Great Eastern Highway Bypass Interchanges Project:

Targeted Carter's Freshwater Mussel Survey

Biologic Environmental Survey

Report to Main Roads Western Australia

November 2022

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3				

EXECUTIVE SUMMARY

Biologic Environmental Survey (Biologic) was commissioned by Main Roads Western Australia (Main Roads) to undertake a targeted survey of the conservation significant Carter's freshwater mussel, *Westralunio carteri* for the Great Eastern Highway Bypass (GEHB) Interchanges Project. The survey was required to inform the Native Vegetation Clearing Permit (NVCP) application for the Project (CPS 9448/1). Carter's freshwater mussel is currently listed as Vulnerable on State (WA *Biodiversity Conservation Act 2016*), Federal (*EPBC Act 1999*), and international conservation lists (IUCN Red List of Threatened Fauna).

The Survey Area comprised an approximate 500 m length of the Helena River, including upstream and downstream of Roe Highway, as well as two adjacent wetlands (Wetland West, located west of Roe Highway, and Wetland East, located east of Roe Highway and where Carter's freshwater mussel have been recorded previously). The Survey Area was searched extensively following best practice methods to increase the likelihood of recording individuals, if present. Methods included mussel rakes, hand searches, and quantitative sampling within quadrats in order to calculate population density. Substrate assessment and water quality measurements were also undertaken to assess habitat suitability.

Carter's freshwater mussels were not detected in the Helena River, despite extensive survey effort. Two live Carter's freshwater mussels were recorded from Wetland West and 46 individuals were recorded at Wetland East. There are several components of habitat which make a particular location suitable for Carter's freshwater mussel, including water quality (within tolerable limits), substrate composition (sufficiently soft to allow burrowing, but not too soft or too compact), and the presence of permanent water. Although the Helena River did record appropriate water quality at the time of the targeted survey, as well as suitable substrate across parts of the Survey Area reach, the lack of permanent water means that Carter's freshwater mussel cannot occur there, and therefore, overall, the habitat is not suitable. Evidence for the fact that the reach is not permanent include the growth of terrestrial grasses throughout the creek bed, as well as the lack of sedges (such as *Machaerina articulata*) which indicate permanent water. Carter's freshwater mussel are known to require permanent surface water to persist. The Helena River is an ephemeral system, but it does support permanent pools upstream and downstream of the Survey Area. Within the section of river adjacent to the NVCP area, however, the lack of permanent water means that their likelihood of occurrence is Unlikely. At Wetland West and Wetland East, occurrence is Confirmed for Carter's freshwater mussels.

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1. INTRODUCTION

1.1 Background and objectives

The Roe Highway and Great Eastern Highway Bypass (GEHB) are strategic road corridors in Perth's north-east (Figure 1.1). These highways and their intersections experience high congestion, leading to the Federal and State Governments allocating funding for the planning, development, and construction of a new grade-separate interchange on the GEHB. As part of the GEHB Interchanges Project (hereafter referred to as the Project), Main Roads Western Australia (Main Roads) submitted a Native Vegetation Clearing Permit (NVCP) application for GEHB (CPS 9448/1) in October 2021. The application was informed by a biological assessment that included a survey for the conservation significant Carter's freshwater mussel, *Westralunio carteri* (Biota, 2021). 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).

While a previous biological survey did not find any evidence of Carter's freshwater mussel, a wetland adjacent to the northern portion of the clearing application area had not been included in that survey at the time. During assessment of the NVCP application, the Department of Water and Environmental Regulation (DWER) requested a further survey for Carter's freshwater mussel which aligned with the recommended methodology for monitoring freshwater mussels and included this additional wetland. As DWER were aware of records of Carter's freshwater mussel from this location, the wetland required targeted survey.

Main Roads commissioned Biologic Environmental Survey (Biologic) to conduct the additional survey work requested by DWER. This involved a targeted survey for Carter's freshwater mussel across aquatic habitats adjacent to the NVCP application area, which was undertaken in August 2022. The Survey Area comprised an approximate 500 m stretch of the Helena River, a wetland located east of Roe Highway where previous records of Carter's freshwater mussel exist (Wetland East), and a wetland located west of Roe Highway and Military Road (Wetland West; Figure 1.2). The main objective was to assess and delineate the extent of suitable habitat for the species, identify the presence of Carter's freshwater mussel within the Survey Area, and assess the extent of populations, if present.

404000
406000
408000
410000
6470000
6468000

James St
East St
Great Eastern Hwy
Hazelmere
Great Eastern Hwy
Greenmount
Great Eastern Hwy Bypa
Roe Hwy
Helena River

Legend

- NVCP Area
- Development Envelope
- State Road

Surface Hydrology

- Minor
- Major

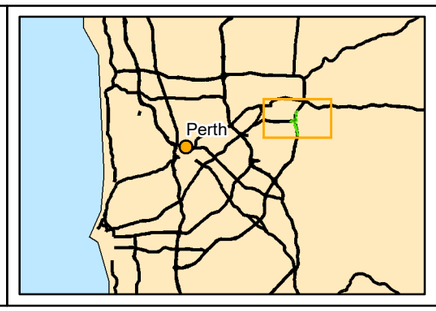
N

biologic Environmental Survey

Scale: 1:22,000

0 0.5 1 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 23/11/2022



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Great Eastern Highway Bypass Interchanges Project: Targeted Carter's Freshwater Mussel Survey

Figure 1.1: NVCP application area

406800 407000 407200 407400

6469600

6469400

Helena River

Roe Hwy

Perth

Bunbury

Legend

- Survey Area
- NVCP Area
- Development Envelope
- State Road

Surface Hydrology

- Minor
- Major

IBRA Region

- Swan Coastal Plain

IBRA Subregion

- Dandaragan Plateau
- Perth

N

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Scale: 1:2,000

0 30 60 90 Meters

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 23/11/2022

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Figure 1.2: Survey Area and regional location

1.2 Carter's freshwater mussel

Carter's freshwater mussel (*Westralunio carteri*) is an Australian hyriid mussel endemic to south-west Western Australia. Until recently, it was considered the only species of Hyriidae which inhabits 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 within populations of this species (Klunzinger & Kirkendale, 2022). As a result, *Westralunio carteri* was redescribed from western coastal drainages, while *Westralunio inbisi* sp. nov. has now been described, representing two subspecies (*Westralunio inbisi inbisi* from southern coastal drainages, and *Westralunio inbisi meridiemus* from the southwestern corner) (Klunzinger & Kirkendale, 2022).

Carter's freshwater mussel is currently listed as Vulnerable on State, Federal and International conservation lists (WA *Biodiversity Conservation Act 2016*, *Environment Protection and Biodiversity Conservation Act 1999*, and IUCN Red List of Threatened Species) (see Appendix A for a description of conservation categories). However, this is likely to change in light of the recent taxonomic changes and subsequent reduction in range of *Westralunio carteri*.

Historically, the distribution of Carter's freshwater mussel 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 reportedly reduced by 49%, with its distribution lying between Gingin Brook in the north and the Kent River in the south (Klunzinger *et al.*, 2015), and two outlying populations existing in the Goodga and Waychincup Rivers. The redescription of Carter's freshwater mussel has since reduced this range, with its current distribution between Gingin and to the north and west of the Blackwood River, within 150 km of the coast (Klunzinger & Kirkendale, 2022). The reduction in range and continuing population decline led to its current conservation listing as Vulnerable (Klunzinger & Walker, 2014), though it is expected this conservation listing will require reassessment.

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

Carter's freshwater mussel are typically dioecious, though hermaphrodites have occasionally been recorded (Klunzinger *et al.*, 2014). They have an obligate parasitic larval stage (glochidia), which attach to host fish and are transported and deposited into suitable sediment as post-parasitic juvenile mussels. As such, mussels are only recorded where 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). Carter's freshwater mussels require sediment that is firm but penetrable (i.e., sand). They are generally absent from sediments that are too soft or too compact (i.e., clay and bedrock).

The greatest threats to Carter's freshwater mussel come from salinisation and drying of water systems. Carter's freshwater mussels 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). Carter's freshwater mussel also cannot survive exposure to direct

sunlight or heat, and do not aestivate, so cannot persist in non-perennial water systems (Klunzinger, 2012). 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 host fish species (Klunzinger, 2012). High turbidity and suspended solids can also negatively impact the filtration ability of freshwater mussels (Klunzinger, 2012).

2 METHODS

2.1 Assessment of Occurrence

The likelihood of Carter's freshwater mussel occurrence within the Survey Area was assessed using a decision matrix (Table 2.1). The decision matrix considers habitat suitability and proximity of previous records. This information was used to assign a likelihood of occurrence.

Table 2.1: Carter's freshwater mussel likelihood of occurrence decision matrix.

		Habitat categories (within Survey Area)			
		Core/critical habitat present	**Feeding /Dispersal habitat present**	**Marginal/ intermittent habitat present**	**No suitable habitat present**
Range/occurrence categories	**Recorded in Survey Area**	Confirmed	Confirmed	Confirmed	Confirmed
	Recorded within < 2 km	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
	Species considered locally/regionally extinct	Unlikely	Unlikely	Highly Unlikely	Highly Unlikely

2.2 Legislation and guidance

There is currently (November 2022) no technical guidance in Australia applicable to targeted surveys for freshwater mussels, but surveys undertaken by Biologic follow best practice and employ sampling design, methods, and general approaches consistent with the following:

- Recommended Methodology for Monitoring Freshwater Mussels (provided to Main Roads by DWER);
- New Zealand Regional Guidelines for Adult Freshwater Mussel Monitoring (Catlin *et al.*, 2017);
- Australian and New Zealand Guidelines for Fresh and Marine Water (ANZG, 2018);
- Environmental Factor Guideline, Inland Waters (EPA, 2018);
- Technical Guidance, Sampling of SRE Invertebrate Fauna (EPA, 2016a);

- Technical Guidance, Terrestrial Fauna Surveys (EPA, 2016b); and
- Similar mussel surveys, including (Klunzinger *et al.*, 2011), Klunzinger *et al.* (2012a) and WRM (2020), as well as previous Biologic surveys for Main Roads (Biologic, 2020, 2021).

2.3 Field survey

2.3.1 Survey team

The targeted survey was conducted by Principal Aquatic Ecologist Jess Delaney, Senior Aquatic Ecologist Kim Nguyen, and Aquatic Ecologist Siobhan Paget. Jess and Kim have a combined experience of over 30 years undertaking aquatic ecosystem surveys throughout Western Australia, including targeted fauna surveys in the Perth Metropolitan Area and south-west region. Fauna sampling was conducted under a DBCA Authorisation to Take or Disturb Threatened Species (TFA 2223-0045) (Appendix D), and a DPIRD Instrument of Exemption to the *Fish Resources Management Act 1994 Section 7 (2)* (EXEM 3386), both issued to Jessica Delaney.

2.3.2 Survey timing and weather

An initial visit to the Survey Area on the 10th of August 2022 found the river in flood, with turbid, fast-flowing water. Conditions were deemed unsuitable for sampling at this time. Therefore, the field survey was rescheduled to the 31st of August 2022 to allow sufficient time following heavy winter rainfall and flooding throughout the area. Maximum ambient temperature at the time of survey was 21.0 °C, which was 1.9 °C warmer than the long-term average for August (BoM, 2022). There was no rainfall on the day or immediately preceding the survey; however, 7 mm was recorded the week prior (BoM, 2022). Water levels had dropped considerably by the time of the targeted survey.

2.3.3 Water quality

In situ water quality was measured using a portable YSI Pro Plus multimeter. Parameters recorded included pH, redox potential (redox; mV), electrical conductivity (EC; µS/cm), dissolved oxygen (DO; mg/L and % saturation), and water temperature (ºC). Spot measurements were taken from five locations within the Helena River, four locations within Wetland West, and three locations in Wetland East. Water quality measurements were undertaken in quadrats where mussels were recorded, as well as in other areas to provide adequate coverage of the Survey Area and water quality characteristics throughout.

2.3.4 Habitat assessment

As Carter's freshwater mussel are often found partially to fully submerged in fine sediment, a visual assessment of benthic sediment characteristics was undertaken within the Survey Area. Percentage cover by bedrock, boulders, cobbles, pebbles, gravel, sand, silt, and clay was recorded. Sediment data assisted in explaining distribution patterns and the presence/ absence of mussels. Observations of the presence of vegetation in-stream (submerged and emergent macrophytes), water depth, and overhanging riparian vegetation were also made.

2.3.5 Mussel sampling

Carter's freshwater mussels were targeted using several methods to increase the likelihood of recording individuals, if present, with factors such as access, water depth, and salinity taken into account. Sampling methods included hand searching, mussel raking and dip nets, targeting areas of optimum habitat (Plate 2.1). Sampling was undertaken throughout the approximate 500 m stretch of the Helena River (including ~215 m upstream and ~200 m downstream of the NVCP application area), up to wadable depth, checking benthic sediments, especially in and around large woody debris, for evidence of mussels. The areas beneath the Roe Highway and Military Road were included in the Survey and searched extensively. Within each wetland, the perimeter was searched in all areas that were safely accessible. The south-western edge of Wetland West was unable to be successfully searched due to the steep banks and high water depth in this area. GPS track logs were recorded during the survey to attest to sampling effort expended (see Figure 3.2 in section 3.2).

Plate 2.1: Using a mussel rake to search within a quadrat at Wetland East (left), and hand searching for mussels in the Helena River (right).

A minimum of ten 1 m^2 quadrats were deployed per site (Helena River, Wetland West, and Wetland East) on benthic sediments. Where present, mussel density (individuals/m^2) was determined using established methods to quantify density and population structure of Carter's freshwater mussel in south-west Western Australian rivers (Klunzinger *et al.*, 2012a; Klunzinger *et al.*, 2012b). Habitat assessments were undertaken within each quadrat.

All mussels recorded were measured for maximum length (ML) and maximum width (MW) using vernier callipers (Plate 2.2). While growth rates can be highly variable across populations of different river systems, field observations reported by others indicate sexual maturity at 27 mm ML (Klunzinger *et al.*, 2014). Therefore, individuals greater than 27 mm ML were considered to be adults in the current study. All mussels were returned alive at the site of capture. Empty shells (i.e., dead mussels) were recorded, but not included in abundance counts or density calculations.

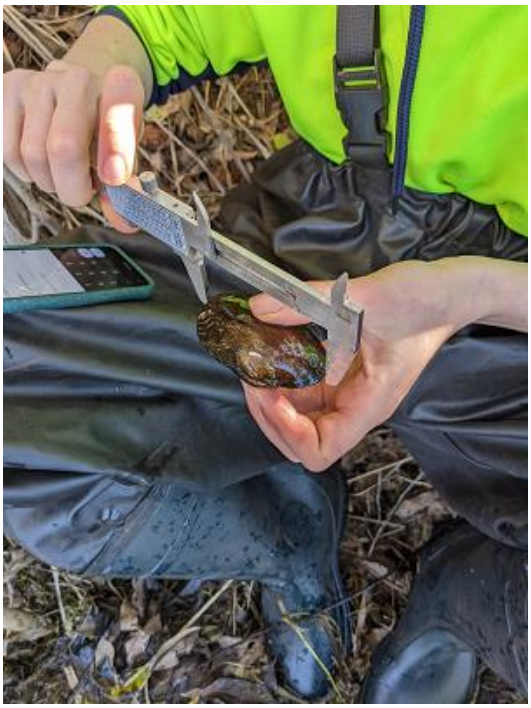


Plate 2.2: Measuring Carter's freshwater mussel (ML in mm).

2.4 Data analysis

2.4.1 Water quality

In situ water quality data were compared against the ANZG (2018) default guideline values (DGVs) for the protection of aquatic ecosystems in the south-west of Western Australia (see Appendix B for default values). 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 lowland rivers and/or wetlands within the south-west (ANZG, 2018). Water quality data provides information on the suitability of habitats within the Survey Area to support Carter's freshwater mussel.

2.5 Assumptions and limitations

The survey was undertaken by qualified personnel with considerable experience in targeted aquatic fauna surveys. Potential limitations and constraints are summarised in Table 2.2.

Table 2.2: Summary of assumptions and limitations in relation to the current survey.

Potential limitation or constraint	Constraint (Yes / No)	Applicability to this survey
Experience of personnel	No	The Principal and Senior Aquatic Ecologists who undertook the survey have a combined experience of over 30 years undertaking targeted invertebrate fauna surveys, with direct and relevant experience leading surveys in the southwest region. The team leader has over 20 years' experience in aquatic invertebrate surveys, including targeted surveys for freshwater mussels.
Scope (faunal groups sampled and whether any constraints affect this)	No	The scope was to undertake a field survey to determine the presence of Carter's freshwater mussel within the vicinity of proposed development envelope for the GEHB Interchanges Project. The survey was undertaken over a short period, limiting the survey effort to a single search event. A third zoologist provided field assistance to ensure adequate coverage of the Survey Area within the short time frame. Therefore, coverage of available habitat was not considered a limiting factor.
Proportion of aquatic fauna identified	No	No constraint.
Sources of information (recent or historic) and availability of contextual information	No	All relevant databases and literature were previously consulted by Main Roads. Additional desktop work was not part of the current scope.
Proportion of the task achieved	No	The upstream section of the Helena River was not surveyed as originally proposed due to time restrictions; however, this was not considered a constraint. This is because the inclusion of this reference site was only necessary in the event that Carter's freshwater mussel was not recorded within the Survey Area, to confirm the lack of records was due to absence of the target fauna from the area, and not due to lack of survey effort. The south-western edge of Wetland West was unable to be successfully searched due to the steep banks and high water depth in this area. This was considered a minor constraint, as the majority of the task was still able to be achieved.

Potential limitation or constraint	Constraint (Yes / No)	Applicability to this survey
Disturbances (e.g. fire or flood)	No	There were no recent fires which posed a constraint to sampling effort. The survey was originally scheduled for early to mid-August, but the Helena River was in flood at that time, with high flows impeding access for sampling. Therefore, the survey was rescheduled to a later date, when conditions were more conducive to sampling. When the targeted survey was undertaken in late August, the river and wetlands had receded sufficiently to allow access to the majority of the Survey Area, though some sections were still quite high from recent flooding. Despite this, recent fires and floods were not considered to pose a limitation to the survey given Carter's freshwater mussel were recorded. It may, however, have limited the ability to accurately assess total abundance within the Survey Area.
Intensity of survey	No	Search effort for Carter's freshwater mussel was considered sufficient throughout the Survey Area, particularly as an epifaunal species that sits on or just beneath the benthic surface. Survey timing was not considered a limitation, as Carter's freshwater mussel are not highly mobile and require permanent water to persist. This is unlike other freshwater fauna in the south-west, such as fish that are more likely to be detected during seasonal inundation of pools, or during very specific breeding periods.
Completeness of survey	No	The survey was adequately completed to meet the requirements of a targeted aquatic fauna survey.
Resources (e.g., degree of expertise available)	No	All resources required to complete the survey were available.
Remoteness or access issues	No	There were no access restrictions at GEHB. Although a gate key could not be provided to access Wetland West at the time of the survey, the wetland was safely accessed by crossing underneath the bridge at Military Road on foot.

3 RESULTS

3.1 Likelihood of Occurrence

Results from the desktop assessment by Biota (2021), and findings by DWER (via Main Roads, pers. comms.), were used to assess the likelihood of occurrence of Carter's freshwater mussel in the Survey Area. Nearby previous records from surveys relevant to the Survey Area (Klunzinger *et al.*, 2011; WRM, 2010, 2011) and recent database results (DBCA, 2020; DWER, 2022) have been provided in Figure 3.1 for context. Nearby survey sites where mussels were not recorded (Biologic, 2020; DWER, 2022) have also been provided to show indicative survey effort within the Helena system. Likelihood of occurrence was considered Highly Likely at all sites based on distance to the nearest historical record, age of record, and potential for suitable habitat (Table 3.1). Although confirmed records exist for Wetland East, a more current assessment was required to confirm that Carter's freshwater mussels were still present, given the last known records were nine years old.

Table 3.1: Likelihood of occurrence for Carter's freshwater mussel at each site.

Site	Within Current Known Distribution	Distance to Nearest Record - Year	Potential Habitat Within Survey Area	Likelihood of Occurrence
Helena River	Yes	~60 m – 2013 (Wetland East)	Yes	Highly Likely
Wetland West	Yes	~275 m – 2013 (Wetland East)	Yes	Highly Likely
Wetland East	Yes	Within Site – 2013	Yes	Highly Likely

3.2 Survey

3.2.1 Survey effort

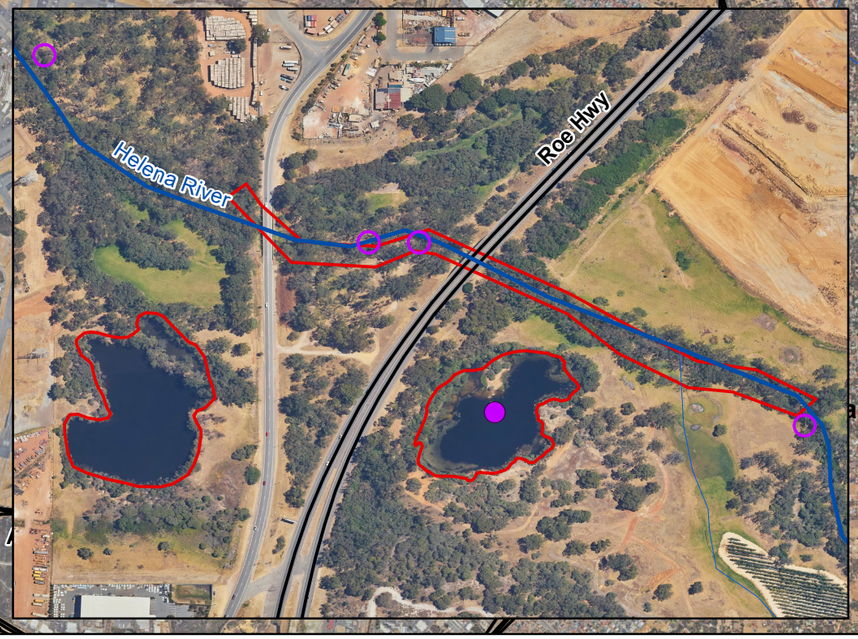
The Survey Area included the banks of Wetland East and Wetland West, and throughout the approximate 500 m stretch of the Helena River, up to wadeable depth. Track logs from the survey show the areas assessed and sampling effort expended (Figure 3.2). A total of 13 quadrats were undertaken within the Helena River, ten within Wetland East, and 13 within Wetland West. Opportunistic searches (hand searching and mussel raking) were undertaken across all areas which were able to be safely accessed outside of the quadrats, across the Survey Area.

At the time of survey, recent flooding within the river had receded, though the water level was still high in some sections. At Wetland West, the south-west margins could not be surveyed due to the steep banks which precluded safe access. Where possible, steeper sections were searched from dry land using mussel rakes.

405000 410000 415000 420000

6470000 6465000

Bennett Brook
Swan River
Swan Rd
James St
James
Guildford
St
Victoria St
Hazelmere
Greenmount
Great Eastern Hwy
Great Eastern Hwy Bypa
Roe Hwy
Jane Brook
Parkerville
Glen Forrest
Bourkes Gully
Darlington
Helena River
Piesse Gully
Gooseberry Hill
Vale



Legend

- Survey Area
- State Road

Surface Hydrology
- Minor
- Major

Mussels Recorded by Source

Biologic (2020)
- Not Present

DBCA (2020)
- Present

DWER (2020a)
- Not Present
- Present

Klunzinger (2011)
- Present

WRM (2010)
- Present

WRM (2011)
- Present

N

biologic Environmental Survey

Scale: 1:46,500

0 1 2 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 25/11/2022

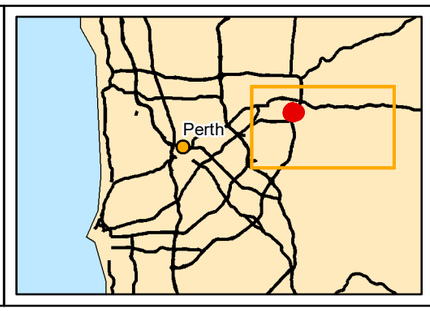


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Figure 3.1: Previous Carter's freshwater mussel surveys relevant to the Survey Area

406800
407000
407200
407400
6469600
6469400

HR Q13
Helena River
HR Q12
HR Q11
HR Q10
HR Q9
HR Q8
HR Q7
HR Q6
HR Q5
HR Q4
HR Q3
HR Q2
HR Q1
Roe Hwy
WW Q1
WW Q3
WW Q11
WW Q8
WW Q7
WW Q2
WW Q4
WW Q13
WW Q5
WW Q12
WW Q10
WW Q9
WW Q6
WE Q3
WE Q1
WE Q4
WE Q9
WE Q6
WE Q5
WE Q2
WE OP1
WE Q10
WE OP2
WE Q7
WE Q8

Legend

- Survey Area
- State Road

Surface Hydrology

- Minor
- Major

Sampling Method

- Opportunistic Record
- Quadrat
- Traverse

N

biologic Environmental Survey

Scale: 1:2,000

0 30 60 90 Meters

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 23/11/2022

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Figure 3.2: Carter's freshwater mussel sample sites and traverses

3.2.2 Water quality

Water quality in the Helena River at the time of the August 2022 survey was characterised by fresh[1] waters, with pH ranging from slightly acidic to circum-neutral (Table 3.2). Electrical conductivity (EC) fell between 915 µS/cm (Q1) and 998 µS/cm (Q12), and demonstrated a longitudinal gradient, with lower EC recorded upstream and greater EC downstream (Table 3.2). The salinity was considered suitable for Carter's freshwater mussel as the highest measurement (0.65 ppt at Q8) was well below the upper tolerance range of Carter's freshwater mussel (~1.6 ppt) (Klunzinger *et al.*, 2015). Although EC from all spot measurements of the Helena River exceeded the ANZG (2018) DGV, all still represented fresh waters and were not considered sufficient to cause ecological stress or impede the presence of mussels. Redox was positive at nearly all spot locations, indicating oxidative conditions (Table 3.2). While dissolved oxygen (DO) fell below the lower DGV, saturation was still considered adequate to support aquatic fauna, including freshwater mussels.

Table 3.2: Summary of in situ water quality results.

		Water quality parameter and units						
Site	**Quadrat no.**	**Water temp. °C**	**pH**	**EC µS/cm**	**Salinity ppt**	**DO mg/L**	**DO %**	**Redox mV**
Helena River	**Q1**	12.5	7.96	915	0.60	6.27	58.6	-4.6
	Q4	12.8	6.89	930	0.61	4.45	41.3	38.2
	Q6	13.0	6.61	954	0.62	5.21	47.4	123.2
	Q8	13.0	6.06	997	0.65	5.34	50.1	57.3
	Q12	13.6	7.59	998	0.64	6.64	60.8	43.0
Wetland West	**Q1**	15.0	6.49	549	0.33	6.26	62.6	93.7
	Q3	16.5	4.07	517	0.30	6.15	62.7	246.9
	Q4	16.7	5.10	619	0.30	6.60	67.6	219.8
	Q11	16.4	3.94	517	0.30	6.96	70.7	255.7
Wetland East	**Q1**	14.4	7.43	558	0.34	5.84	56.9	32.0
	Q2	14.4	5.83	555	0.34	6.34	61.8	106.5
	Q4	14.3	6.38	554	0.34	6.66	63.6	90.6

NB: Highlighting indicates exceedances of the ANZG (2018) DGVs for lowland rivers (Helena River), and wetlands (Wetland East and Wetland West).

The wetlands were also fresh at the time of survey, with EC being generally lower in the wetlands than the Helena River (Table 3.2). Spot measurements of pH ranged from acidic (3.94, in Wetland West) to circum-neutral, with nearly all measurements falling below the lower pH DGV for wetlands in the south-

[1] Salinity categories are based on the Department of Water and Regulation (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).

west (Table 3.2). Although no specific tolerance studies have been undertaken on Carter's freshwater mussel 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 Carter's mussels from habitats ranging from pH 4.24 to 9.7, suggesting mussels can survive within this range. DO also fell below the lower DGV in both wetlands, but was considered adequate to support aquatic fauna, including freshwater mussels.

3.2.3 Habitat assessment

Sediment composition was assessed within each quadrat for habitat suitability. The Helena River Survey Area was dominated by clay, with some silt (Figure 3.3). Quadrats 6 and 7, located just upstream of Roe Highway, were comprised almost exclusively of soft silt. Quadrat 8, located directly underneath the Roe Highway bridge, comprised a heterogenous mix of substrates, including cobbles, pebbles, gravel, sand, and silt. Quadrat 9 was dominated by sand, with some gravel, silt, pebbles, and clay. Sand was present throughout the Helena River, though in relatively low proportions.

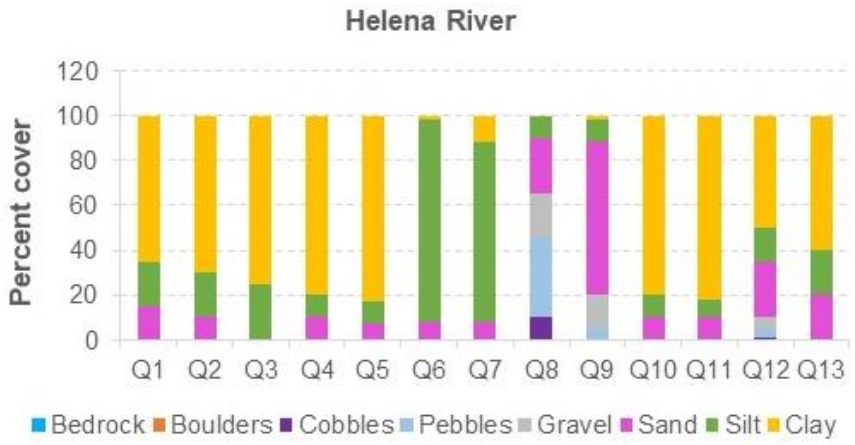

Figure 3.3: Substrate composition within quadrats taken from the Helena River.

Wetland West was relatively homogenous by comparison, being dominated by clay, with some sand and a small proportion of silt also present (Figure 3.4). The northern section of the wetland was covered in a soft, anoxic organic layer. Bedrock, boulders, cobbles, and gravel were present in very low amounts in some quadrats. At Wetland East, sediment substrates comprised clay and sand, with low amounts of silt (Figure 3.5). Bedrock was present within Quadrats 9 and 10, located towards the north-east side of the wetland.

Figure 3.4: Substrate composition within quadrats taken from Wetland West.

Figure 3.5: Substrate composition within quadrats taken from Wetland East.

Locations sampled within the Survey Area are further described in Table 3.3.

3.2.4 Suitable habitat

From the water quality results and habitat assessments, suitable habitat was identified within each location (see Figure 3.6). However, when persistence was considered, the Helena River within the Survey Area became unsuitable for Carter's freshwater mussel because no permanent pools exist in this reach.

Table 3.3: Habitat summary for all sites sampled in the Survey Area, including site photos.

Site	Description	Site Photo
Helena River	A ~500 m section of the Helena River covering the area beneath the Roe Highway bridge and ~200 m upstream and downstream of the NVCP application area. Water was fresh, with pH ranging from slightly acidic to circum-neutral. DO was below the ANZ (2018) DGV, but still considered suitable for supporting aquatic fauna. Sediment was generally dominated by clay, with some sections high in silt, while other sections comprised sand and gravel. Introduced grasses such as couch grass were observed throughout the stretch of river surveyed, particularly in the more upstream section. High amounts of large woody debris (LWD) were observed throughout. Water depth was highly variable throughout, ranging from 0.1 m up to > 2 m. Although the water quality and sections of substrate were suitable for Carter's freshwater mussel, the fact that the reach does not hold permanent water indicates that overall, this section of the Helena River does not support suitable habitat.	
Wetland West	A large, deep (estimated over 3 m deep) permanent wetland located west of Roe Highway. Water quality was fresh, with acidic pH, moderate DO, and generally clear waters. Sediments were dominated by clay, with some sand and silt. A thick layer of soft organics was present on the northern section of the wetland. Sedges and *Melaleuca* surrounded the wetland. The majority of the surveyed area of Wetland West supported suitable habitat for Carter's freshwater mussel, with the exception of a north-eastern portion where the substrate was too soft and anoxic, and	

Site	Description	Site Photo
	a north-western portion where the low, acidic pH was recorded.	
Wetland East	A large, deep (estimated over 2 m) permanent wetland located east of Roe highway. Spot measurements of water quality indicated slightly acidic to circum-neutral waters, which were fresh and clear. DO was below the ANZ (2018) DGVs. Sediments predominately comprised clay and sand, with some silt and bedrock also present. Sedges and submerged macrophytes were common throughout the wetland, along with LWD. The vast majority of Wetland East exhibited habitat suitable for Carter's freshwater mussel, with the exception of the western edge where substrates were too soft and anoxic.	

406800 407000 407200 407400

6469600 6469400

Helena River

Roe Hwy

Legend

Survey Area

State Road

Surface Hydrology

Minor

Major

Habitat

Potentially unsuitable habitat - low pH

Suitable habitat available

Habitat not suitable - soft/anoxic substrate

Habitat not suitable - not perennial

Habitat not suitable - hard substrate

Habitat not assessed

N

biologic Environmental Survey

Scale: 1:2,000

0 30 60 90 Meters

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 23/11/2022

MAIN ROADS WA

Great Eastern Highway Bypass Interchanges Project: Targeted Carter's Freshwater Mussel Survey

Figure 3.6: Habitat assessment of the Survey Area

3.2.5 Carter's freshwater mussel

A complete list of Carter's freshwater mussel records and locations from the current study are provided in Appendix C. No Carter's freshwater mussels were recorded from the Helena River within the Survey Area, despite extensive searching, including thorough exploration within the 13 quadrats and along the banks and further in-stream up to wadeable depth.

Two live Carter's freshwater mussels were recorded from Wetland West, within the same quadrat (Quadrat 4), located on the north-eastern end of the wetland. The individuals were both mature specimens, measuring 65 and 69 mm ML. Three dead specimens (i.e., empty shells) were also found within this quadrat. No other live individuals were recorded in the remaining 12 quadrats, or during opportunistic searches throughout Wetland West. Evidence of a mussel shell was recorded in Quadrat 13 on the western end of the wetland, though no live individuals were recorded from this location.

A total of 46 live Carter's freshwater mussels were recorded from Wetland East, the wetland previously known to support Carter's freshwater mussel. Of the ten quadrats undertaken within this site, live mussels were recorded from four (Quadrats 2, 3, 8 and 9). Opportunistic records were also made whilst hand searching. Size of individuals from Wetland East ranged from 48 mm to 87 mm ML. Examination of size classes indicated that the population structure consists exclusively of mature specimens, with no juveniles recorded (Figure 3.7). The highest number of individuals recorded in one quadrat was 19 (from Quadrat 2), followed by 17 individuals (from Quadrat 3).

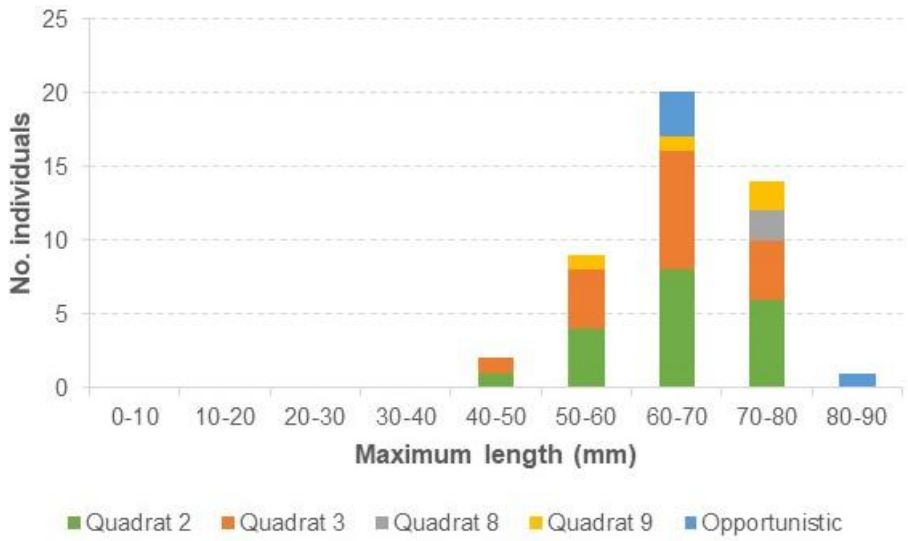

Figure 3.7: Size class structure of Carter's freshwater mussels recorded from Wetland East.

Population densities were calculated for each wetland where Carter's freshwater mussels were recorded. Densities were based on the number of individuals found and the size of the search area within each wetland, which was estimated using satellite aerials (Table 3.4). Population density was 0.004 per m^2 at Wetland West and 0.095 per m^2 at Wetland East. Population extents are shown in Figure 3.8.

406800
407000
407200
407400
6469600
6469400
Helena River
Roe Hwy

Legend

Survey Area
State Road

Surface Hydrology
Minor
Major

Indicative Mussel Density
1
2
3
4
>5

N

biologic Environmental Survey

Scale: 1:2,000
0 30 60 90
Meters

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 23/11/2022

MAIN ROADS WA
Great Eastern Highway Bypass Interchanges Project: Targeted Carter's Freshwater Mussel Survey

Figure 3.8: Mussel density within the Survey Area

Table 3.4: Estimated population densities of Carter's freshwater mussel based on survey results.

Site	Area (m^2)	No. live mussels	Density of live mussels (number/ m^2)
Wetland West	551	2	0.004
Wetland East	485	46	0.095

3.2.6 Other aquatic fauna

Other aquatic fauna were observed within the Survey Area, indicating suitable habitat conditions with which to support fauna. A native crayfish, the gilgie (*Cherax quinquecarinatus*) was recorded amongst LWD within the Helena River (Plate 3.1). The gilgie was female, measuring 60 mm in carapace length. Two fish species were observed in Wetland East; the native western pygmy perch (*Nannoperca vittata*) and the introduced common carp (*Cyprinus carpio*). The carp observed at Wetland East was approximately 1 m in length, indicating a mature specimen that has likely been there for some time (Plate 3.1).

Plate 3.1: A native gilgie from Helena River (left), and introduced carp from Wetland East (right).

3.2.7 Reassessment of likelihood of occurrence

Each site within the Survey Area was reassessed for likelihood of occurrence. The Helena River within the Survey Area was reassessed, and likelihood of occurrence downgraded from Highly Likely to Unlikely (Table 3.5). This assessment was based on the lack of Carter's freshwater mussel recorded despite extensive search effort. While water quality conditions and sediment composition (across the majority of the reach sampled) were considered suitable at time of sampling, the fact that this section of the river dries out precludes Carter's freshwater mussel because they require permanent water. The presence of terrestrial grasses throughout this reach of the Helena River provides evidence that this

section dries out over summer, with no permanent pools remaining. The terrestrial grass likely moved into the creek bed when the river was dry, but sediments still waterlogged, and now persists because inundation events are not sufficiently long to completely kill it off, with recolonising events occurring again in summer. The lack of sedges such as *Machaerina articulata* in this reach also indicates that there are no permanent pools present.

At Wetland West and Wetland East, the likelihood of occurrence was reassessed to Confirmed, based on the presence of live Carter's freshwater mussels at the time of the survey.

Table 3.5: Survey summary and reassessment of likelihood of occurrence of Carter's freshwater mussel based on survey results.

Sites	Within Current Known Distribution	Suitable Water Quality Within Survey Area	Potential Habitat Within Survey Area	Recorded Within Survey Area	Likelihood of Occurrence
Helena River	Yes	Yes	No	No	Unlikely
Wetland West	Yes	Yes	Yes	Yes	Confirmed
Wetland East	Yes	Yes	Yes	Yes	Confirmed

4 DISCUSSION

4.1 Distribution, density, and abundance of Carter's freshwater mussels

Carter's freshwater mussels have specific habitat and water quality requirements. Ma (2018) noted that in-stream mussel distribution was negatively correlated with distance to riverbank and water velocity, and positively correlated with debris and vegetation cover. This means that mussels occur in slow-flowing waters where debris is able to build up. They also require a medium-grain substrate for ease in burrowing, as well as vegetative cover for protection from sunlight (Ma, 2018). Shade provided by riparian vegetation can significantly reduce mortality rates of Carter's freshwater mussel (Lymbery *et al.*, 2020). Riparian vegetation also provides complex microhabitats in-stream, such as leaf litter and large woody debris which support food sources for Carter's freshwater mussel, as well as protection from high flows (Ma, 2018), and predators (Klunzinger, 2012). Carter's freshwater mussel occurs exclusively in perennial water bodies (Klunzinger, 2012).

No Carter's freshwater mussels were recorded within the Helena River, in the Survey Area, despite water quality conditions (including salinity) being within the tolerance range for this species, and substrates being suitable in some sections of the reach. The absence of mussels is due to the lack of permanent water within this section of the Helena River, as indicated by the high coverage of terrestrial grasses observed across the riverbed at the time of survey, and lack of sedges such as *Machaerina articulata*. Permanent pools do persist within ephemeral rivers, which provide refugia for various types of aquatic fauna, including Carter's freshwater mussel. Records of Carter's freshwater mussel are known from other locations on the Helena River, where permanent pools exist, including sites near the

Pipehead Dam (Klunzinger *et al.*, 2011), and a pool approximately 4.9 km downstream of the Survey Area (2014 record) (DBCA, 2020). However, the lack of permanent water within the Survey Area reach means that Carter's freshwater mussel cannot persist there.

Carter's freshwater mussels were recorded in both Wetland West and Wetland East. At Wetland West, only two live individuals were recorded, despite extensive searching, while 46 individuals were recorded at Wetland East. Substrate types (i.e., a mix of clay and sand) were generally similar in both wetlands, although some sections of Wetland West were covered in a soft, anoxic layer or comprised bedrock substrate, both of which preclude Carter's freshwater mussels. The south-western edge of Wetland West was unable to be successfully searched or assessed for suitable habitat due to the steep banks and high water depth in this area. Additional searches would not likely locate many more specimens, however, given the high level of survey effort throughout the rest of the wetland. Wetland West was more acidic than Wetland East or the Helena River, with pH in the north-western section being particularly low (pH 3.94). pH ranged from this low value (3.94 at Quadrat 11) to 6.49 (Quadrat 1), with the location where mussels were recorded having a pH of 5.10. Although pH is not thought to affect Carter's freshwater mussel to the same extent as other factors such as salinity, turbidity, and the availability of permanent surface water (Klunzinger, 2012), freshwater mussels are known to be sensitive to low pH (Strayer, 2008). Klunzinger *et al.* (2015) reported records of Carter's mussels from habitats ranging from pH 4.24 to 9.7, suggesting mussels can survive within this range. Therefore, the more acidic pH recorded from the north-western section of Wetland West may be outside the acceptable limits for Carter's freshwater mussel. As a result, it is possible that some sections of Wetland West are not suitable for Carter's freshwater mussel, influencing the distribution of mussels within this wetland. Also, the current survey measured in situ water quality only, and there may be other water quality factors (such as ammonia or other pollutants) that may be influencing population size and density within Wetland West.

Connectivity between the wetlands and Helena River, facilitated by the adjacent floodplain and drainage lines, is also important. There appears to be connectivity between the wetlands and the river currently during high rainfall and flooding events. At the time of the survey, sections between the wetlands and the river were still inundated. Both native and introduced fish were observed in Wetland East at the time of survey, though fish were not observed at Wetland West. Fish are essential to the lifecycle of Carter's freshwater mussel, as they act as a host for glochidia (the larval stage of freshwater mussels) and are necessary for this species' dispersal (Klunzinger, 2012). Any changes to the connectivity of the Helena River with adjacent wetlands would impact the ability of aquatic fauna (including Carter's freshwater mussel) to colonise these areas in future.

No juveniles were recorded despite extensive searching. Juvenile mussels are difficult to find in nature, given their relatively short time span within this life history stage relative to their life, coupled with the fact that juveniles are thought to burrow slightly deeper than adults (Ma, 2018). A Carter's freshwater mussel is considered juvenile if they are below 27 mm. This is still relatively large, and hand searching should pick them up assuming they are not buried too deep within the substrate. Reductions in recruitment and an ageing population for such a long-lived species could result in long-term population

losses (Klunzinger *et al.*, 2014), which may not become evident for some time. It is unclear from the current survey whether lack of juveniles recorded is indicative of the absence of juveniles, a reduction in recruitment, or simply an artefact of juveniles being difficult to detect in nature.

4.2 Importance of recorded populations

The Carter's freshwater mussel records from the current survey at Wetland West represent additional records of this conservation significant species within its known distribution. These confirmed records are considered important for a species experiencing population decline and reduction in available habitat. Presence of live mussels at Wetland East confirm that this wetland continues to support the conservation significant species, with abundances recorded from the north-western section of the wetland being relatively high compared to previous surveys undertaken by the authors on behalf of Main Roads (Biologic, 2020, 2021). As the Healthy Rivers database only indicates presence/absence data for Carter's freshwater mussel (DWER, 2022), conclusions regarding population trends over time within the wetland cannot be made.

It is not known whether this reach of the Helena River supported this species historically, although, the Healthy Rivers database indicates that there are no records of Carter's freshwater mussel from two survey sites immediately downstream of the Roe Highway bridge (within the current Survey Area) (DWER, 2022). Additional information about these sites could not be obtained from either DWER or DPIRD due to limitations in their databases (Chris Bird, DPIRD, pers. comms.), so there is no information available about when these sites were surveyed, or the type of survey undertaken. Two other sites sampled by DWER on the Helena River system (one location near Whiteman Road ~1.2 km downstream of the Survey Area, and one below Mundaring Weir, ~13 km east of the Survey Area) also found no Carter's freshwater mussel to be present at time of sampling (Kelli O'Neill, Healthy Rivers team, pers. comms.); however, there are records between these locations (see Figure 3.1). The distribution of Carter's freshwater mussel within the Helena River system is patchy, with records restricted to permanent pools, which is not surprising for an ephemeral system. Records of Carter's freshwater mussel from 2014, further downstream and outside of the Survey Area (see Figure 3.1) indicate that this system may still be able to support such conservation significant species, where permanent water is present. Drying climate leading to reduction of permanent water and salinisation of freshwater systems have been identified as the biggest threats to Carter's freshwater mussel (Klunzinger, 2012). Therefore, the persistence of, and connectivity to, adjacent permanent water bodies where Carter's freshwater mussel can persist, are becomingly increasingly important to the maintenance of biodiversity in the system.

Notably, the recent redescription of Carter's freshwater mussel has reduced its current range (Klunzinger & Kirkendale, 2022). As a species already listed as Vulnerable (BC Act, EPBC Act, IUCN) and experiencing population decline, this reduction has implications for the conservation status of this species. The importance of existing populations is likely to become more significant following the reassessment of this species.

4.3 Conclusion

This survey represents the second Carter's freshwater mussel survey of the NVCP application area. Extensive survey of the Helena River within the NVCP application area was undertaken, but no Carter's freshwater mussels were located. However, 46 Carter's freshwater mussels were recorded in Wetland East and two Carter's freshwater mussels were recorded in Wetland West, adjacent to the proposed clearing area.

Although known from elsewhere on the Helena River, the lack of permanent surface water in this reach would preclude the presence of Carter's freshwater mussel here. Based on this, it is considered unlikely that this species would be able to recolonise this part of the Helena River, though this area would be important for passage of host fish and/or larval forms of mussels when seasonally inundated.

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APPENDICES

Appendix A: Conservation status codes

International Union for Conservation of Nature

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

Environment Protection and Biodiversity Conservation Act 1999

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

Biodiversity Conservation Act 2016

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

Department of Biodiversity, Conservation and Attractions Priority codes

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

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

Default trigger values for some physical and chemical stressors for south-west Australia for slightly disturbed ecosystems (TP = total phosphorus; FRP = filterable reactive phosphorus; TN = total nitrogen; NOx = total nitrates/nitrites; NH4+ = ammonium). Data derived from trigger values supplied by Western Australia (ANZECC/ARMCANZ 2000).

Aquatic Ecosystem	Analyte						
	TP	FRP	TN	NOx	NH_4^+	DO	pH
	mg/L	mg/L	mg/L	mg/L	mg/L	% saturation[i]	
Upland River[f]	0.02	0.010	0.45	0.20	0.06	90-na	6.5-8.0
Lowland River[f]	0.06	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[d]	0.06	0.030	1.50	0.10	0.04	90-120	7.0[e]-8.5[e]

na = not applicable;

e = in highly coloured wetlands (gilven >52 $g_{440}m^{-1}$) 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 indicative of slightly disturbed ecosystems in south-west Australia (ANZECC/ARMCANZ 2000).

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 and SPM are highly variable and dependant on seasonal rainfall runoff. These values representative of 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.

Appendix C: Survey records of Carter's freshwater mussel (*Westralunio carteri*).

Site ID	Latitude	Longitude	ML (mm)	MW (mm)	Observations
Wetland West Q4	-31.9067	116.0151	69	42	
Wetland West Q4	-31.9067	116.0151	65	41	
Wetland West Q4	-31.9067	116.0151			Three empty shells; not live
Wetland West Q13	-31.9069	116.0142			Empty shell; not live
Wetland East Q2	-31.9065	116.0183	77	45	
Wetland East Q2	-31.9065	116.0183	77	45	
Wetland East Q2	-31.9065	116.0183	80	47	
Wetland East Q2	-31.9065	116.0183	73	45	
Wetland East Q2	-31.9065	116.0183	66	40	
Wetland East Q2	-31.9065	116.0183	69	41	
Wetland East Q2	-31.9065	116.0183	69	40	
Wetland East Q2	-31.9065	116.0183	71	43	
Wetland East Q2	-31.9065	116.0183	55	33	
Wetland East Q2	-31.9065	116.0183	68	40	
Wetland East Q2	-31.9065	116.0183	76	44	
Wetland East Q2	-31.9065	116.0183	65	37	
Wetland East Q2	-31.9065	116.0183	53	33	
Wetland East Q2	-31.9065	116.0183	62	37	
Wetland East Q2	-31.9065	116.0183	64	36	
Wetland East Q2	-31.9065	116.0183	62	37	
Wetland East Q2	-31.9065	116.0183	55	32	
Wetland East Q2	-31.9065	116.0183	54	33	
Wetland East Q2	-31.9065	116.0183	48	30	
Wetland East Q3	-31.9065	116.0183	66	38	
Wetland East Q3	-31.9065	116.0183	68	40	
Wetland East Q3	-31.9065	116.0183	66	40	
Wetland East Q3	-31.9065	116.0183	79	46	
Wetland East Q3	-31.9065	116.0183	75	46	
Wetland East Q3	-31.9065	116.0183	75	45	
Wetland East Q3	-31.9065	116.0183	74	43	
Wetland East Q3	-31.9065	116.0183	66	40	
Wetland East Q3	-31.9065	116.0183	64	39	
Wetland East Q3	-31.9065	116.0183	56	34	
Wetland East Q3	-31.9065	116.0183	63	36	
Wetland East Q3	-31.9065	116.0183	56	34	
Wetland East Q3	-31.9065	116.0183	62	38	
Wetland East Q3	-31.9065	116.0183	59	36	
Wetland East Q3	-31.9065	116.0183	69	38	
Wetland East Q3	-31.9065	116.0183	52	31	
Wetland East Q3	-31.9065	116.0183	49	29	
Wetland East Q8	-31.907	116.0186	71	45	
Wetland East Q8	-31.907	116.0186	75	43	
Wetland East Q9	-31.9065	116.0186	77	45	
Wetland East Q9	-31.9065	116.0186	76	44	

Site ID	Latitude	Longitude	ML (mm)	MW (mm)	Observations
Wetland East Q9	-31.9065	116.0186	65	37	
Wetland East Q9	-31.9065	116.0186	60	36	
Wetland East OP1	-31.9064	116.0182	66	44	
Wetland East OP2	-31.907	116.0186	87	52	
Wetland East OP2	-31.907	116.0186	70	39	
Wetland East OP2	-31.907	116.0186	64	37	

Appendix D: Section 40 Threatened Fauna Authorisation.

GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

AUTHORISATION TO TAKE OR DISTURB THREATENED SPECIES

Section 40 of the Biodiversity Conservation Act 2016

AUTHORISATION DETAILS

Authorisation number: TFA 2223-0045

Authorisation duration: From date signed by Minister's delegate below until 31 July 2023.

AUTHORISATION HOLDER

Jessica Delaney

Principal Zoologist and Manager of Aquatic Ecology

Biologic Environmental Survey

24-26 Wickham Street

East Perth WA 6004

AREA TO WHICH THIS AUTHORISATION APPLIES

Upstream and downstream of Roe Highway in the Helena River, and nearby wetlands (Swan Region).

AUTHORISED ACTIVITY

Purpose of taking/disturbance:

Undertake a targeted survey for Carter's freshwater mussels for Main Roads Western Australia to determine mussel presence in an area targeted for future roadworks.

Threatened species authorised to be taken/disturbed (including conservation status):

Carter's freshwater mussel, *Westralunio carteri* (Vulnerable)

Quantity of threatened species authorised to be taken/disturbed:

Any number of individual animals of the above listed threatened fauna species may be captured and released and/or disturbed during the targeted survey.

Authorised taking/disturbance methodology:

Take Carter's freshwater mussels by hand (foraging), dip net (2mm mesh) and mussel rake during targeted searches. Up to ten (10) quadrats ($1m^2$) will be deployed per site in suitable habitat and within two metres of the shoreline.

Captured mussels will have shell length and width measured to the nearest 1 mm, before immediate release at the capture site.

Dates within which taking/disturbance authorised:

From date signed by Minister's Delegate below until 31 July 2023.

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Authorisation to take or disturb threatened species *Authorisation number: TFA 2223-0045*

AUTHORISED PERSONS

Jessica Delaney	Kim Nguyen	Alex Riemer
Siobhan Paget	Morgan Lythe	

Additional personnel who are suitably qualified and experienced in the Authorised Activities working under the direction of the Authorisation Holder.

Field assistants assisting working under the direct supervision of the Authorisation Holder or suitably qualified and experienced named Authorised Persons.

CONDITIONS

1. The written authorisation of the person in possession or occupation of the land accessed and upon which threatened fauna is taken or disturbed must:
    a. state location details (including lot or location number, street/road, suburb and local government authority);
    b. state land owner or occupier name, and contact phone number;
    c. specify the time period that the authorisation is valid for;
    d. be signed and dated; and
    e. be attached to this Authorisation to take or disturb threatened species at all times.
2. This Authorisation to take or disturb threatened species, and any other written authorisation or lawful authority which authorises the take or disturbance of fauna on specified locations for the Authorised Activities must be carried at all times while conducting Authorised Activities and be produced on demand by a wildlife officer.
3. Authorised Persons who are not suitably qualified and experienced in the Authorised Activities, and field assistants assisting with the Authorised Activities, must be working under direct supervision of experienced and competent named Authorised Persons.
4. Any inadvertently captured species of non-target threatened fauna or non-threatened fauna (threatened fauna as defined in *Biodiversity Conservation Act 2016* Section 19) is to be released immediately at the point of capture. Details of such fauna must be included in the fauna taking/disturbance return as required under this Authorisation.
5. The Authorisation Holder, unless specified in the Authorised Activities, must not:
    a. release any threatened fauna in any area where it does not naturally occur;
    b. transfer threatened fauna to any other person or authority (other than the Western Australian Museum) unless the fauna is injured or abandoned fauna (condition 6); or
    c. dispose of the remains of threatened fauna in any manner likely to confuse the natural or present-day distribution of the species.
6. All threatened fauna injuries, unexpected deaths, unplanned euthanasia, and abandoned young or eggs, must be reported by the Authorisation Holder to the DBCA Wildlife Protection Branch, Wildlife Licensing Section (wildlifelicensing@dbca.wa.gov.au) to notify of the incident and for advice on treatment or disposal. All deceased threatened fauna must be offered to the Western Australian Museum.
7. The Authorisation Holder must create, compile and maintain records and information as required in a DBCA approved "Return of Fauna Taken/Disturbed" of all fauna taking/disturbance activities as they occur.
8. A DBCA approved "Return of Fauna Taken/Disturbed" must be completed in full (including nil taking/disturbance details) and submitted to DBCA Wildlife Licensing Section

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(wildlifelicensing@dbca.wa.gov.au) prior to the end of the Authorisation duration and, if the Authorisation duration is greater than 12 months, prior to the end of each annual period of the Authorisation (from the date signed by the Minister's delegate) (refer to "Additional Information" section below). Where a licence to take or disturb fauna is issued in conjunction with this Authorisation to take or disturb threatened species, a combined "Return of Fauna Taken/Disturbed" may be completed and submitted.

9. A written report detailing the undertaken Authorised Activities, outcome, unintended incidents, injuries and mortalities of threatened fauna, implemented monitoring, mitigation and management, and explaining the records and information as required in a DBCA approved "Return of Fauna Taken/Disturbed" must be submitted, in addition to a "Return of Fauna Taken/Disturbed" to DBCA Wildlife Licensing Section (wildlifelicensing@dbca.wa.gov.au).

ADDITIONAL INFORMATION

1. Before undertaking the Authorised Activity, permission must be obtained from: (a) the owner or occupier of private land; or (b) the department or authority controlling Crown land, on which the threatened fauna occurs. This includes obtaining the written endorsement from Department of Biodiversity, Conservation and Attractions (DBCA) if the Authorised Activity is proposed for land managed by DBCA.
2. This Authorisation to take or disturb threatened species does not constitute lawful authority issued under regulations 4 and 8 of the *Conservation and Land Management Regulations 2002*. Contact the applicable Department District Officer for further information.
3. The approved DBCA "Return of Fauna Taken/Disturbed" template can be obtained from DBCA Wildlife Licensing Section (wildlifelicensing@dbca.wa.gov.au).
4. Any interaction involving nationally listed threatened fauna that may be harmful to the fauna and/or invasive may require approval from the Commonwealth Department of the Environment and Energy (http://www.environment.gov.au/biodiversity/threatened/permits). Interaction with such species is controlled by the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and *Environment Protection and Biodiversity Conservation Regulations 2000*.
5. It is the responsibility of the Authorisation Holder to ensure that they comply with the requirements of all applicable legislation.
6. An Authorisation to take or disturb threatened species does not constitute an animal ethics approval or a licence to use animals for scientific purposes as required under the *Animal Welfare Act 2002* and *Animal Welfare (Scientific Purposes) Regulations 2003*. Enquiries relating to the Animal Welfare Act scientific purposes licence and animal ethics committee approvals are to be directed to the Western Australian Department of Primary Industries and Regional Development (https://www.agric.wa.gov.au/animalwelfare).

Margaret Byrne
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Dr Margaret Byrne
Executive Director of Biodiversity and Conservation Science
AS DELEGATE OF THE MINISTER
DATE: 28/7/2022