. Moderate amounts of clay were present at Q1 to Q6, while some cobbles were present at upstream quadrats Q7 and Q8 (Figure 4.5).

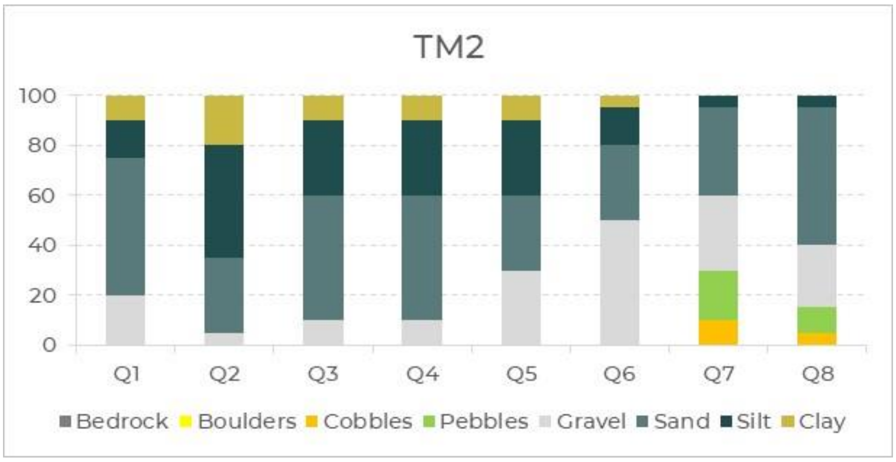


Figure 4.5: Sediment composition (%) within each quadrat at TM2

4.3.5 TM3

Sediment composition at TM3 was dominated by gravel and sand in most quadrats. Q2 had the largest diversity of substrates, with all substrate types present except clay. All other quadrats had varying compositions of pebbles, gravel sand and silt (Figure 4.6).

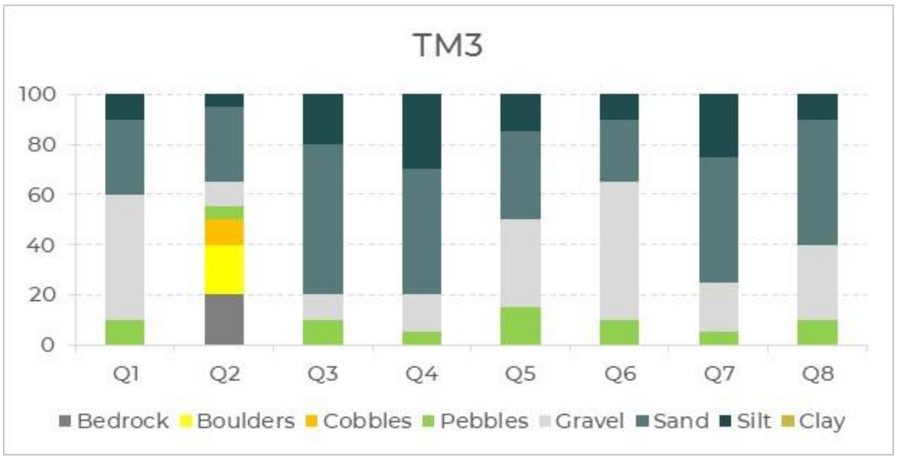


Figure 4.6: Sediment composition (%) within each quadrat at TM3

4.3.6 TM4

Sediment composition at TM4 was homogeneous at quadrats Q1 to Q4, upstream of the walk-bridge crossing, with quadrats in this area generally dominated by gravel, sand and silt. Downstream of the crossing, quadrats recorded higher proportions of larger substrate types such as boulders and cobbles. Gravel was still the dominant substrate at Q5 to Q8, however Q7 was dominated by cobbles (Figure 4.7).

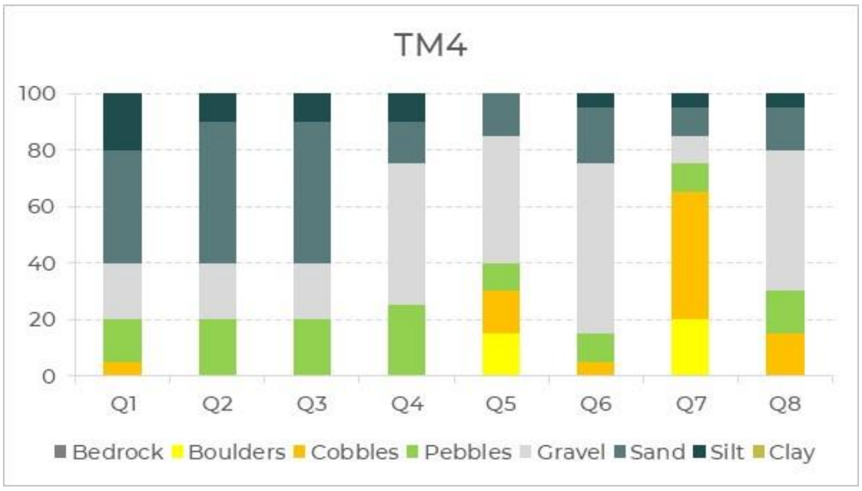


Figure 4.7: Sediment composition (%) within each quadrat at TM4

4.3.7 TM5

Only two quadrats were able to be sampled at TM5 due to the dense vegetation, and difficulties with access. Q1 was heavily dominated by sand with a small proportion of silt, while Q2 was heterogeneous, with boulders, cobbles, pebbles, gravel, sand and silt all present (Figure 4.8).

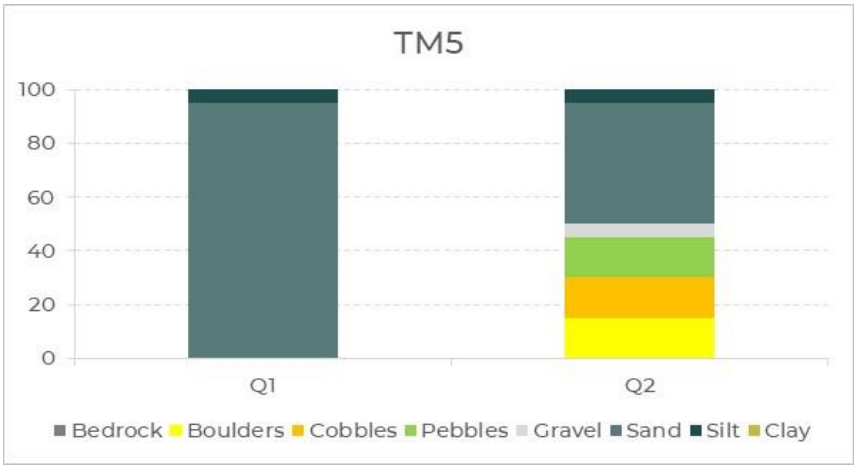


Figure 4.8: Sediment composition (%) within each quadrat at TM5

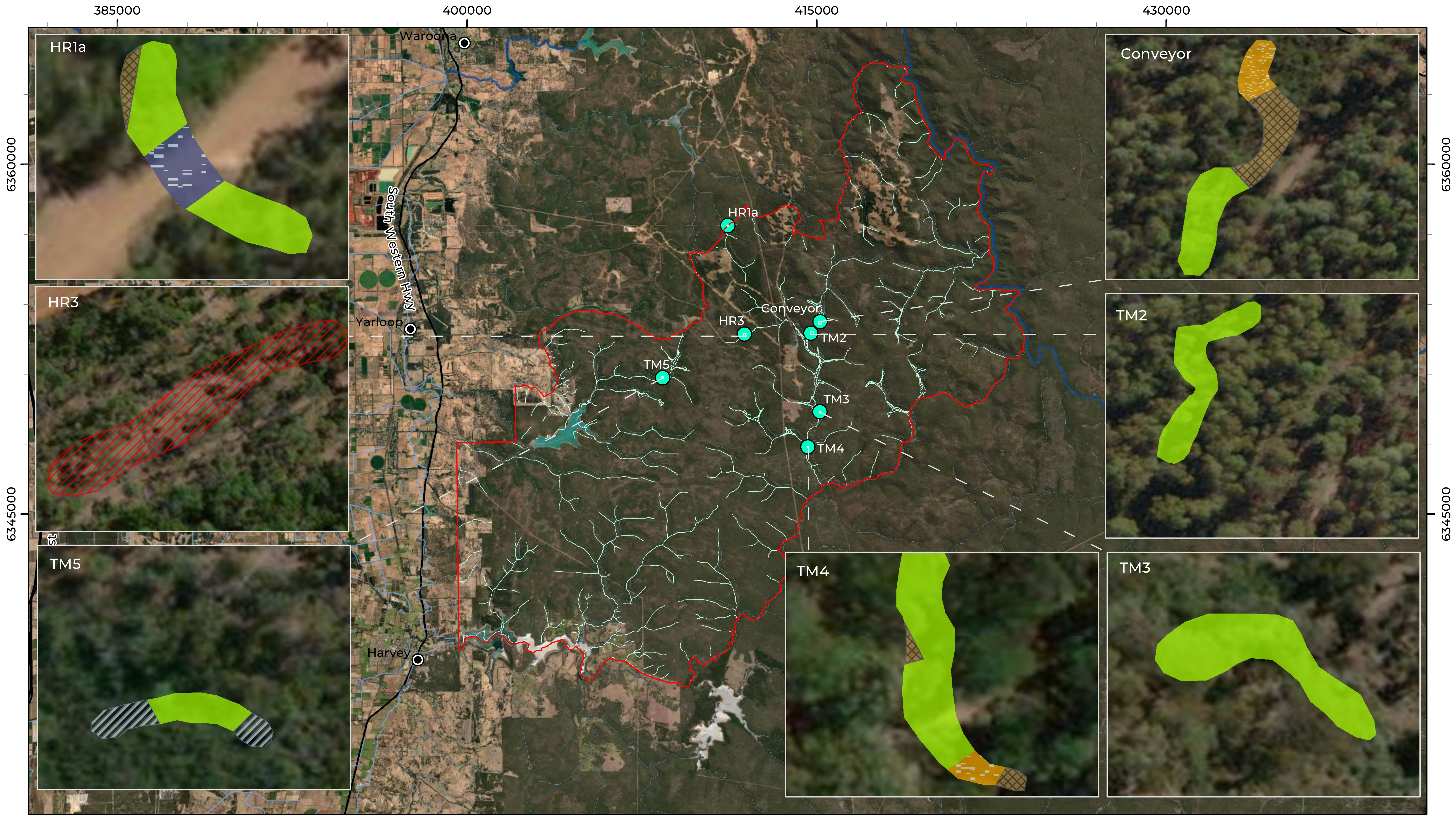
4.4 Suitable Habitat

The water quality and habitat assessments indicated that the in-stream habitat present in the Survey Area should not preclude absence/ presence of CFM on this basis alone (Figure 4.9). Suitable habitat for CFM occurred at all sites, with the exception of HR3, which is likely ephemeral. At HR1a, Conveyor and TM4 thick detrital layers were present in some areas, which were too soft for CFM. Sections of Conveyor and TM4 also contained unsuitable rocky substrates. A portion of TM5 was unable to be assessed due to the overgrown, dense vegetation (Figure 4.9). Water quality parameters were all within the known range of tolerance for CFM at all sites.

4.5 Carter's Freshwater Mussel

CMF were recorded from two sites within the Harvey River system (TM3 and TM4). Eight deceased CFM were recorded in quadrats at TM3, ranging in size from 37 mm to 55 mm in length (Table 4.4). All CFM at TM3 were therefore considered adults at the time of death. Additional opportunistic searches at this site failed to locate any live individuals. The cause of the deaths is unclear, as they did not appear to be related to water quality based on conditions at the time of sampling. However, this assessment was based on spot measurements, with no indication of whether there were any previous spikes in concentrations or contamination events which may have impacted CFM in this area. There were moderate flows at TM3 at the time of sampling, so it is also possible the deaths could have occurred upstream.

At TM4, one live CFM was recorded outside quadrats during opportunistic searches (Table 4.4). The recorded individual was an adult at 55 mm ML. This individual was found in sand built up inside a car tyre. No other CFM were recorded during the survey from any site.



LEGEND

Larego Survey Area
State Road
Surface Hydrology
Minor
Major
Stream

Habitat Assessment
Suitable Habitat
Not Suitable - culvert
Not Suitable - thick detrital layer
Not Suitable - rocky substrate
Not Suitable - ephemeral
Not Assessed

Biologic

Scale 1:150,000

0 2 4 6 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 19/03/2024

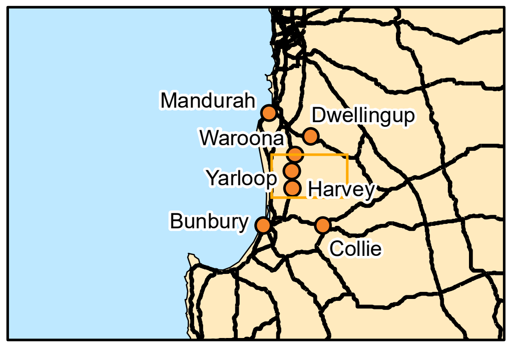


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Figure 4.9: Habitat assessment

Table 4.4: CFM recorded during the survey

Site name	Type	Latitude	Longitude	ML (mm)	MW (mm)	CFM observations
TM3	Quadrat (Q1)	-32.9906	116.0917	39	27	Deceased
TM3	Quadrat (Q1)	-32.9906	116.0917	44	29	Deceased
TM3	Quadrat (Q1)	-32.9906	116.0917	47	29	Deceased
TM3	Quadrat (Q1)	-32.9906	116.0917	45	30	Deceased
TM3	Quadrat (Q2)	-32.9906	116.0917	44	31	Deceased
TM3	Quadrat(Q2)	-32.9906	116.0917	47	29	Deceased
TM3	Quadrat (Q2)	-32.9906	116.0917	45	28	Deceased
TM3	Quadrat (Q6)	-32.9906	116.0917	37	23	Deceased
TM4	Opportunistic	-33.0041	116.0861	55	37	Alive

4.6 Other Aquatic Fauna

While methods for sampling other aquatic species such as fish and crayfish were not used in the targeted CFM survey, other aquatic fauna were observed at the time of sampling. Schools of the native freshwater fish, western minnow (*Galaxias occidentalis*), were observed throughout the creek at TM2, TM3, TM4 and TM5. At Conveyor, a single large (> 300 mm standard length), introduced rainbow trout (*Oncorhynchus mykiss*) was observed in the rocky pool upstream of the quadrats. Crayfish burrows were observed along the banks at most sites. One crayfish species was confirmed (at Conveyor and TM3). This was the native koonac (*Cherax preisii,* Plate 4.1).

Plate 4.1: Native koonac (*Cherax preisii*) at Conveyor

4.7 Reassessment of Likelihood of Occurrence

The likelihood of occurrence of CFM was reassessed following the targeted survey. The likelihood of occurrence at Haul Road site HR1a was reduced from 'Likely' to 'Possible', while HR3 was reduced from 'Likely' to 'Highly Unlikely' as the creek was likely ephemeral in this area, and the highly compacted substrate would make it difficult for CFM to burrow. Turbidity Monitoring sites TM2 and TM5 were reduced from 'Likely' to 'Possible' as no CFM were found but suitable habitat was present. In particular, the latter site was difficult to sample effectively due to the overgrown vegetation. The likelihood of occurrence at Conveyor was reassessed as 'Unlikely' due to limited availability of suitable habitat (Table 4.5).

Table 4.5: Reassessment of likelihood of occurrence of Carter's freshwater mussel based on survey results

Site	Within current known distribution	Suitable water quality within Survey Area	Core/critical habitat within Survey Area	Recorded within Survey Area	Likelihood of Occurrence
HR1	Yes	Not Sampled	Not Sampled	Not Sampled	Possible[d]
HR1a	Yes	Yes	Yes[b]	No	Possible
HR2	Yes	Not Sampled	Not Sampled	Not Sampled	Possible[d]
HR3	Yes	Yes	No[c]	No	Highly Unlikely
Conveyor	Yes	Yes	Limited[b]	No	Unlikely
TM2	Yes	Yes	Yes[b]	No	Possible
TM3	Yes	Yes	Yes[b]	Yes	Confirmed[a]
TM4	Yes	Yes	Yes[b]	Yes	Confirmed
TM5	Yes	Yes	Yes[b]	No	Possible

a.) confirmed, but no individuals were alive

b.) assessment based on current conditions at the time of the targeted survey

c.) pool considered likely to be ephemeral

d.). site not able to be accessed and therefore potential for occurrence remains as 'Possible' given suitable water quality was considered likely based on other sites. It was not possible to extrapolate substrate composition from other sampled sites.

5 Discussion

5.1 Distribution and Abundance of Carter's Freshwater Mussel

CFM have specific habitat and water quality requirements, which limit their distribution. CFM are acutely intolerant of salinity and generally not found in ephemeral habitats (Klunzinger, 2012). Studies of microhabitat preference found CFM abundance is most strongly associated with fine substrate grain size, proximity to the river bank, and presence and height of debris above the surface of the creek bed (Ma, 2018). The ability to burrow into substrates and protection from high flows are also important habitat requirements for this species. Burrowing can protect CFM from water emersion for a short time, as long as riparian vegetation is available to provide shade (Lymbery *et al.*, 2020).

The targeted survey confirmed the presence of CFM in the Survey Area at two of seven sites, although all CFM recorded from TM3 were deceased at the time of sampling. The cause of deaths is unknown and may be related to a previous contamination event or spike in concentration of water quality analytes outside the threshold of CFM. It is also possible that given the moderate flows present at TM3, it is also possible the deaths occurred upstream, with individual shells transported downstream to TM3 with the flow. Spot measurements of water quality at the time of sampling indicated surface waters at TM3 were suitable for CFM at that time.

One live CFM was recorded at TM4. Based on age-at-length estimates in other systems, this individual was estimated to be between 7 to 10 years old (Klunzinger *et al.*, 2014). No juveniles were encountered during the survey. Although sieving of sediments was undertaken at all sites to target juveniles, the high density of vegetation, roots and large woody debris present across the benthic surface made this difficult at most sites. Juveniles are known to be more difficult to locate, especially without sediment sieving, because hand searching tends to bias towards larger mussels (Klunzinger, 2012). CFM density (individuals/m^2) was not calculated due to low abundance and fact that the one live individual was recorded outside the quadrats.

Given the presence of CFM at both TM3 and TM4, the absence of CFM on the Tributary of Harvey River upstream at TM2 was perhaps unexpected, particularly given the favourable sediment composition and water quality present. However, no freshwater fish were observed at TM2, possibly due to some physical barrier between TM3 and TM2. The lack of fish would explain the absence of CFM, as larval glochidia are dependent on freshwater fishes for dispersal into upstream tributaries (Ma, 2018). At Conveyor, further upstream on a Tributary of the Harvey River, the absence of CFM was likely explained by the fact that suitable habitat was less abundant, water levels were low, and there were no fish present.

Suitable habitat and favourable in situ water quality was available at TM5, as well as the presence of abundant freshwater fish (*Galaxias occidentalis).* Despite this, no CFM were recorded from this site. This could be due to survey effort, as dense vegetation impeded thorough assessment, with the creek being impassable in parts. The Healthy Rivers database search (DWER, 2023b) indicated that a site sampled in close proximity to TM5, also did not record CFM. With CFM recorded <10 km to the west, near Yarloop, and no CFM recorded downstream at Brockman Dam, freshwater fish populations may have been separated from CFM, which would limit reproductive dispersal.

The Haul Road site HR3 also recorded no mussels. This site was relatively small, and the likelihood of occurrence was reassessed as 'Highly Unlikely' to support CFM, due to the site being considered to be ephemeral. The low water level at the time of sampling and compacted sediment would make it difficult for mussels to burrow when water levels recede during the summer months. Haul Road sites HR1 and HR2 were unable to be surveyed due to issues with access, and therefore the likelihood of CFM at these sites remains 'Possible'. Based on water quality readings at other sites, including HR3, it is assumed that HR1 and HR2 would have suitable water quality to support CFM. However, it is not possible to draw conclusions regarding the permanence of water or the sediment composition at HR1 and HR2 without accessing the sites directly.

The CFM record at TM4 represents the only known live record of this significant species in the Survey Area, particularly as nearby sites have failed to record CFM previously (DWER, 2023b). Confirmed records are important for a species experiencing population decline and reduction in available habitat.

5.2 Conclusion

This survey represents the first targeted survey for CFM in the Larego region. A total of nine mussels (eight dead, one alive) were recorded from the Survey Area, in close proximity to the Willowdale mine. Water quality and habitat data could not provide any insight into the cause of deaths at TM3, however, this should be investigated.

The recent redescription of CFM has reduced its current range. As the species is currently listed as Vulnerable (BC Act, EPBC Act, IUCN) and known to be experiencing population decline, the reduction in range due to the recent taxonomic change has implications for the conservation status of CFM. The importance of existing populations is likely to become more significant following any reassessment of the conservation significance of this species.

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Appendix A: Conservation Codes

International Union for Conservation of Nature

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

Environment Protection and Biodiversity Conservation Act 1999

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

Biodiversity Conservation Act 2016

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

Department of Biodiversity Conservation and Attraction Priority Codes

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

Appendix B: Default ANZG (2018) Water Quality Guidelines

Default trigger values for some physical and chemical stressors for South West 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]	0.02	0.010	0.45	0.20	0.06	90-na	6.5-8.0
Lowland River[e]	0.065	0.040	1.20	0.15	0.08	80-120	6.5-8.0
Lakes & Reservoirs	0.01	0.005	0.35	0.01	0.01	90-no data	6.5-8.0
Wetlands[3]	0.06	0.030	1.5	0.10	0.04	90-120	7.0[e]-8.5[e]

na = not applicable;

e = in highly coloured wetlands (gilven >52 g440m-1) pH typically ranges 4.5-6.5;

f = all values derived during base river flow conditions not storm events;

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

Default trigger values for salinity and turbidity for the protection of aquatic ecosystems, applicable to the South West of Australia

Salinity	(µs/cm)	Comments
Aquatic Ecosystem		
Upland & lowland rivers	120- 300	Conductivity in upland streams will vary depending on catchment geology. Values at the lower end of the range are typically found in upland rivers, with higher values found in lowland rivers. Lower conductivity values are often observed following seasonal rainfall.
Lakes, reservoirs & wetlands	300-1,500	Values at the lower end of the range are observed during seasonal rainfall events. Values even higher than 1,500 μScm^{-1} are often found in saltwater lakes and marshes. Wetlands typically have conductivity values in the range of 500-1,500 μScm^{-1} over winter. Higher values (>3,000 μScm^{-1}) are often measured in wetlands in summer due to evaporative water loss.
Turbidity	**(NTU)**	
Aquatic Ecosystem		
Upland & lowland rivers	10-20	Turbidity is highly variable and dependent on seasonal rainfall runoff. These values represent base river flow in lowland rivers.
Lakes, reservoirs & wetlands	10-100	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.