APPENDIX F

BORR Northern and Central Investigation Area: Targeted Conservation Aquatic Fauna Survey (WRM 2020)

BUNBURY OUTER RING ROAD NORTHERN AND CENTRAL INVESTIGATION AREA: TARGETED CONSERVATION SIGNIFICANT AQUATIC FAUNA SURVEY

August 2019 SAMPLING FINAL REPORT

Wetland Research & Management

April 2020



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Recommended Reference Format

WRM (2020) Bunbury Outer Ring Road Northern and Central Investigation Area: Targeted Conservation Significant Aquatic Fauna Survey 2019. Unpublished report by Wetland Research & Management to BORR Team. April 2020.

Acknowledgements

This report was written by *Wetland Research and Management* (WRM) for BORR ITP Team. WRM would like to acknowledge Vicki Davies and Fionnuala Hannon for efficient overall management on behalf of BORR ITP, and thank the landowners for allowing us access to their properties. The BORR IPT Environment Team provided comments this report.

Disclaimer

Document history

Version	Author	Submitted	Reviewed by	Comments received by author
Draft v1	Mel Tucker	24/09/2019	Andrew Storey, Chris Hofmeester (internal review)	26/09/2019
Draft v2	Mel Tucker	27/09/2019	Andrew Storey, Chris Hofmeester (internal review)	02/10//2019
Draft v3	Mel Tucker	21/10/2019	BORR IPT Environment Team	20/12/2019
Final	Mel Tucker	20/12/2019		20/01/2020
Final Rev.1	Mel Tucker	28/01/2020		27/02/2020
Final Rev. 2	Mel Tucker	05/03/2020	Andrew Storey (internal review)	02/04/2020
Final Rev. 3	Mel Tucker	02/04/2020		

Frontispiece (left to right): Fyke net set at North 2; Carter's freshwater mussel (*Westralunio carteri*); and, North 3 (all photos by WRM© /August 2019).

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EXECUTIVE SUMMARY

The Bunbury Outer Ring Road (BORR) is a planned Controlled Access Highway linking the Forrest Highway and Bussell Highway. BORR will be a high standard route for access to the Bunbury Port and facilitate proposed development to the east of the City of Bunbury. BORR provides an effective bypass of Bunbury for interregional traffic. The BORR Project comprises three sections:

- BORR Northern Section – Forrest Highway to Boyanup-Picton Road,
- BORR Central Section – Boyanup-Picton Road to South Western Highway, an existing four kilometre (km) section which was completed in May 2013, along with a three km extension of Willinge Drive southwards to South Western Highway, and
- BORR Southern Section – South Western Highway (near Bunbury Airport) to Bussell Highway.

The BORR alignment passes through an area characterised by creeklines and wetlands. As part of the approvals process, it was necessary to document the ecological values of these creeklines and wetlands, and determine if they support any listed aquatic fauna species of conservation significance.

In November 2018, WRM undertook a targeted aquatic fauna survey within BORR the northern and central investigation area BORR and identified one wetland that supported the black-stripe minnow. Due to the high mobility of the black-stripe minnow, and the relatively late timing of the sampling, with wetlands receding and black-stripe minnows likely in preparation for summer aestivation, it was postulated that black-stripe minnows occurred more widely in the area but were not recorded due to the lateness of the November 2018 sampling, and general habitat unsuitability throughout the majority of the investigation area, with many wetlands altered from their natural state due to agricultural landuse. WRM was therefore contracted to undertake a winter 2019 targeted survey for the black-stripe minnow both within, and just outside of, the north central investigation area at wetlands deemed likely to contain black-stripe minnow. Assessment of aerial images identified a total of six potential sites (seasonal wetlands) where black-stripe minnow were likely to occur. Due to site restrictions around private property access, only four of the six identified black-stripe minnow sites were sampled during the August 2019 survey.

Black-stripe minnows were recorded at all four wetland sites, with the presence of black-stripe minnow at site “North 5” representing the first record of the species within the northern and central investigation area (it was previously recorded at a wetland coded “Northern 9” during November 2018 sampling, which is located approximately 100 m north of the investigation area). Little information is available on the biology and ecology of the black-stripe minnow, with this study providing valuable information about the habitat and water quality requirements of the species.

A second conservation significant species, the Carter’s freshwater mussel, was also targeted, with five potential sites (creeklines) visited during the winter 2019 survey (five creekline sites were also visited during the November 2018 survey). Carter’s freshwater mussels were confirmed present at two of the five creekline sites sampled in 2019, with evidence of mussel presence (dead shells on the banks) at a third.

1 INTRODUCTION

1.1 Background

The Commissioner of Main Roads Western Australia (Main Roads) is proposing to construct and operate the Northern and Central sections of the Bunbury Outer Ring Road project (BORR; see Figure 1). The BORR is a planned Controlled Access Highway linking the Forrest and Bussell Highways and will provide a high standard route for access to the Bunbury Port and will facilitate proposed development to the east of the city of Bunbury. The completed BORR will also provide an effective bypass of Bunbury for inter-regional traffic. Project development of the BORR is being conducted through the BORR Integrated Project Team (IPT) which is composed of Main Roads, GHD and BG&E.

The proposed BORR alignment ("northern and central investigation area") passes through or adjacent to a number of creeklines and wetlands. As part of the approval process, it is necessary to document the ecological values of these ecosystems, and determine if they support any aquatic fauna species of conservation significance. Based on species' distributions and habitat present, the creeklines and wetlands were deemed likely to support two State, Federally and internationally listed species:

- Carter's freshwater mussel (*Westralunio carteri*); Vulnerable (EPBC Act 1999), Vulnerable (BC Act 2016, Schedule 3 of the Wildlife Conservation Specially Protected Fauna Notice 2019), Endangered (IUCN Redlist 2020), and
- Black-stripe minnow (*Galaxiella nigrostriata*); Endangered (EPBC Act 1999), Endangered (BC Act 2016, Schedule 2 of the Wildlife Conservation Specially Protected Fauna Notice 2019), Endangered (IUCN Redlist 2020).

In late-November 2018, WRM undertook a targeted aquatic fauna survey of nine wetlands within the northern and central investigation area, recording a single black-stripe minnow at one wetland (site "Northern 9" at the south-western end of the northern and central investigation area; WRM 2019b). Due to the high mobility of the black-stripe minnow, and the relatively late timing of the sampling, with wetlands receding and black-stripe minnows likely in preparation for summer aestivation, it was postulated that black-stripe minnows occurred more widely in the area around Northern 9 but were not recorded due to the lateness of the 2018 sampling. During the same survey, Carter's freshwater mussel were also observed at a number of creekline sites intersecting the northern and central investigation area. As such, WRM was requested to conduct a second targeted aquatic fauna survey for the species listed above in winter 2019. To better understand the local extent of each species, locations both within and adjacent to the investigation area were sampled.

1.2 Scope of works

The scope of works for the winter 2019 targeted conservation significant aquatic fauna survey were:

- targeted sampling of black-stripe minnow and Carter's freshwater mussel, *in situ* water quality (pH, DO, EC & temperature), habitat assessments, and observations of other fauna (if present),
- an assessment of the conservation status of aquatic fauna recorded,
- preparation of a detailed technical report of all findings,
- updated mapping of Carter's freshwater mussel distribution, and
- strategies to manage, monitor and mitigate direct and indirect impacts to Carter's freshwater mussel and black-stripe minnow within the study area to be provided as a separate memo.

2 SPECIES OF CONSERVATION SIGNIFICANCE

Aquatic ecosystems in the south-west of the state support a diverse range of taxa with different local, regional, national and international distributions, and therefore taxa vary in their conservation status depending upon their distribution and evolutionary origins. To assess the conservation significance of aquatic fauna recorded are range of sources were referenced, including:

- Nationally threatened Fauna listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act 1999),
- Threatened and Priority Fauna in Western Australia under the *Biodiversity Conservation (BC) Act 2016* (as listed on the Department of Biodiversity, Conservation and Attractions Threatened and Priority Fauna List (DBCA 2019)),
- Threatened Fauna under the IUCN Redlist of Threatened Species (IUCN 2020), and
- Conservation status of Australian Fishes List (Australian Society for Fish Biology 2016).

Two species of conservation significance were specifically targeted during this survey; the black-stripe minnow and the Carter's freshwater mussel. Information on each species is outlined below.

2.1 Black-stripe minnow

The black-stripe minnow (*Galaxiella nigrostriata*; Plate 1) is currently listed as Endangered nationally (EPBC Act 1999) and at a state level in Western Australia (Schedule 2 of the Wildlife Conservation Specially Protected Fauna Notice 2018), as well as Endangered at an international level (IUCN Redlist 2020). The black-stripe minnow is capable of aestivating (burrowing) into soils to survive drying habitat and therefore can inhabit wetlands that dry over summer, appearing in pools within hours following first rains (Morgan *et al*. 2011). Interestingly, it does not have any specific anatomical or physiological adaptations to aid aestivation, and is assumed to survive either within moist soils or within crayfish burrows that contain water through dry periods. It appears that most individuals only live for one year, dying shortly after spawning (Morgan *et al*. 2011).

The black-stripe minnow is endemic to south-western Australia and rare throughout its distribution. Its main distribution lies within the Warren sub-region, where numerous populations are found between Albany and Augusta. However, there are isolated populations on the Swan Coastal Plain, including Lake Chandala (near Gingin), Melaleuca Park (north of Perth), and wetlands within the Kemerton Nature Reserve (north of Bunbury) (Morgan *et al*. 1998, Allen *et al.* 2002). A survey by WRM in October 2018 within the BORR southern alternate investigation area also recorded a population of black-stripe minnow in Gelorup (WRM 2019a). They are restricted to shallow, tannin stained, ephemeral pools and are most common in waterbodies of peat flats (Morgan and Gill 2000). It is thought that the populations on the Swan Coastal Plain are remnants of a once wider distribution (Morgan *et al.* 1998), suggesting that the loss of habitat caused by urban and rural development during the previous hundred years has had a significant impact on the extent of this species. As such, their biggest threat is loss of suitable habitat through urbanisation and rural development.

Plate 1. Black-stripe minnow, photo WRM ©.

2.2 Carter's freshwater mussel

Carter's freshwater mussel (*Westralunio carteri*; Plate 2) is currently listed as Vulnerable on state (Schedule 3; DBCA 2019), national (EPBC Act 1999), and international (IUCN Redlist 2020) conservation lists. This species occurs in greatest abundance in slower flowing riverine habitats with stable sediments and low salinity. The lifecycle involves an obligate parasitic 'larval' stage, known as glochidia, which attach to host fish for several weeks to complete their development (Beatty *et al*. 2010). The glochidia aids with the distribution of this species, with individuals being dispersed by migrating fish.

Carter's freshwater mussel is endemic to the South West Coast Drainage Division, where it is the only freshwater mussel to be found. The distribution of this species is from the Moore River in the north, to the south coast, west of Esperance (Klunzinger *et al*. 2010). Carter's freshwater mussel is threatened by secondary salinisation, as well as sedimentation. Reservoir dewatering and rainfall reductions also appear to have a negative effect on populations (Klunzinger *et al*. 2012).

Plate 2. Carter's freshwater mussels, photo by WRM ©.

2.3 Other fauna

Two other species of conservation significance that could occur within the survey area include Balston's pygmy perch and Australian water rat. Information about these two species is included below.

2.3.1 Balston's pygmy perch

Balston's pygmy perch (*Nannatherina balstoni;* Plate 3) is currently listed as Vulnerable nationally (EPBC Act 1999) and at a state level in Western Australia (Schedule 3 of the Wildlife Conservation Specially Protected Fauna Notice 2018). This species is confined to smaller streams within major river systems of south-west Western Australia (Allen *et al.* 1994). They typically inhabit acidic, tannin-stained freshwater pools, streams and lakes (Morgan *et al.* 1998). Balston's pygmy perch are threatened by changes in hydrology, loss of suitable habitat and the introduction of non-native fish species such as mosquitofish (*Gambusia holbrooki*) (Morgan *et al.* 2002).

Plate 3. Balston's pygmy perch, photo from DWER

2.3.2 Australian water rat / rakali

The Australian water rat (*Hydromys chrysogaster*; Plate 3) is currently listed as a Priority 4 species in the State of Western Australia (DBCA 2019). Water rats are adapted to semi-aquatic life with broad, partially webbed feet and water repellent fur (Scott and Grant 1997). They are opportunistic feeders, often preying on large aquatic invertebrates, fish, mussels and crustaceans.

The Australian water rat is distributed across a range of habitats from permanent water bodies to lowland streams, with the highest abundances associated with permanent wetlands (Scott and Grant 1997). Threats to their distribution include swamp reduction and flood mitigation practices.

Plate 4. Australian water rat, *Hydromys chrysogaster* (photo taken and provided by Bert and Bab Wells)

3 METHODS

This study was conducted under Department of Primary Industries and Regional Development (DPIRD) Fisheries Licence EXEM 2483 (*Instruments of Exemption to the Fish Resources Management Act 1994* for Scientific Research Purposes). As a condition of this licence, taxa lists and reports are required to be submitted to DPIRD. The study was also conducted under Department of Biodiversity, Conservation and Attractions (DBCA) Fauna Taking (Biological Assessment) Licence BA27000105. As a condition of this licence, a fauna return including taxa lists and locations, is required upon project completion.

Sampling was undertaken by Senior Aquatic Ecologists Melissa Tucker and Christopher Hofmeester over five consecutive days; 19th to 23rd August 2019.

Aquatic fauna sampling by WRM is consistent with methodology used by others in similar surveys across Australia (i.e. Cheal *et al.* 1993, Storey *et al.* 1993, Edward *et al.* 1994), including the sampling of wetlands of the SCP by Murdoch University (Davis *et al.* 1993) and the National Monitoring River Health Initiative (Department of Environment Sport and Territories *et al*. 1994).

3.1 Sampling sites

A desktop assessment identified a total of six potential sites (seasonal wetlands) where black-stripe minnows were likely to occur, based on previous records and habitat preferences. Due to site restrictions around private property access, only four of the six identified black-stripe minnow sites were sampled during the August 2019 survey (Table 1, Figure 1). Table 1 and Figure 1 also denote November 2018 targeted aquatic fauna sampling locations. Note that none of the original sites were resampled in August 2019, as the majority of wetlands were deemed unsuitable for black-stripe minnow based on observations made during the November 2018 survey (Table 1). However, 2019 site North 5 is located approximately 100 m south of 2018 site Northern 9, where a black-stripe minnow was recorded (Figure 1). Northern 9 (site North 4 2019) was not sampled in the 2019 survey due to site access restrictions at the time of sampling. As mentioned previously, sites located both within and outside of the investigation area were surveyed, in order to provide information of the local extent of black-stripe minnow for environmental impact assessment and species management (Figure 1).

The presence of Carter's freshwater mussel was confirmed from the Ferguson and Preston rivers by WRM ecologists during the November 2018 survey (Sites North Creek 2 and North Creek 5; Table 2, Figure 2). In 2019, two additional sites on the Preston River, and three additional sites on the Ferguson River were surveyed for Carter's freshwater mussel, in an attempt to understand their wider distribution in the area, particularly upstream and downstream of the investigation area (Table 2 and Figure 2). Table 2 and Figure 2 denote those sites surveyed in August 2019, as well as in November 2018.

Table 1. Summary of all sampling locations where black-stripe minnow were targeted (wetlands) within and adjacent to the northern and central investigation area, August 2019 and November 2018 (bold indicates within investigation area). Notes on habitat suitability for black-stripe minnow are provided from the November 2018 survey.

Northern/Central targeted wetlands: Black-stripe minnow				
Site name	Easting	Northing	Sampling event	Suitable black-stripe minnow habitat?
North 1	376332	6305846	August 2019	-
North 2	375638	6305379	August 2019	-
North 3	376926	6305230	August 2019	-
North 4*	377037	6304974	August 2019	Not sampled (due to site access restrictions)
North 5	**377031**	**6304815**	August 2019	-
North 6	377050	6304141	August 2019	Not sampled (due to site access restrictions)
Northern 1	**384148**	**6318099**	November 2018	No - modified wetland (excavated)
Northern 2	**384684**	**6317630**	November 2018	No - modified wetland (excavated)
Northern 3	**385589**	**6314505**	November 2018	No - saline wetland
Northern 4	381911	6308024	November 2018	No - modified wetland (excavated)
Northern 5	381206	6307767	November 2018	No - degraded wetland in industrial park
Northern 7	379056	6304461	November 2018	No - modified drainage channel
Northern 8	**379387**	**6305074**	November 2018	No - modified drainage channel
Northern 9*	377037	6304974	November 2018	Yes – species recorded

**Note: North 4 (2019) and Northern 9 (2018) are the same site. North 4 was not sampled in the 2019 survey due to site access restrictions at the time of sampling, although with the positive record in 2018 the species is still assumed to persist within the wetland.*

Table 2. Summary of all sampling locations where Carter's freshwater mussels were targeted (creeklines) within and adjacent to the northern and central investigation area, August 2019 and November 2018.

Northern/Central targeted creeklines: Carter's freshwater mussel				
Site name	Easting	Northing	Sampling event	Creekline / Location
Mussels 1	**378638**	**6305622**	August 2019	Preston River within proposed alignment
Mussels 2	381387	6307240	August 2019	Ferguson River just upstream of alignment
Mussels 3	379246	6308752	August 2019	Ferguson River downstream of alignment
Mussels 4	378731	6308697	August 2019	Ferguson River downstream of alignment
Mussels 5	376952	6309059	August 2019	Preston River downstream of alignment
North Creek 1	**385483**	**6314596**	November 2018	Collie River within proposed alignment
North Creek 2	379297	6303282	November 2018	Preston River upstream of alignment
North Creek 3	383993	6315508	November 2018	Tributary of Collie River, downstream of alignment
North Creek 4	385167	6311922	November 2018	Millars Creek adjacent to alignment
North Creek 5	**381373**	**6307582**	November 2018	Ferguson River within alignment

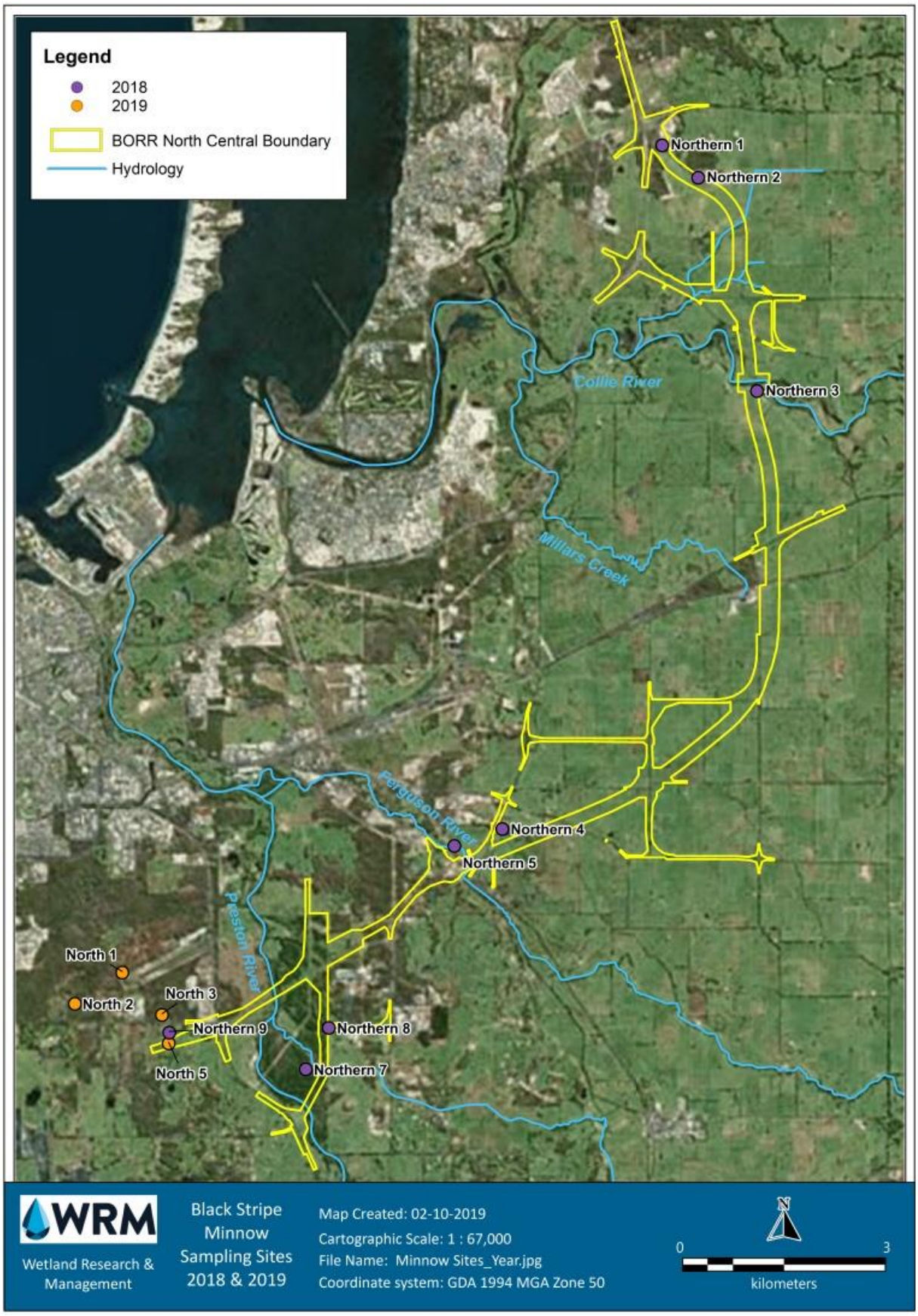

Figure 1. Summary of all sampling locations where black-stripe minnow were targeted (wetlands) within and adjacent to the northern and central investigation area, in November 2018 (purple) and August 2019 (orange).

Figure 2. Summary of all sampling locations where Carter's freshwater mussels were targeted (creeklines) within and adjacent to the northern and central investigation area, in November 2018 (purple) and August 2019 (orange).

3.2 Survey methods

3.2.1 Black-stripe minnow

A number of methods were used at each site to effectively collect as many species/individuals as possible and increase the likelihood of recording the conservation significant black-stripe or any additional listed species, such as the Balston's pygmy perch (*Nannatherina balstoni*). Fish sampling methods included beach seine netting, dip netting and fyke netting.

A minimum of three (depending on wetland size) fyke nets (Plate 5) comprising a double 10 m leader/wing (4 - 6 mm mesh, 1.5 m drop) and a 5 m hoop were set at each site overnight. Fyke nets were set at a 45° angle to the bank to create a complete barrier to fish passage at each site. A custom-made floating fauna platform was placed at the cod (closed)-end (closest to the bank) to provide an air space and resting stage for air-breathing fauna such as freshwater turtles, frogs and water rats. A minimum of five baited box traps (26 x 26 x 46 cm, 20 mm mesh) were deployed overnight at each site, each baited with a mixture of cat biscuits and chicken pellets.

Coarse mesh dip nets (500 mm x 500 mm opening x 450 mm deep and 3 mm mesh) were used in areas that were shallow and dense with vegetation. Dip nets were swept through the water, encompassing a variety of different habitat types.

Where habitat complexity and water depth allowed, replicate seine netting was used. Each seine (10 m net, with a 2 m drop and 6 mm mesh) was deployed in shallow areas where there was little vegetation or large woody debris to obstruct the "looping" action of the net. A minimum of two seine hauls were conducted at each site where seining was possible.

All fish were identified in the field following nomenclature of Allen *et al.* (2002) and standard length (SL mm)[1] measured. The measurement of fish provided information on population structure, which reflects breeding and recruitment success. In order to comply with conditions of the Fisheries Exemption, any introduced species that were caught were not returned to the environment. Condition 8 of the exemption states: "*All species of fish, other than known introduced species, shall be immediately returned to their natural environment with the least possible injury*." Therefore, introduced fish were euthanised humanely in an ice slurry. All other fish and aquatic fauna (crayfish, frogs, turtles) were returned alive to the water.

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

Plate 5. Fyke net set within North 2, August 2019

3.2.2 Carter's freshwater mussel

Visual observations were made for live mussels under select road bridges (Table 2, Figure 2) on the Preston and Ferguson Rivers, in order to confirm species extent and inform future impact assessment as required.

3.2.3 Water quality

In situ water quality data were recorded using portable WTW and TPS field meters. Variables recorded included pH, dissolved oxygen (DO; % and mg/L), electrical conductivity (EC; µS/cm) and water temperature (°C).

3.2.4 Habitat

Details of in-stream habitat characteristics were recorded from each site. WRM has specific worksheets for this task so that recordings between sites remain as comparable as possible. Habitat characteristics recorded included percent cover by inorganic sediment, submerged macrophyte, floating macrophyte, emergent macrophyte, algae, large woody debris, detritus, roots and trailing vegetation. Details of substrate composition were also recorded and included percent cover by bedrock, boulders, cobbles, pebbles, gravel, sand, silt and clay. Notes on riparian vegetation and geomorphology of each wetland were also made during the survey.

3.2.5 Opportunistic sightings

Freshwater crayfish were sampled using the methods described above for fish fauna, specifically, dip netting, box traps and fyke nets. Crayfish were identified to species, carapace length measured (CL mm), and sex noted. Opportunistic records of any turtle or frog species observed whilst sampling were also made, with turtles sexed and measured for carapace (shell) length. Turtles are often captured using sampling methods designed for fish (especially fyke netting). Opportunistic survey of frog species included identification of:

- any adults seen while sampling for aquatic fauna, and
- species identified from mating calls.

4 RESULTS AND DISCUSSION

4.1 Water quality

4.1.1 Black-stripe minnow survey sites (wetlands)

In situ water quality within the wetland sites (i.e. sites where black-stripe minnow were targeted) was characterised by slightly acidic to neutral pH (6.59 to 7.35), low to saturated dissolved oxygen levels (55.6% to 127.2%), and moderate temperatures (12.7 ^{o}C to 19.3 ^{o}C; Table 3). Most sites were considered fresh, with one brackish site as defined by the DoE (2003)[2] (North 1) with conductivity ranging from 672 µs/cm (at North 2) to 1878 µs/cm (at North 1) (Table 3). Aside from North 1, EC values were within the ANZG (2018) default guideline range for slightly disturbed wetlands in the southwest of Western Australia (300 – 1500 µS/cm) (Table 3). pH was below the default guideline values (DGVs) (ANZG 2018) for the protection of slightly/moderately disturbed wetland ecosystems in the southwest of W.A. (pH 7 – 8.5) at North 2, North 3 and North 5 (Table 3). However, highly coloured (tannin stained) wetlands such as these can be naturally acidic, due to the microbial breakdown of organic matter (leaf litter and woody debris). As such, the pH values recorded (6.59 – 6.89) are considered normal.

Similarly, three sites recorded DO saturation less than the lower DGV (90%); North 1 (55.6%), North 2 (52.2%) and North 3 (83.2%). While the oxygen needs of aquatic biota differ between species and life history stage, values less than 50% saturation are known to result in chronic responses in macroinvertebrates and fish (Butler *et al.* 1970, Davis 1975, Alabaster and Lloyd 1982). One site recorded saturated DO, in excess of the upper DGV (120%); North 5 (127.2%). Oxygen saturation occurs when net photosynthesis exceeds total oxygen consumption and is common in areas of high algal and macrophyte growth, and/or areas of high turbulence. Sites which have high day-time DO are likely to experience oxygen stress overnight, as respiration by plants, algae, bacteria and other aquatic fauna deplete DO. Super-saturation is also known to cause gas bubble disease in fish (Bouck 1980).

4.1.2 Carter's freshwater mussel survey sites (creeklines)

In situ water quality at creekline sites was characterised by neutral pH (7.38 to 7.81), normal dissolved oxygen (83.3% - 98.1%), and relatively cool temperatures (12.0 ^{o}C to 13.0 ^{o}C; Table 3). Although EC was above the ANZG (2018) upper guideline value for lowland rivers in the south-west of W.A. (300 µs/cm) at all sites, all were still considered "fresh" as defined by the DoE (2003)[3] with EC ranging from 577 µs/cm to 803 µs/cm (Table 3).

[2] Fresh defined as < 1500 µS/cm, Brackish = 1500 – 4500 µS/cm, Saline = 4500 – 50,000 µS/cm, Hypersaline > 50,000 µS/cm (DoE 2003). Classifications were presented as TDS (mg/L) in DoE (2003) so a conversion factor of 0.68 was used to convert to conductivity µS/cm as recommended by ANZG (2018).

Table 3. *In situ* water quality results from all sites sampled in August 2019, with default ANZG (2018) water quality guideline values.

	Date	Temp°C	Cond (µs/cm)	pH	DO%	DO mg/L
ANZG guidelines – wetlands			**300 - 1500**	**7 – 8.5***	**90 - 120**	
North 1	21/08/2019	12.7	1878	7.35	55.6	5.80
North 2	22/08/2019	13.2	672	6.59	52.2	5.64
North 3	19/08/2019	16.2	1306	6.89	83.2	8.28
North 5	21/08/2019	19.3	1005	6.67	127.2	12.16
ANZG guidelines – lowland river			**120 - 300**	**6.5 - 8**	**80 - 120**	
Mussels 1	21/08/2019	13.0	803	7.41	83.3	6.85
Mussels 2	20/08/2019	12.0	577	7.81	98.1	10.43
Mussels 3	20/08/2019	12.3	734	7.59	95.6	10.24
Mussels 4	20/08/2019	12.3	734	7.59	95.6	10.24
Mussels 5	21/08/2019	12.2	794	7.38	83.7	6.97

* ANZG recognises that pH can typically range between 4.5 and 6.5 in highly coloured wetlands, such as those in the study area.

4.2 Habitat

4.2.1 Black-stripe minnow survey sites (wetlands)

North 1 and North 2 are minimally disturbed wetlands situated among relatively dense *Melaleuca* woodland within Manea Park bushland reserve (Plate 4). North 3 is also situated within Manea Park, with some remnant riparian vegetation present (though some clearing of riparian vegetation has taken place). North 5 is part of a small wetland chain on cleared farmland, with only small patches of riparian vegetation remaining (Plate 6). North 1, 3 and 5 appear to be hydrologically linked during periods of high rainfall via culverts and a small drainage channel, though at the time of sampling were isolated wetlands. North 2 may also connect with North 1 during periods of high rainfall, but was also isolated at the time of sampling. All four wetland sites had a diversity of instream habitat types including large woody debris, emergent macrophyte, trailing vegetation, submerged macrophyte and detritus. All sites had sand substrate, with a percentage of riparian cover ranging from 10 - 85% (Table 4).

Table 4. Percentage of different habitat types of wetland sites sampled in August 2019.

	Date	Mineral substrate	Emergent macrophyte	Submerged macrophyte	Floating macrophyte	Algal cover	Detritus	Trailing veg	Large woody debris
North 1	21/08/19	5	10	5	15	5	20	20	20
North 2	22/08/19	20	5	5	0	0	20	30	20
North 3	19/08/19	20	15	30	0	5	10	10	10
North 5	21/08/19	0	20	70	0	0	5	3	2

4.2.2 Carter's freshwater mussel survey sites (creeklines)

The five potential mussel sites were located at river crossings (road bridges) on either the Preston River or Ferguson rivers, and held a small diversity of instream habitat types including detritus, trailing vegetation and/or large woody debris (see Table 5 and Plate 7).

Substrate at all sites was predominantly comprised of a mix of sand, silt and clay, with minimal percentage of cobbles, pebbles and/or gravel (Table 5). Mussels 1, 4 and 5 had a relatively high percentage of boulders present, most likely placed during recent bridge construction.

Table 5. Percentage of different habitat and substrate types of creekline sites sampled in August 2019.

Site	Date	Mineral substrate	Emergent macrophyte	Submerged macrophyte	Floating macrophyte	Algal cover	Detritus	Trailing veg	Large woody debris
Mussels 1	21/08/19	60	10	0	0	0	10	15	5
Mussels 2	20/08/19	70	0	0	0	0	10	10	10
Mussels 3	20/08/19	60	10	0	0	0	10	10	10
Mussels 4	20/08/19	60	0	0	0	0	10	20	10
Mussels 5	21/08/19	60	10	0	0	0	5	5	20
Site	**Date**	**Bedrock**	**Boulders**	**Cobbles**	**Pebble**	**Gravel**	**Sand**	**Silt**	**Clay**
Mussels 1	21/08/19	0	10	5	5	5	10	10	55
Mussels 2	20/08/19	0	0	0	0	0	30	10	60
Mussels 3	20/08/19	0	0	0	10	20	40	10	20
Mussels 4	20/08/19	0	10	0	10	10	10	30	30
Mussels 5	21/08/19	0	5	5	0	5	5	5	75

North 1

North 2

North 3

North 5

Plate 6. Site photographs from North 1, 2, 3, 5, at the time of sampling in August 2019.

Mussels 1

Mussels 2

Mussels 3

Mussels 4

Mussels 5

Plate 7. Site photographs from Mussels 1, 2 3, 4 and 5 at the time of sampling in August 2019.

4.3 Black-stripe minnow

4.3.1 Abundance and population structure

A total of 164 black-stripe minnow (Plate 6) were recorded during the August 2019 survey, with the species present at all four sampling sites including North 5 within the investigation area. Introduced mosquitofish (*Gambusia holbrooki*) were also recorded during the survey, though only from site North 1. The black-stripe minnows collected ranged in length from 5 mm to 48 mm (SL), although the majority were between 31 mm - 35 mm (Figure 3). All individuals (minus a 5 mm new recruit) were displaying breeding colours (i.e. two distinctive lateral black stripes bordering a narrow band of orange; Plate 8) and many of the females recorded were gravid (carrying eggs).

Plate 8. Black-stripe minnow, *Galaxiella nigrostriata* in breeding colours (photo by WRM ©).

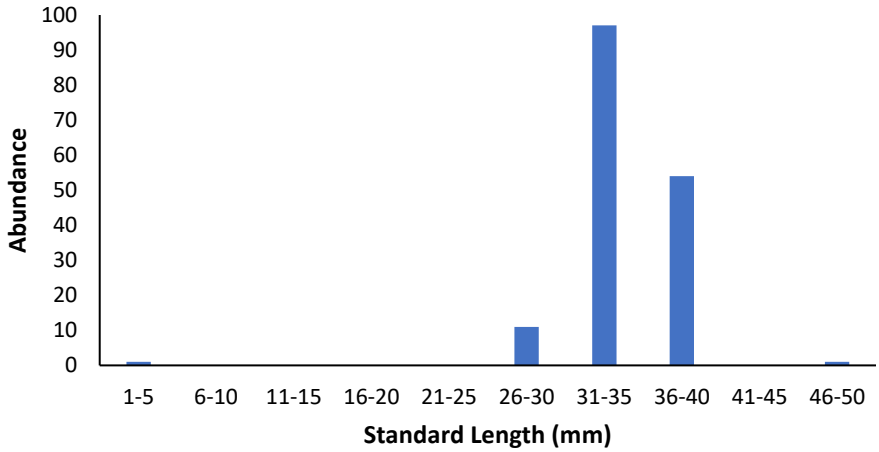

Figure 3. Standard length (mm) frequency graph of black-stripe minnows in August 2019.

4.3.2 Distribution of black-stripe minnow within and adjacent to the BORR northern and central investigation area

Targeted surveys for black-stripe minnow in November 2018 and August 2019 revealed that the black-stripe minnow is present at wetlands both within, and adjacent to, the northern and central investigation area (Figure 4). However, it appears restricted to an area near south-western end of the BORR central section (Figure 4) where there are a number of unaltered (i.e. not cleared, excavated or modified) wetlands within and just outside of the Manea Park bushland reserve. Suitable wetland habitats (e.g. unaltered, seasonal wetlands) are not present further north, with the majority of the remaining proposed central and northern alignment located on cleared farmland (WRM 2018).

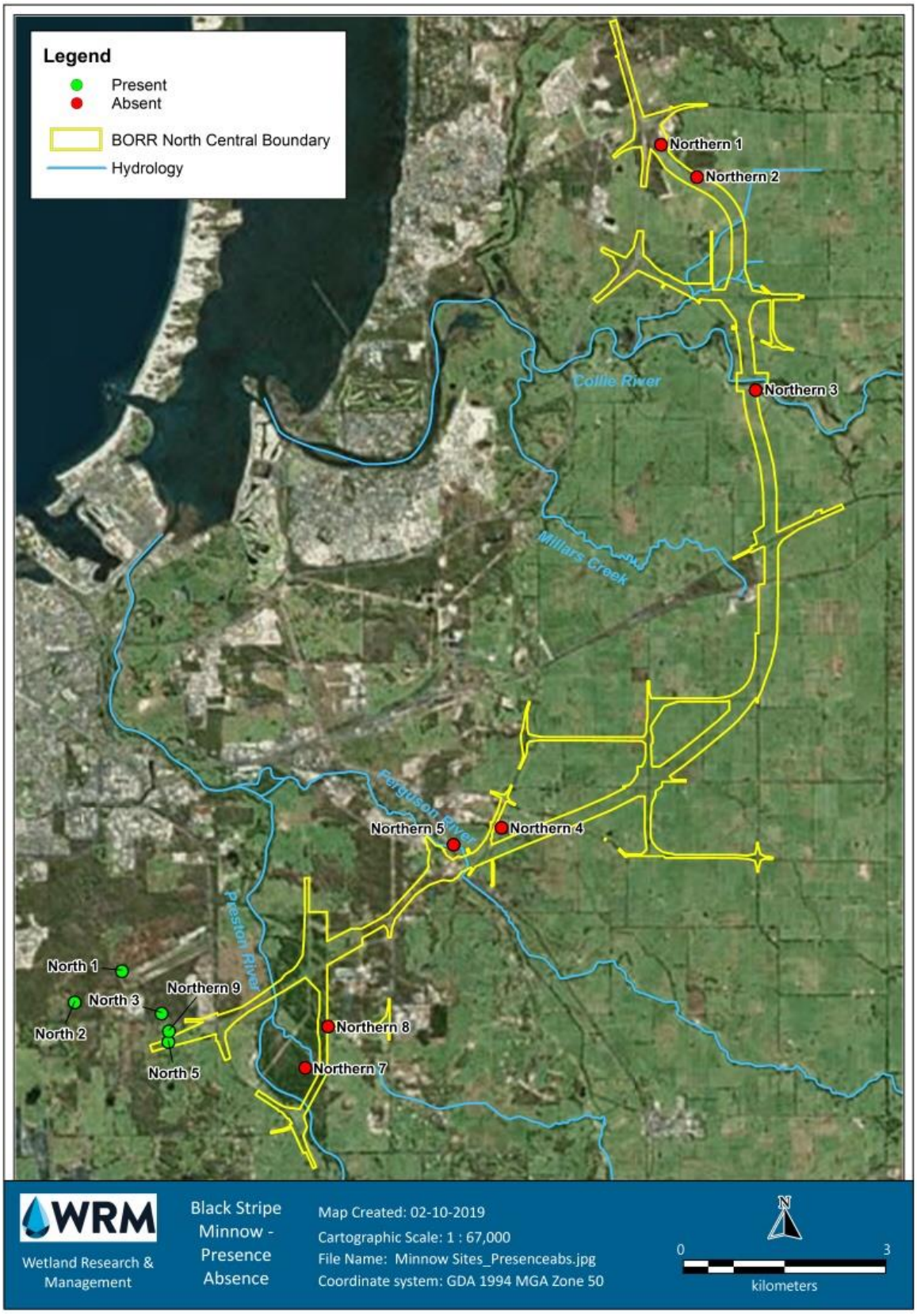

Figure 4. Summary of black-stripe minnow presence and absence within and adjacent to the northern and central investigation area (November 2018 and August 2019 records provided).

4.3.3 Regional distribution of black-stripe minnow, with notes on water quality and habitat preferences

The majority of *G. nigrostriata* populations are confined to peat flat wetlands of the Warren sub-region between Augusta and Albany in the extreme south-west corner of W.A. (Figure 5), though three isolated populations exist between Bunbury and Gingin on the Swan Coastal Plain (Lake Chandala *ca.* 55 km north-east of Perth, Melaleuca Park *ca.* 30 km north-east of Perth, and Kemerton Nature Reserve *ca.* 130 km south of Perth), intimating its historically-wider distribution (Figure 5). The discovery of black-stripe minnow during 2018 and 2019 surveys of the BORR northern central investigation area, as well as nearby wetlands in Gelorup within the BORR southern investigation area (WRM 2019 in prep.) and the BORR southern alternate alignment investigation area (WRM 2019a, Table 4, Figure 5), extends the distribution of this species on the Swan Coastal Plain approximately 30 km further south.

Black-stripe minnows inhabit tannin stained, vegetated wetlands of approximately 300 mm deep with a pH range of 3 - 8 (Galeotti *et al.* 2008). Other than these general observations, and anecdotal information, little is known about the preferred physio-chemical water properties of their habitats, with no correlations found between physio-chemical variables measured in wetlands across the south-west (Galeotti 2013). However, individual populations appear to be sensitive to sudden, localised changes in water quality variables (Knott *et* al. 2002). Little is known about the salinity tolerances for the black-stripe minnow, although the authors have previously recorded them in wetlands with salinity levels above 3330 µS/cm (Table 6). Table 6 outlines all the known water quality variables reported for sites where black-stripe minnows have been recorded in Western Australia.

Table 6. *In situ* water quality results from all sites with positive black-stripe minnow records (Green text highlights lowest of the range, orange text highlights highest of the range).

Reference	Site Code	Temp °C	Cond (µS/cm)	pH	DO (%)
Current study	Manea Park (North 1)	12.7	1878	7.35	55.6
Current study	Manea Park (North 2)	13.2	672	6.59	52.2
Current study	Manea Park (North 3)	16.2	1306	6.89	83.2
Current study	North Boyanup (North 5)	19.3	1005	6.67	127.2
WRM (2019b)	North Boyanup (Northern 9)	26.1	3360	7.70	109.7
WRM (2019a)	Gelorup (Wetland 1a&b)	22.0-25.0	983-1422	6.51-6.67	28.7-95.5
WRM (2019a)	Gelorup (Wetland 2)	21.1	855	6.68	170.8
WRM (2019a)	Gelorup (Wetland 3a&b)	19.0-22.7	365-596	6.52-6.62	57.7-103.9
WRM (2019a)	Gelorup (Wetland 4a&b)	18.8	278	6.42	49.5
WRM 2019 in prep.	Gelorup (South 8)	17.2	1391	7.13	52.2
WRM 2019 in prep.	Gelorup (South 11)	22.2	1427	7.60	92.2
Knott *et al.* (2002)	Melaleuca Park	12.8-17.0	3060-5000	3.3-5.0	40.0-70.0
Galeotti (2013)	Swan Coastal Plain	19.6±0.6	960±150	5.4±0.3	71±4.2
Galeotti (2013)	Warren sub-region	16.2±0.5	350±0.40	5.2±0.3	61±1.7

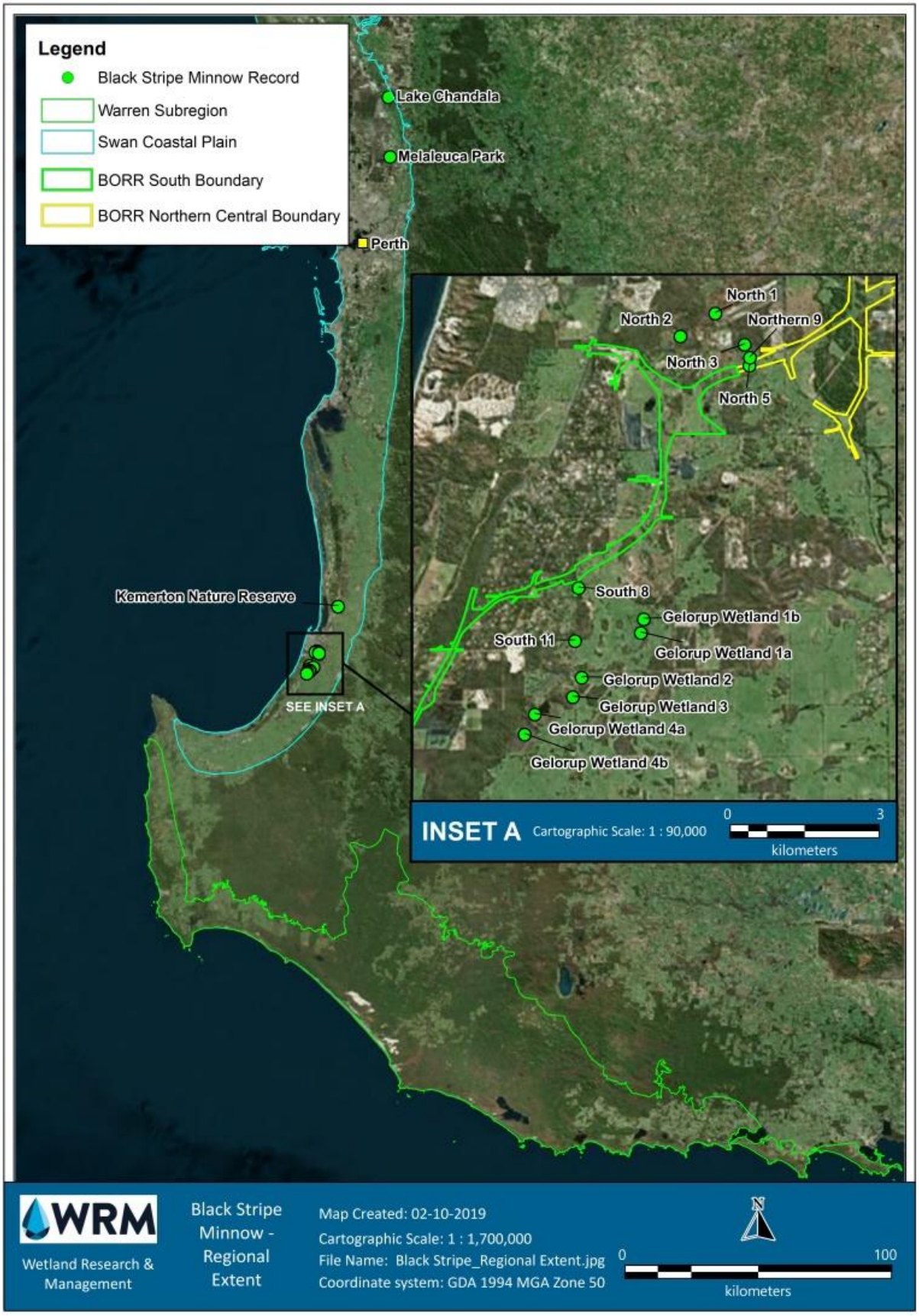

Figure 5. Regional distribution of black-stripe minnow. Note that the majority of populations are found in the Warren sub-region (green outlined area), but only four are known from the Swan Coastal Plain (blue outlined area), including that discovered during BORR aquatic fauna surveys.

4.4 Carter's freshwater mussel

4.4.1 Distribution of Carter's freshwater mussel within and adjacent to the BORR northern and central investigation area

During the August 2019 survey, Carter's freshwater mussels were recorded from sites Mussels 2 (Ferguson River upstream of the investigation area) and Mussels 3 (Ferguson River downstream of the investigation area) (Figure 6). There was an empty shell on the bank of site Mussels 1 (Preston River, within the investigation area), although no live specimens were recorded in the water (Figure 6). No live mussels were recorded at Mussels 4 (Ferguson River downstream of Mussels 3) or Mussels 5 (Preston River downstream of its confluence with the Ferguson River) (Figure 6). These sites have been modified recently due to bridge constructions and as such, large rocks are now submerged in the channel. The rocks occupy space on the substrate that mussels could utilise and may be the reason why mussels weren't recorded at the site.

During the November 2018 survey, Carter's freshwater mussel was recorded on the Ferguson River within the investigation area (site North Creek 5; Figure 6), and on the Preston River upstream of the investigation area (North Creek 2). They were also recorded within the upper reaches of Millars Creek (North Creek 4, adjacent the investigation area; Figure 6), as well as a small tributary of the Collie River near Raymond Road, downstream of the investigation area (North Creek 3; Figure 6). There are likely to be common within these systems. Carter's mussels were not recorded from the Collie River where the investigation area intersects the river (North Creek 1; Figure 6), likely due to the high salinity in the lower reaches of this system due to estuarine intrusion.

4.4.2 Regional distribution of Carter's freshwater mussel

Carter's freshwater mussel is endemic to the South West Coast Drainage Division, where it is the only freshwater mussel to be found. The distribution of this species is from the Moore River in the north, to the south coast, west of Esperance (Klunzinger *et al*. 2010).

Mussels filter large volumes of water, thereby removing nutrients and detritus from the water column. They are also a food source for water birds, freshwater crayfish and water rats (Morgan *et al.* 2011). Carter's freshwater mussel is highly sensitive to high salinity, with mortality known to occur at 4000 µS/cm (Bailey *et al.* 2002). These mussels have an early larval phase that is parasitic on the gills of native freshwater fish. Fish appear to be essential for completion of their life cycle.

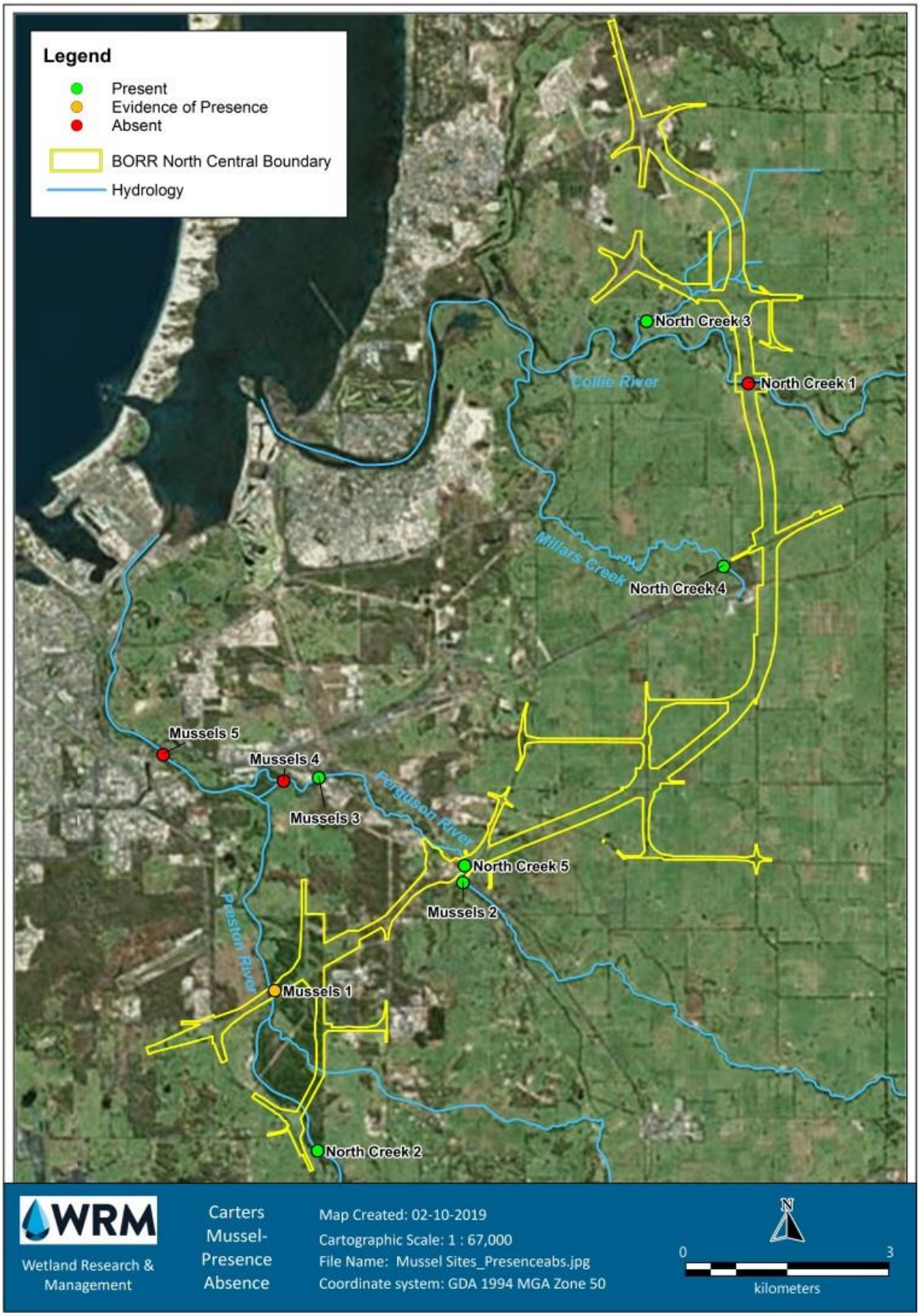

Figure 6. Summary of Carter's freshwater mussel presence and absence within and adjacent to the northern and central investigation area (November 2018 and August 2019 records provided).

4.5 Other fauna

4.5.1 Turtles

A total of 16 south-western snake-necked turtles, *Chelodina colliei*[4], were caught within the investigation area; five from North 1, three from North 2 and eight from North 3 (Plate 9). *Chelodina colliei* is endemic to the south-west of W.A. and is listed on the IUCN Redlist of Threatened Species as Near Threatened (IUCN 2020), although not listed on a state or national level. This species is restricted to the south-west of Western Australia, between the Hill River in the north, Blackwood River in the south, and east to the Sussetta River (Cann 1998). Throughout this range, snake-necked turtles are known to occur in both permanent and seasonal habitats, including rivers, lakes, farm dams, swamps, damplands and natural and constructed wetlands (Balla 1994, Guyot and Kuchling 1998). They can migrate relatively long distances overland if local conditions deteriorate (Dr Gerald Kuchling, UWA, pers. comm.) and can aestivate for up to six months to avoid drought in seasonal waterbodies (Kuchling 1988, 1989). Since their diet includes tadpoles, fish, and aquatic invertebrates, south-western snake-necked turtles only eat when open water is present. In permanent waters, this species has two nesting periods (September-October and December-January), but in seasonal systems, nesting will only occur in spring. Females can travel inland as far as 1 km to find appropriate nesting sites at this time (Clay 1981, Kuchling 1998). They generally nest in sandy soils, and eggs take up to two hundred days to hatch. The main threats to these turtles are road deaths during movement in the nesting season and predation by feral animals (Bencini and Turnbull 2012).

Plate 9. South-western snake-necked turtle recorded from Northern 8 (November 2018 survey).

Of the 16 turtles recorded, six were female, seven were male and three were juvenile. Thirteen were of size to be considered sexually mature. Clay (1981) indicates males reach sexual maturity at ≥ 130 mm CL and females at 160 mm CL.

4.5.2 Crustaceans

A total of three species of decapod crustaceans (freshwater crayfish) were recorded during the survey. Native species, gilgie (*Cherax quinquecarinatus*) and koonac (*Cherax preissii*); were recorded from North 1, 2 and 3. Neither of these species are listed for conservation significance, although both are south-west endemics, and have inland ranges that have been reduced due to salinisation

[4] This species was referred to as *Chelodina oblonga* in the past. However, there was some debate over species names and distributions. In 2013, the ICZN handed down its decision on nomenclature, with *C. colliei* given to the south-western snake-necked turtle, and *C. oblonga* given to the northern snake-necked turtle (previously *C. rugosa*).

(Morgan *et al*. 2011). One introduced species, the yabby (*Cherax destructor)* was recorded at North 1. This species is extremely adaptable to site conditions and is capable of burrowing down to the water table to survive dry conditions (Morrissy *et al.* 1984). It is also more tolerant than native species of extremes in temperature (Morrissy 1990), hypoxia (Morrissy *et al.* 1984, Holdich and Lowery 1988), and salinity. Since its introduction, the yabby has proven to be a highly successful invasive species and is spread throughout much of the southwest of the state (Lynas *et al.* 2004, 2007a). It has a highly aggressive nature and the potential for the yabby to out-compete native species has been well documented (Lynas *et al*. 2004, 2006, 2007a, 2007b). Due to their considerable negative impact on native freshwater species there are restrictions on the farming and movement of yabbies in Western Australia.

4.5.3 Balston's pygmy perch

No Balston's pygmy perch were recorded during the current or previous surveys of the study area. Historically, the distribution of Balston's pygmy perch ranged from the Moore River (north of Perth) to the Goodga River near Albany in the south, and the Collie River to the east. Balston's Pygmy Perch has been lost from the northern half of its range, including the Swan Coastal Plain, and is extremely rare or has been lost from many other rivers of the south-west, now occurring in just 13 primary locations between Margaret River and Two People's Bay (Morgan 2005, Department of the Environment 2020). There are old records of single populations in these outlier locations recorded in the early to mid – 1990s, however given recent extensive survey effort has failed to detect this species north of Margaret River (Morgan 2005, Department of the Environment 2020), and no Balston's pygmy perch were recorded during the current or previous surveys of the study area, there does not appear to be any habitat suitable for this species within the study area, and Balston's pygmy perch is highly unlikely to occur within the north/central investigation area.

4.5.4 Australian water rat

No Australian water rats were observed during the survey, nor was there any evidence of water rats (e.g. the presence of middens). Similarly, no water rats were recorded from the north/central investigation area in November 2018. Although not recorded in either 2018 or 2019 surveys, it is still considered likely that water rats could occur in the north/central investigation area, as the species is widely distributed across the south west of W.A., and a number of suitable wetland habitats exist for water rats in the investigation area, with intact riparian zones, good water quality and prey species such as freshwater crayfish.

5 CONCLUSIONS

A targeted aquatic fauna survey was completed within the northern and central investigation area for the Bunbury Outer Ring Road in August 2019 to supplement an initial targeted survey in November 2018. A total of four seasonal wetland sites were surveyed for the black-stripe minnow (listed as Endangered under both the federal EPBC Act 1999 and the State BC Act 2016); one within the investigation area, and three just outside but adjacent to the investigation area. Five creekline sites were visited for visual observations of Carter's freshwater mussel (listed as Vulnerable under the EPBC Act 1999 and the BC Act 2016).

Black-stripe minnows were recorded at all four seasonal wetland sites, with the presence of black-stripe minnows at site North 5 representing the first record of the species within the northern and central investigation area. Most of the aquatic habitat available for the black-stripe minnow within the survey area only receives surface water or has standing water immediately after persistent rainfall, and completely dry during summer. The majority of sites were bound by paperbarks, with emergent and submerged macrophytes present.

The discovery of this population (along with the previous discovery by WRM of a population at wetlands in Gelorup as part of BORR southern alternate alignment surveys) extends the Swan Coastal Plain distribution of black-stripe minnow approximately 30 km further south. There are only four known populations from the Swan Coastal Plain.

Loss of habitat, including habitat degradation and fragmentation is one of the most critical potential impacts to black-stripe minnow in the investigation area. There has been a considerable decline in the number of known extant populations and the geographical distribution of the black-stripe minnow, largely due to climate change and habitat loss (Ogston *et al.* 2016). Currently, information on aestivation duration, timing and physiological tolerances for the black-stripe minnow is unknown, however changes to water inundation extent and duration could alter the length of aestivation, thus adversely impacting reproduction and recruitment success.

Carter's freshwater mussels were recorded on the Ferguson and Preston rivers at locations within, upstream and downstream of the northern and central investigation area. They have also been recorded on other creeklines which the proposed road alignment intersects. Mussel larvae (glochidia) utilise fish to complete development and as a dispersal mechanism. Barriers to upstream movement of fish may restrict gene flow between mussel populations, limit upstream-downstream recruitment of mussels, restrict distributions and prevent recolonisation. Though Carter's freshwater mussel may be common locally in some areas, many populations are in decline due to habitat fragmentation or secondary salinisation (Morgan *et al.* 2012).

Freshwater mussels are sensitive to changes in environmental variables, such as salinity, nutrients and sedimentation (Klunzinger *et al.* 2012). Declines in mussel populations are due principally to a decline in quality of habitat resulting from secondary salinisation, seasonal water availability and increases in total nitrogen concentration. Physical disturbance of riverbeds and potential increases in turbidity and resuspension of organic material into the water column, could result in burying of individuals and would likely have a negative impact on freshwater mussel populations.

6 REFERENCES

Alabaster JS, Lloyd R (1982) Water quality criteria for freshwater fish. 2nd edition. pp. 127-142. London, England: Butterworth Scientific.

Allen GR, Midgley SH, Allen M (2002) *Field Guide to the Freshwater Fishes of Australia.* Western Australian Museum, Perth WA.

ANZG (2018) Guidelines for Water Quality Management. http://www.waterquality.gov.au/guidelines.

Australian Society of Fish Biology (2016) Conservation Status of Australian Fishes. http://www.asfb.org.au/commitees/threatened-species-committee/

Balla S (1994) Wetlands of the Swan Coastal Plain Volume 1: Their Nature and Management. Water Authority of Western Australia, and the Western Australian Department of Environmental Protection.

Beatty SJ, Morgan DL, Klunzinger M, Lymbery AJ (2010) Aquatic microfauna of Ellen Brook and the Brockman River: Freshwater refuges in a salinised catchment. A report to Ellen Brockman Integrated Catchment Group.

Beatty S, Ma L, Morgan D, Lymbery A (2017) Baseline assessment of Carter's Freshwater Mussel, *Westralunio carteri*, at proposed bridge construction site on the Lower Vasse River. A report to Strategen Environmental.

Bencini R, Turnbull A (2012) Monitoring a population of the Western Australian oblong turtle (*Chelodina oblonga*) at Lake Mabel Talbot, progress report 2012. School of Animal Biology, The University of Western Australia, Perth.

Bouck GR (1980) Etiology of Gas Bubble Disease. *Transactions of the American Fisheries Society* **109**: 703-707.

Butler B, Doudoroff P, Shumway DL (1970) Dissolved oxygen requirements of freshwater fishes. FAO Fisheries Technical Paper No. 86, 291 pp.

Cann J (1998) *Australian Freshwater Turtles*. Beumont Publishing, Singapore.

Cheal F, Davis J, Growns J, Bradley J, Whittles F (1993) The influence of sampling method on the classification of wetland macroinvertebrate communities. *Hydrobiologia* **257**: 47-56.

Clay B (1981) Observations on the breeding biology and behaviour of the long-necked tortoise *Chelodina oblonga. Journal of the Royal Society of Western Australia* **4**: 27-32.

Davis JC (1975) Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: A review. *Journal of Fisheries Research Board of Canada* **32**: 2295-2332.

Davis JA, Rosich RS, Bradley JS, Growns JE, Schmidt LG, Cheal F (1993) *Wetlands of the Swan Coastal Plain Volume 6: Wetland Classification on the Basis of Water Quality and Invertebrate Community Data*. Murdoch University and the Water Authority of Western Australia.

Department of Biodiversity, Conservation and Attractions (2020). Threatened and Priority Fauna List. February 2020.

Department of the Environment (2020). *Nannatherina balstoni* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: http://www.environment.gov.au/sprat. Accessed Thu, 2 Apr 2020

Department of Environment Sport and Territories, Land and Water Resources – Research and Development Corporation, Commonwealth Environment Protection Authority (1994) National River Processes and Management Program: Monitoring River Health Initiative. River Bioassessment Manual, Version 1.0. February 1994.

Donaldson A, Bennett A (2004) Ecological effects of roads: Implications for the internal fragmentation of Australian parks and reserves. Parks Victoria Technical Series No. 12. Parks Victoria, Melbourne.

Edward DHD, Gazey P, Davies PM (1994) Invertebrate community structure related to physico-chemical parameters of permanent lakes of the south coast of Western Australia. *Journal of the Royal Society of Western Australia* **77**: 51-63.

Galeotti DM, McCullogh CD, Lund MA (2008) Current state of knowledge of the black-stripe minnow *Galaxiella nigrostriatal* (Pisces: Galaxiidae) in Western Australia. Centre for Ecosystem Management report 2008-12.

Galeotti DM (2013) *Metapopulation theory explains black-stripe minnow (Pisces: Galaxiidae, Galaxiella nigrostriata) distribution in seasonal wetlands in south-western Western Australia*. Retrieved from https://ro.ecu.edu/theses/708

Guyot G, Kuchling G (1998) Some ecological aspects of populations of oblong turtles *Chelodina oblonga* in the suburbs of Perth (Western Australia) [In] *Le Bourget Du Lac*, Miaud C and Guyetant G (eds) Societas Europacea Herpetologica, France, pp. 173-181.

Holdich DM, Lowery RS (eds) (1988) Freshwater crayfish: biology, management and exploitation. Croom Helm London, UK.

IUCN (2020) IUCN Red List of Threatened Species. Version 2017.3. www.iucnredlist.org Downloaded in February 2020.

Klunzinger MW, Beatty SJ, Morgan DL, Lymbery R, Thomson GJ, Lymbery AJ (2010) Discovery of a host fish species for glochidia of *Westralunio carteri* Iredale, 1934 (Bivalvia: Unionoida: Hyrridae). *Journal of the Royal Society of Western Australia* **94**: 19-23.

Klunzinger MW, Beatty SJ, Morgan DL, Lymbery AJ, Pinder AM, Cale DJ (2012) Distribution of *Westralunio carteri* Iredale 1934 (Bivalvia: Unionoida: Hyriidae) on the south coast of southwestern Australia, including new records of the species. *Journal of the Royal Society of Western Australia* **95**: 77-81.

Knott B, Jasinka J, Smith K (2002). Limnology and aquatic fauna of EPP173, Melaleuca Park, refuge for an outlier population of the Black-stripe minnow *Galaxiella nigrostriata* (Galaxiidae), in southwestern Australia. *Records of the Western Australian Museum* **21**: 291-298.

Kuchling G (1988). Gonadal cycles of the Western Australian long-necked turtles *Chelodina oblonga* and *Chelodina steindachneri* (Chelonia: Chelidae). *Records of the Western Australian Museum* **14**: 189-198.

Kuchling G (1989). Assessment of ovarian follicles and oviducal eggs by ultra-sound scanning in live freshwater turtles, *Chelodina oblonga*. *Herpetologica* **45**:89-94.

Lynas J, Lindhjem P, Storey AW, Knott B (2004) Is the yabby, *Cherax destructor* (Parastacidae) in Western Australia an ecological threat? *Freshwater Crayfish* **14:** 37–44.

Lynas J, Storey AW, Armstrong K, Prince J, Knott B (2006) Invasion by the exotic crayfish, *Cherax destructor* Clark (Parastacidae) into habitats of local crayfish near Perth, Western Australia. *Freshwater Crayfish* **15:** 176–188.

Lynas J, Storey AW, Knott B (2007a) Introductions and spread of freshwater crayfish (Parastacidae) in Western Australia, and the potential for displacement of indigenous species. [In] Gherardi F (ed) *Biological Invaders in Inland Waters: Profiles, Distribution and Threats*. Springer. Chapter 31, 577-596.

Lynas J, Storey AW, Knott B (2007b) Aggressive interactions between three species of freshwater crayfish of the genus *Cherax* (Decapoda: Parastacidae). *Marine and Freshwater Behaviour and Physiology* **40**: 105-116.

MBS Environmental (2009). Kemerton Silica Sand: Public Environmental Review Extension of Kemerton Silica Sand, Dredge Mining. A report prepared for Kemerton Silica Sand Pty. Ltd.

Morgan DL, Gill HS, Potter IC (1998) Distribution, identification and biology of freshwater fishes in south-western Australia. *Records of the Western Australian Museum*. Supplement No. 56. Western Australian Museum, Perth.

Morgan DL, Gill HS (2000) Fish associations within the different inland habitats of lower south-western Australia. *Records of the Western Australian Museum* **20**: 31-37.

Morgan, D. (2005). Nomination form for listing changing the status, or delisting a native species under the Environment Protection and Biodiversity Conservation Act 1999 *(EPBC Act) Nannatherina balstoni*

Morgan DL, Beatty SJ, Klunzinger MW, Allen MG, Burnham QF (2011) *A field guide to freshwater fishes, crayfishes and mussels of southwestern Australia*. SERCUL and Freshwater Fish Group, Perth WA.

Morrissy NM, Caputi N, House RR (1984) Tolerance of marron (*Cherax tenuimanus*) to hypoxia in relation to aquaculture. Aquaculture **41:** 61–74.

Ogston G, Beatty S, Morgan D, Pusey B, Lymbery A (2016) Living on burrowed time: Aestivating fishes in south-western Australia face extinction due to climate change. *Biological Conservation* **195:** 235-244.

Smith K, Knott B, Jaskina E (2002) Biology of the Black-stripe minnow *Galaxiella nigrostriatal,* (Galaxiidae) in acidic, black-water lake in Melaleuca Park near Perth, Western Australia. *Records of the Western Australian Museum* **21**: 277-284.

Storey AW, Halse SA, Shiel RJ (1993) Aquatic invertebrate fauna of the Two Peoples Bay area, southwestern Australia. *Journal of the Royal Society of Western Australia* **76**: 25-32.

WRM (2019a) Bunbury Outer Ring Road: Targeted Conservation Significant Aquatic Fauna Survey 2018. Unpublished final v2 report by Wetland Research & Management to BORR Team Pty Ltd. January 2019.

WRM (2019b) Bunbury Outer Ring Road Northern and Central Investigation Area: Targeted Conservation Significant Aquatic Fauna Survey 2018. Unpublished final report by Wetland Research & Management to BORR Team Pty Ltd. April 2019.

WRM (2019c) Bunbury Outer Ring Road Southern Alignment: Targeted Conservation Significant Aquatic Fauna Survey 2018. Unpublished final report by Wetland Research & Management to BORR Team Pty Ltd. September 2019.