Alcoa of Australia Ltd

Pinjarra Alumina Refinery Revised Proposal

Aquatic Fauna Desktop Assessment for Myara North and Holyoake Regions

Final Report September 2021

Aquatic Fauna Desktop Assessment for Myara North and Holyoake Regions

Prepared for:

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Frontispiece: Jack Rocks on 39 Mile Brook, Myara North region.

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SUMMARY

Alcoa of Australia Limited (Alcoa) is proposing to increase production at the Pinjarra Alumina Refinery by 5 per cent from 5.0 million tonnes per annum (Mtpa) to 5.25 Mtpa and transition the Huntly Bauxite Mine to the proposed Myara North and Holyoake mine regions (the Proposal). The Proposal is located in the Peel Region of Western Australia (WA), approximately 100 km southeast of Perth.

The Proposal will be subject to environmental impact assessment under Part IV of the WA *Environmental Protection Act 1986* (EP Act), and the *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act). The environmental impact assessment will be via a Public Environmental Review (PER).

Huntly Mine lies in the Northern Jarrah Forest (NJF) sub-region, and is predominantly within State forest managed for multiple uses including conservation, recreation, timber production and water supply. The Myara North region is adjacent to Jarrahdale townsite and lies within the drinking water catchment area of the Serpentine Dam. It is bordered by Monadnocks Conservation Park to the north-east and Serpentine National Park to the west. The Holyoake region lies approximately 5 km east of Dwellingup and is located within the drinking water catchment of the South Dandalup Dam.

Alcoa engaged GHD Pty Ltd (GHD) to prepare the environmental approval documentation and supporting technical studies for the Proposal. One of these technical studies was a desktop aquatic fauna assessment for which GHD sub-contracted Wetland Research & Management (WRM). The current report presents the findings of the aquatic fauna desktop assessment, which identifies potential aquatic fauna habitats and species. The primary focus for this assessment is the Myara North region, with a secondary focus on the Holyoake region, and includes all relevant available information within a 50 km radius of each region. The review has synthesised over 30 consultancy reports that document relevant aquatic fauna survey work, nine scientific journal publications, and data from publicly available government and academic databases. Experts at the Department of Biodiversity Conservation and Attractions (DBCA), the Department of Water and Environmental Regulation (DWER), and The Centre for Fish and Fisheries Research (CFFR, Murdoch University) were also contacted directly for any additional survey data. Additional data were available from DWER.

Historic studies have included four sites within the Myara North region (BF01, SN04, SWA04, 39MB) and one within the Holyoake region (MY44). Potential aquatic ecological values were therefore broadly inferred from the numerous studies that have been conducted in similar adjacent regions in State forest in the upper Wungong, Serpentine, and North and South Dandalup River catchments of the NJF. These are summarised below.

Myara North Region

Aquatic fauna habitats of the Myara North region are likely dominated by first-order seasonal creeklines and ephemeral headwater swamps/damplands. In higher rainfall years, baseflow in higher-order streams may maintain isolated pool refuges over summer. Aquatic fauna communities are expected to be characterised by a high degree of seasonality and high level of species endemicity.

Known Values	• Inflow Dependent Ecosystems • Groundwater Dependent Ecosystems

Potential Values	• Seasonal connectivity of headwaters for reproductive migration of native fish (western minnow) and habitat for native freshwater crayfish (gilgies and koonacs) • Minute freshwater snail *Glacidorbis occidentalis* (P3) • Hyporheic zone affords seasonal feeding habitat for stygal amphipods (*Uroctena* sp., *Wesniphargus nichollsi*) that are potential SREs
	• Forested catchment maintains high water quality, particularly low salinity and sediment loads • High beta diversity - characteristic of interconnected ephemeral, seasonal and permanent (*e.g.* Serpentine reservoir) waterways • Drought refuges in headwater streams • High endemicity in macroinvertebrate fauna • Carter's freshwater mussel *Westralunio carteri* (EPBC Act Vulnerable, WA BC Act Vulnerable) • Rakali *Hydromys chrysogaster* (P4) • Habitat for candidate priority dragonflies and damselflies with rare and/or restricted distributions • Potential seasonal spawning habitat for western pygmy perch and nightfish

Holyoake Region

The Holyoake region is expected to support similar diversity of aquatic habitats to the Myara North region, with aquatic fauna communities characterised by a high degree of seasonality and high level of species endemicity. Holyoake is within the eastern boundaries of the high rainfall zone (HRZ) where groundwater discharge has historically played a greater role in streamflow generation. However, surface-groundwater connection may not be as strong as in Myara North as the latter extends further west than Holyoake and has relatively deeper valleys and generally lower forest cover due to dieback and past forest harvesting (A. Grigg, Alcoa, pers. comm., 2020). There are strong resemblances between Holyoake and the long-studied Camerons research catchments to the immediate north of Holyoake, and the Yarragil catchments to the immediate south, where in both cases groundwater is well below the valley floors (A. Grigg, Alcoa, pers. comm., 2020).

Known Values	• Inflow Dependent Ecosystems • Connectivity to one of the last remaining unregulated (un-dammed) rivers in the NJF (Murray River)
Potential Values	• Groundwater Dependent Ecosystems • Seasonal connectivity of headwaters for reproductive migration of several native fish species and habitat for native freshwater crayfish (gilgies, koonacs, smooth marron) • Forested catchment maintains high water quality, particularly low salinity and sediment loads • High beta diversity - characteristic of interconnected ephemeral, seasonal and permanent waterways • Drought refuges in headwater streams • High endemicity in macroinvertebrate fauna • Carter's freshwater mussel *Westralunio carteri* (EPBC Act Vulnerable, WA BC Act Vulnerable) • Pouched lamprey *Geotria australis* (P1) • Minute freshwater snail *Glacidorbis occidentalis* (P3) • Rakali *Hydromys chrysogaster* (P4)

- Stygal amphipods (*Uroctena* sp., *Wesniphargus nicholIsi*) and isopods (*Hyperoedesipus plumosus*) that are potential SREs
- Habitat for candidate priority dragonflies and damselflies with rare and/or restricted distributions
- Potential seasonal spawning habitat for western pygmy perch and nightfish

Knowledge Gaps

Although aquatic fauna in surrounding areas of the NJF have been surveyed, populations within the Myara North and Holyoake regions have been historically understudied. As such, there is very little information on extant aquatic species, their distribution, conservation status and local hydro-ecological relationships. At a higher level, potential impacts of future hydrological change or disturbance by the Proposal can be inferred based on longitudinal studies of macroinvertebrates for the existing Huntly and Willowdale mines. These studies found no detrimental impact from mining, though communities did respond to consistent downward trends in rainfall over the study period.

Few sites have previously been surveyed in Myara North and only one in Holyoake. The data generated by the limited surveys, which effectively only capture a 'snap-shot' of the aquatic ecology, are likely insufficient for adequate characterisation of aquatic fauna values regions. Both regions undoubtedly support relatively undisturbed riparian habitats, that in turn potentially support a high diversity of aquatic invertebrate fauna, including endemic, locally restricted, and/or conservation listed species. Although it could be inferred from the available data from adjacent, better studied catchments, that conservation significant species (*Westralunio carteri*, *Geotria australis*, *Glacidorbis occidentalis*, *Hydromys chrysogaster* and stygal species) may occur within both Myara North and Holyoake because these regions are within the broader distribution of those species, this needs to be supported by location-specific data. The presence of suitable headwater swamps and hyporheic habitats that may support candidate priority or stygal species is also unknown, as is the presence of any long-term pools, or small seeps or springs that may act as summer refuges.

1. INTRODUCTION

1.1 Background

Alcoa of Australia Limited (Alcoa) is proposing to increase production at the Pinjarra Alumina Refinery by 5 per cent from 5.0 million tonnes per annum (Mtpa) to 5.25 Mtpa and transition the Huntly Bauxite Mine to the proposed Myara North and Holyoake mine regions (the Proposal). The Proposal is located in the Peel Region of Western Australia (WA), approximately 100 km southeast of Perth.

The Proposal will be subject to environmental impact assessment under Part IV of the WA *Environmental Protection Act 1986* (EP Act), and the *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act). The environmental impact assessment will be via a Public Environmental Review (PER).

1.2 Proposal Overview

Alcoa propose to gradually increase alumina production at the Pinjarra Alumina Refinery through ongoing efficiency upgrades. Alumina will continue to be refined from bauxite using the Bayer process. The Alinta Cogeneration project will continue to supply some of the refinery's steam requirements and generate electrical power for customers in the South West Interconnected System (SWIS). Alumina product will continue to be transported *via* rail to Bunbury Port for export.

Alcoa propose to transition the Huntly Mine operations by moving over the next 25 years first into the Myara North region, and then the Holyoake and East Murray regions (see Figure 1). Huntly Mine lies predominantly within State forest, in the Northern Jarrah Forest (NJF) sub-region, managed for multiple uses under the Regional Forest Agreement (RFA) and Forest Management Plan (FMP). Uses include conservation, recreation, timber production and water supply.

The mining sequence will comprise initial harvest of commercial timber by the Forest Products Commission, with the remaining timber used by third-party customers or burnt. Topsoil and overburden will then be stripped and either re-used immediately in an area prepared for rehabilitation or stockpiled for later re-use. Bauxite will be extracted typically to depths of 3 - 4m, crushed and delivered by conveyor to the Pinjarra refinery. Rehabilitation will be undertaken progressively, involving landscaping of the pit walls and floor, overburden and soil return in the correct sequence, surface tillage and broadcasting of seed and fertiliser, and planting of nursery-raised seedling stock. Rehabilitation of the topography/landform is typically completed within 2 - 4 years from clearing.

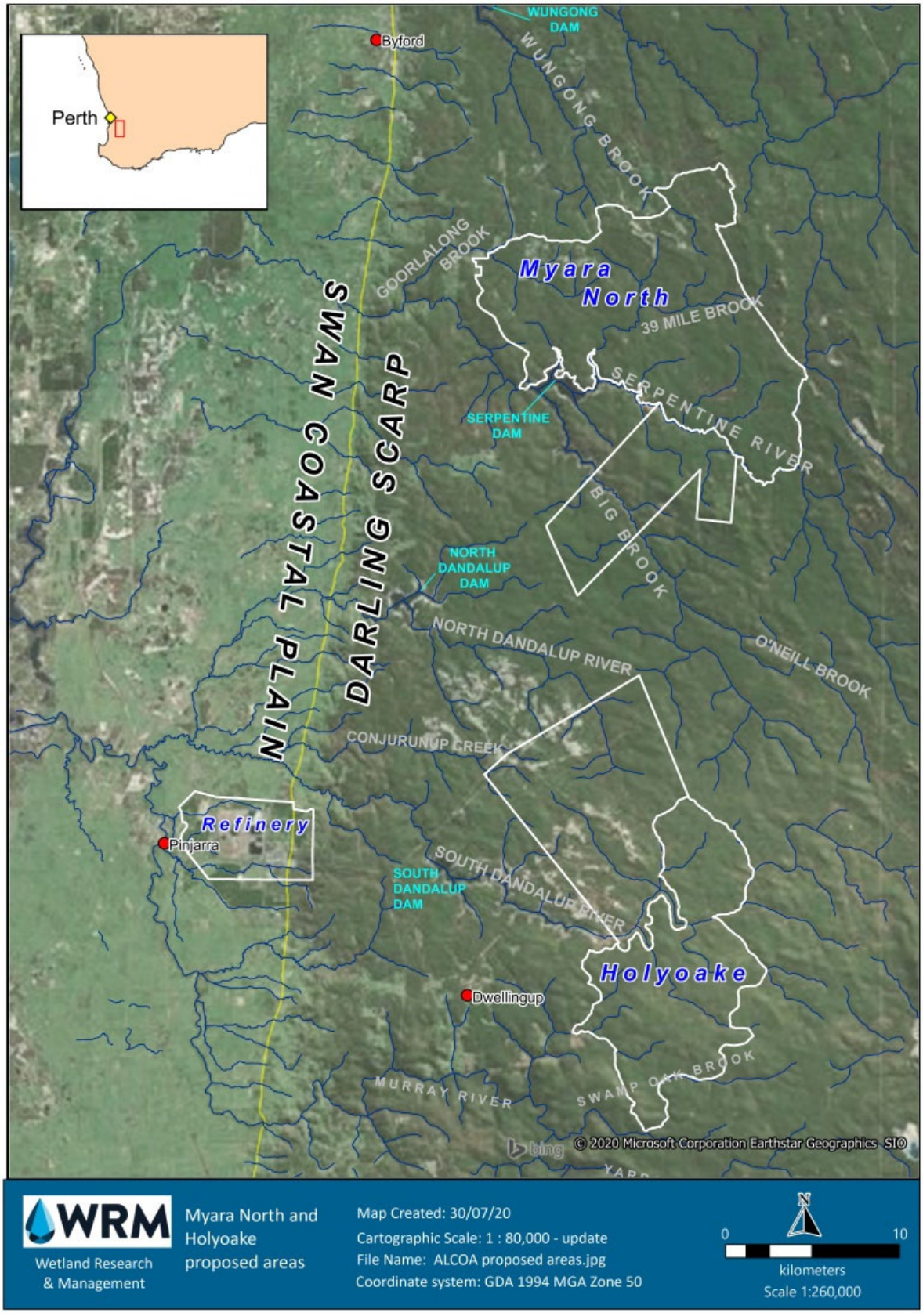

Figure 1. Overview of study area.

1.3 Background to this Desktop Assessment

Alcoa engaged GHD Pty Ltd (GHD) to prepare the environmental approval documentation and supporting technical studies (the Project) for the Alcoa Proposal under the EP Act and EPBC Act. The Project includes detailed environmental studies for the Myara North and Holyoake regions.

One of the technical studies is a desktop aquatic fauna assessment for the Myara North and Holyoake regions to identify potential presence of aquatic fauna habitats and species in the areas. GHD sub-contracted Wetland Research & Management (WRM) to conduct the desktop aquatic fauna assessment.

1.4 Scope of Work for the Desktop Assessment

The aim of the desktop assessment was to determine, as far as possible, the ecological values of the waterways within the Myara North and Holyoake regions, and outline any knowledge/sampling gaps and data uncertainty for each area. The desktop assessment was to focus primarily on Myara North (as mining will transition first into this region), but to also include Holyoake.

The scope of work for the assessment was to review existing information for the study area, upper Serpentine and South Dandalup rivers, and similar river catchments of the jarrah forest to identify the potential aquatic fauna habitats and species that may be present in the study area. The review was to include all available data including databases, literature and geospatial information, including but not limited to the following:

- Aquatic ecology surveys and monitoring undertaken by Alcoa elsewhere in the jarrah forest/Darling Plateau;
- Aquatic fauna biodiversity assessments commissioned by the Water Corporation for the Wungong Catchment Trial Project (WCT) (2005 - 2012);
- DAWE Protected Matters database to identify species listed under the EPBC Act (*e.g.* Carters freshwater mussel *Westralunio carteri*);
- WA Department of Primary Industries and Regional Development (DPIRD), formerly Department of Fisheries, database of freshwater fish distribution.

1.5 Legislative Framework

Relatively few aquatic species in Western Australia are listed as threatened or endangered under the EP Act or EPBC Act. Aquatic invertebrates in particular, have historically been under-studied. Lack of knowledge of their distributions often precludes aquatic invertebrates for listing as threatened or endangered.

The EPA has determined to assess the Proposal under Part IV of the EP Act *via* a Public Environmental Review (PER). In determining to assess the Proposal, the EPA has identified *Inland Waters* and *Terrestrial Fauna* as preliminary key environmental factors to be considered in the PER, and has noted the potential significant effects to include:

> "The revised proposal has the potential to impact on Flora and Vegetation and Terrestrial Fauna through clearing of up to 6,710 ha of native vegetation and fauna habitat. The proposed mining areas lie over the catchment areas of developed reservoirs that are used for drinking water, which may lead to impacts on Inland Waters."

The *Inland Waters* factor encompasses:

> "The occurrence, distribution, connectivity, movement, and quantity (hydrological regimes) of inland water including its chemical, physical, biological and aesthetic characteristics (quality)" (EPA 2018).

The *Terrestrial Fauna* factor encompasses:

> "Terrestrial fauna are defined as animals living on land or using land (including aquatic systems) for all or part of their lives. Terrestrial fauna includes vertebrate (birds, mammals including bats, reptiles, amphibians, and freshwater fish) and invertebrate (arachnids, crustaceans, insects, molluscs and worms) groups." (EPA 2016).

Inland Waters are considered to include groundwater systems, wetlands, estuaries, and any river, creek, stream or brook (and its floodplain), including systems that "flow permanently, for part of the year or occasionally, and parts of waterways that have been artificially modified" (EPA 2018). The objective for this factor is "to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected" (EPA 2018).

Environmental value is defined under the EP Act as a beneficial use or an ecosystem health condition. The EPA (2018) identify the ecosystem health values related to *Inland Waters* as including the ability to sustain vegetation, aquatic fauna and birdlife and the ecological processes that support them. For the purposes of impact assessment for ecosystem health, the EPA focusses on impacts to significant ecosystems, which include (EPA 2018):

- Ramsar Wetlands of International Importance,
- Conservation category or Resource enhancement management wetlands mapped on the Swan Coastal Plain,
- wetlands listed in the Directory of Important Wetlands in Australia,
- wetlands protected by Environmental Protection Policies under the EP Act,
- wild rivers, as identified by the Australian Heritage Commission and DWER,
- wetland types which may be poorly represented in the conservation reserves system,
- springs and pools, particularly in arid areas,
- ecosystems which support significant flora, vegetation and fauna species or communities, including migratory waterbirds, bats, and subterranean fauna,
- ecosystems which support significant amenity, recreation and cultural values,
- saline lakes, estuaries and near shore ecosystems reliant on groundwater or surface water inputs, and
- downstream marine ecosystems.

The EPA's objective for the *Terrestrial Fauna* factor is "to protect terrestrial fauna so that biological diversity and ecological integrity are maintained" (EPA 2016). EPA define ecological integrity as "the composition, structure, function and processes of ecosystems, and the natural range of variation of these elements". Considerations for EIA for the factor *Terrestrial Fauna* include, but are not necessarily limited to:

- application of the mitigation hierarchy to avoid or minimise impacts to terrestrial fauna, where possible,
- the terrestrial fauna affected by the proposal,
- the potential impacts and the activities that will cause them, including direct and indirect impacts,

- the implications of cumulative impacts,
- whether surveys and analyses have been undertaken to a standard consistent with EPA technical guidance,
- the scale at which impacts to terrestrial fauna are considered,
- the significance of the terrestrial fauna and the risk to those fauna,
- the current state of knowledge of the affected species/assemblages and the level of confidence underpinning the predicted residual impacts, and
- whether proposed management approaches are technically and practically feasible.

2. APPROACH

2.1 Literature Searches

Past aquatic and relevant aquatic biology survey reports were sourced and reviewed as part of the desktop assessment. This included, but was not limited to, relevant scientific reports and studies that have been undertaken on a local and regional scale, together with published and grey literature (Table 1). Locations of study areas are shown in Appendix 1. Various databases (see section 2.2) were searched for relevant records within/in close proximity to the study area.

Table 1. Aquatic biology reports relevant to the study area, arranged by year of publication.

Reports and Journal Publications	Author	Year
First record of a petalurid dragonfly from Western Australia	Watson	1957
Community structure and functional organization of streams of the northern jarrah forest, Western Australia. PhD Thesis, Department of Zoology, The University of Western Australia	Bunn	1985
Spatial and temporal variation in the macroinvertebrate fauna of streams of the northern jarrah forest, Western Australia	Bunn	1986
Spatial and temporal variation in the macroinvertebrate fauna of streams of the northern jarrah forest, Western Australia: Community structure	Bunn *et al*.	1986
Life histories of some benthic invertebrates from streams of the northern jarrah forest, Western Australia	Bunn	1988
The association of *Glacidorbis occidentalis* (Gastropoda: Glacidorbidae) with intermittently-flowing forest streams in south-western Australia	Bunn *et al.*	1989
Stream Fauna Studies: Results and Recommendations 1984 - 1988	ARL	1989
Spatial variation in fish communities in two south-western Australian river systems	Pusey *et al.*	1989
Classification of the macroinvertebrate fauna of two river systems on southwestern Australia in relation to physical and chemical parameters	Storey *et al*.	1990
Population status of the rare dragonfly *Petalura hesperia* on the Darling Range and Swan Coastal Plain, Western Australia	Brown *et al.*	1996
Baseline Biomonitoring of Aquatic Fauna and Water Chemistry of Creeks in the Willowdale and Cameron Corridor Areas of Operation 1995 - 1996	Streamtec	1997
Distribution of the Western Petalura dragonfly *Petalura hesperia* Watson in Western Australia	Barrett & Williams	1998
Aquatic Biomonitoring in the Cameron Corridor Area of Operation: Baseline Survey 2000	Streamtec	2000
Aquatic Biomonitoring in the Cameron Corridor Area of Operation: Baseline Survey 2001	Streamtec	2001
Aquatic Ecosystem Surveys of Brooks in the Willowdale North Area Baseline and Monitoring Surveys 1995, 1996 and 2003	Creagh *et al.* (Streamtec)	2003
Baseline Aquatic Ecosystem Surveys in the Cameron Corridor area: 1995 - 2003	Creagh *et al.* (Streamtec)	2004
Cameron Corridor and Jayrup Project Area: Stream zone monitoring Spring 2005	WRM	2006
Willowdale North Project Area: Stream Zone Monitoring Spring 2005	WRM	2006
Wungong Catchment [Trial] Environment and Water Management Project: Aquatic Fauna Biodiversity Assessment December 2005	Storey & Creagh (ARL)	2006
Western Petaltail Dragonfly: Survey for *Petalura hesperia* on Manjedal Brook and Surrounds 2007	WRM	2007

Reports and Journal Publications	Author	Year
Wungong Catchment Environment and Water Management Project: Aquatic Fauna Biodiversity Assessment October 2006	Storey & Creagh (ARL)	2007
Wungong Catchment Trial Project: Aquatic Fauna Biodiversity Assessment October 2007	Storey & Creagh (ARL)	2008
Cameron Corridor and Jayrup Project Area: Stream Zone Monitoring Spring 2007	WRM	2008
Wungong Catchment Trial Project: Aquatic Fauna Biodiversity Assessment September 2008	Storey & Creagh (ARL)	2009
Wungong Catchment Trial Project: Aquatic Fauna Biodiversity Assessment October 2009	Davies & Storey (ARL)	2010
Cameron Corridor and Jayrup Project Area: Stream Zone Monitoring Spring 2009	WRM	2010
Wungong Catchment Trial Project: Aquatic Fauna Biodiversity Assessment October 2010	ARL	2011
Effects of catchment clearing and sedimentation on macroinvertebrate communities of cobble habitat in freshwater streams of southwestern Australia.	Armstrong *et al*.	2011
Temporal Persistence in Northern Jarrah Forest Aquatic Macroinvertebrate Communities - Preliminary Investigation of Response to Declining Rainfall	Davies & Storey	2012
Mitigating the Impact of Serpentine Pipehead Dam Works on Carter's Freshwater Mussel	Klunzinger *et al.*	2012
Range decline and conservation status of Westralunio carteri Iredale, 1934 (Bivalvia: Hyriidae) from south-western Australia	Klunzinger *et al.*	2014
Serpentine River Ecological Condition Assessment Spring 2012	WRM	2012
North and South Dandalup River and Conjurunup Brook Ecological Condition Assessment Spring 2012	WRM	2013
Wungong Catchment Trial: Aquatic Fauna Biodiversity Assessment October 2011	WRM	2013
Wungong Catchment Trial: Aquatic Fauna Biodiversity Assessment October 2012	WRM	2013
Ecological Condition of Streams in South-west Forests	Pennifold	2013
Willowdale North Project Area: Streamzone Monitoring Spring 2011	WRM	2013
Cameron Corridor and Jayrup Project Areas: Stream Zone Monitoring Spring 2011	WRM	2013
Cameron Corridor and Jayrup Project Areas: Stream Zone Monitoring Spring 2014	WRM	2015
Range decline and conservation status of *Westralunio carteri* Iredale, 1934 (Bivalvia: Hyriidae) from south-western Australia	Klunzinger *et al.*	2015
Willowdale North Project Area: Streamzone Monitoring Spring 2015	WRM	2016
Whole-landscape modelling of compositional turnover in aquatic invertebrates informs conservation gap analysis: An example from Western Australia	Pennifold *et al.*	2017
Identifying Priority Species Within the South-western Australian Aquatic Invertebrate Fauna	Pennifold	2018
North and South Dandalup River and Conjurunup Creek Ecological Condition Assessment 2018/19	WRM	2019
Serpentine River Ecological Condition Assessment Spring 2019	WRM	2019
Streamzone Monitoring 2019 Cameron Corridor and O'Neil Project Areas	WRM	2020

2.2 Database Searches

Table 2 lists the databases searched to ascertain aquatic fauna distribution and significance of relevance to this desktop assessment.

Table 2. Databases searched.

Database	Description	Authority	Area of Search/ Species
Threatened Flora, Fauna and Ecological Communities	Search was requested by GHD on 10th June 2020 (see Appendix 2)	DBCA	50 km radius of study area
NatureMap	Search conducted by WRM on 2nd July 2020 (see Appendix 2)	DBCA and WAM	50 km radius of study area
Freshwater Fish Distribution in Western Australia	Search conducted by WRM on 23rd June 2020	DBIRD	All freshwater fish species
The Australian Faunal Directory (AFD)	Utilised in assessing taxonomic status and distribution of aquatic fauna	Australian Biological Resources Study (ABRS; an initiative of DAWE)	All relevant species
Atlas of Living Australia (ALA)	Search conducted by WRM on 24th June 2020 Utilised in assessing taxonomic status and distribution of aquatic fauna	Collaborative project between academic, private and community groups.	10 km radius of study area

2.3 Limitations and Assumptions

Table 3 below summarises the potential limitations and constraints affecting the current aquatic fauna desktop assessment.

Table 3. Summary of limitations and constraints for the desktop assessment.

Limitation	Constraint? (yes or no)	Comment
Entire scope of works achieved	No	All activities outlined in the scope of works were able to be completed.
Resources and personnel	No	The desktop assessment was conducted by Senior Ecologist Nicole Carey who has 6+ years' experience in conducting aquatic fauna assessments, specifically the jarrah forest of WA.
		The project manager, Susan Davies (Principal Scientist, WRM) has 30+ years' experience in aquatic fauna assessment in WA, and was responsible for overseeing and assisting in the preparation of this desktop assessment.
		Dr Andrew Storey (Director and Principal Scientist, WRM) has 30+ years' experience in aquatic fauna assessment in WA, and was responsible for high level technical advice and internal review of the current report.
Availability of information	No	All online databases and government websites were able to be accessed.

Limitation	Constraint? (yes or no)	Comment
		DBCA, the WA Department of Water and Environmental Regulation (DWER), and The Centre for Fish and Fisheries Research (CFFR, Murdoch University) were all contacted directly for any relevant survey data additional to that sourced in the database searches. The only additional data available were those provided by DWER.
		All reports by WRM, Streamtec Pty Ltd, and the Aquatic Research Laboratory (ARL, the University of Western Australia) for surveys in catchments within and adjacent to the study area were available for the assessment.
Database incompleteness	Yes	It was noted that database records were not always consistent across ALA and NatureMap, with some records existing in one database but not the other. It is possible that additional records of aquatic species have been collected and have not been included in either database.

3. AQUATIC FAUNA OVERVIEW

In relation to ecosystem health values for Inland Waters as applied in EIA (section 1.5), significant aquatic ecosystems present or potentially present within the Myara North and Holyoake regions include:

- Wetland types which are poorly represented in the conservation reserves system, *i.e*. ephemeral and seasonal headwater swamps and first-order streams;
- Springs and pools in low rainfall zones where permanent waterbodies are otherwise scarce;
- Hyporheic zones which support subterranean fauna, *i.e.* stygal amphipods and isopods.

Seasonal and ephemeral waterways which likely dominate most of the Myara North and Holyoake catchments, are under-represented in the State formal conservation estate as a whole. They are likely better represented in the informal reserves of State forest within the NJF, which protect an estimated 20 - 25% of the ecological environments within them (Pennifold *et al*. 2017). However, a growing number of scientists consider far higher proportional protection is required if ecological processes and services are to be maintained over the long-term, especially under a changing climate (Bush *et al.* 2014, Locke 2014, Woodley *et al.* 2019).

Seasonal and ephemeral waterbodies support important ecosystem processes and services, and often high biodiversity, even when surface water is not present (Boulton 2014). Shallow sub-surface flows can be critical for the transport of energy, water, nutrients and sediments to permanent surface waters downstream, and may also support a diversity of hyporheic[1] biota (Leigh *et al*. 2013). Hyporheic zones in both Myara North and Holyoake are known to support stygal species that are potentially short-range endemics (SREs) (WRM 2020).

The ecological importance, and hence conservation value of temporary waters is considered higher in lower rainfall areas where permanent waterbodies are scarce (Levick *et al*. 2008, Acuña *et al.* 2014, Boulton 2014). Temporary waterbodies transition through flowing, ponded and dry phases, allowing lotic, lentic and terrestrial species to effectively 'share' the one space (Stubbington *et al*. 2020, and citations therein). Therefore, regions with temporary streams frequently support high, if not higher biodiversity than nearby regions with only permanent streams. At the local-scale, aquatic invertebrate species richness is often similar between temporary and permanently flowing reaches of jarrah forest streams, with numbers of species in the order of 50 to 100 per m^2 (see Armstrong *et al.* 2005, WRM 2013d).

Life history strategies of aquatic fauna are intrinsically linked to seasonality and predictability of flow regimes (Boulton & Lake 1988, Bunn 1988, Boulton 1989, Bunn *et al*. 1989). Permanence of water is an overall determinant of aquatic fauna composition within jarrah forest ecosystems, such that headwater swamps and tributaries show distinctive communities compared to higher-order streams within the same sub-catchment (ARL 1989; Storey *et al*. 1990). This is likely the case for the Myara North and Holyoake regions. Communities in temporary waterbodies typically comprise a combination of species including those only found in temporary waters and those that periodically recolonise from adjacent permanent refuges.

Many aquatic invertebrates in south-west WA are found only in temporary waters (Bunn *et al*. 1989). They are specifically adapted to drying and refilling cycles, and require a period of desiccation in order for further development to take place (Balla 1994, Williams & Hynes 1977). Survival strategies include short maturation times and terrestrial adult stages (*e.g.* mayflies, dragonflies, caddisflies and some beetles), drought-resistant

[1] The hyporheic zone is the saturated interstitial spaces below the stream bed, and where present, can act as an ecotone between the surface water and hypogean (subterranean) environments.

spores, eggs or larval stages (*e.g.* microinvertebrates), ability to burrowing into moist sediments, below stones, or into decomposing wood debris (*e.g.* freshwater mussels, gilgies, koonacs, some mayflies and two-winged flies). Burrowing appears to be a common strategy among jarrah forest macroinvertebrates, but is yet to be adequately researched. Two of the three native crayfish species that occur in the NJF, gilgies (*Cherax quinquecarinatus*) and koonacs (*C. preissii*), inhabit in both temporary and permanent streams and wetlands, though koonacs have a preference for seasonally dry headwater swamps and wetlands. The third crayfish species, smooth marron (*C. cainii*), are largely restricted to permanent water bodies. All three species are able to exist in slightly brackish water, but their ranges have reduced in some south-west areas due to secondary salinisation.

The relative success of each of the above strategies to survive drying, and subsequent recruitment and ecological succession, will vary from year to year depending on a number of biotic (*e.g.* predator avoidance) and abiotic factors (*e.g.* weather - rainfall/evaporation). Therefore, large variations in community structure and composition may ensue in the absence of anthropogenic disturbance. Long-term temporal variation in jarrah forest aquatic communities has not been well-documented. Although longitudinal studies of surrounding areas have been conducted for the Alcoa Huntly and Willowdale mines since the mid 1990's (Table 1 above, and sections 4.2 and 5.2 below), these involved irregular sampling at various sites over time, with no replication within sites. While this type of sampling design is appropriate for detecting gross changes, it is unlikely to detect more subtle change that can be definitively attributed to mining versus natural temporal change. Interpretation of such data is more exposed to Type I/II errors (*i.e.* a change has occurred, but the low replication and high variance prevent statistical tests detecting significant change), than would more intensive replicated sampling. However, replicated sampling is not always possible or practical for monitoring mine impacts, dependent on the spatial extent of the aquatic habitats potentially affected by mining, and the location of the mine within the catchment.

At a higher level, the longitudinal studies do show that Alcoa's current management practices have been effective, as gross changes (*e.g.* significant declines in species diversity) would have been detected if they were occurring (see sections 4.2.1.2 and 5.2.1.2). Though, it is difficult to know the degree to which less common species may or may not have been affected. By comparison, annual replicated sampling commissioned by the Water Corporation for the Wungong Catchment Trial (WCT) over 8 years, together with historic data for the catchment, did detect shifts in community structure due to changes in abundance of less common species, including species sensitive to environmental disturbance (WRM 2013d). But again, this was based on comparison of more recent data (2005 - 2012) against much earlier data (1984 - 1987), with minimal data available for interceding years.

The hyporheic zone can act as a refuge for aquatic fauna with ability to move between the stream and hyporheos to avoid desiccation during low or no flow periods, or take refuge from seasonally high flows (Stubbington *et al*. 2020). Crustaceans such as amphipods and isopods, aquatic earthworms and many insect larvae (*e.g.* mayflies, beetles, two-winged flies) frequent hyporheic zones. Streams in the jarrah forest have variable connectivity to groundwater, and presence of groundwater dependent taxa (*e.g.* stygal amphipods and isopods) are indicative of surface expression of groundwater (WRM 2016a).

The main disturbance factors known to have long-term effect on jarrah forest aquatic fauna communities include streamside vegetation clearing and sedimentation (Kay *et al*. 2001, Armstrong *et al*. 2005). Refuges in perennial streams appear more vulnerable to human disturbances during dry periods because a loss of suitable refuges can affect the ability of some macroinvertebrate taxa to recolonise after flow recovery (Young *et al*. 2011, Chester & Robson 2011).

In addition to the naturally seasonal flow, the North and South Dandalup dams, Serpentine Main Dam, Pipehead Dam and Serpentine Falls (approx. 6.6 km below the Pipehead Dam), present barriers to fish movement in the upper catchments. Native freshwater fishes migrate upstream during winter-spring into tributaries (particularly seasonal creeks that start to flow) to spawn. Migration is triggered by flow and spawning occurs over spring and summer. Pools that persist late into summer and autumn provide important summer refuges for juvenile fish.

4. MYARA NORTH REGION

4.1 Hydrological Setting and Water Quality

The Myara North region (Figure 2) comprises approximately 17,500 ha within Jarrahdale State Forest No. 22, located south-east of the town of Jarrahdale and predominantly within the Shire of Serpentine-Jarrahdale. The region lies within the drinking water catchment area of the Serpentine Dam, and is bordered by Monadnocks Conservation Park to the north-east and Serpentine National Park to the west. The region supports seasonal and ephemeral waterways (*i.e.* Inflow Dependent Ecosystems) associated with the upper Serpentine River and floodplain/palusplain wetlands in valley floors/depressions within the jarrah forest, which may be connected seasonally to the Serpentine Dam reservoir (Figure 2) on the Darling Plateau. In the vicinity of the reservoir, winter rainfall recharge through the gravelly soils historically maintained local sub-surface flow year-round (DoW 2007).

Most of the headwater streams are likely to be low-gradient and swampy with clay-based bed substrates, grading into larger, more defined, sandy-gravel channels some 100 - 200 m downstream. Maximum water levels in winter-spring are likely to range from < 5 cm in headwater swamps, to > 1 m in the larger stream channels (*e.g.* Jack Rocks on 39 Mile Brook).

The eastern section of Myara North is within a zone historically categorised as the Intermediate Rainfall Zone (IRZ, 900 - 1,100 mm/annum). In general, land-use changes in the IRZ are considered to pose a higher risk of salinisation, because the deep permanent groundwater is moderately saline and the water table is high enough to discharge saline water to surface streams (Bari & Ruprecht 2003, Kinal & Stoneman 2011). However, to date mining activities for the existing Huntly mine in the IRZ have not resulted in rising salinities in nearby streams and wetlands (Croton *et al.* 2013, WRM 2020). Below average rainfall in recent decades has placed downward pressure on groundwater tables in the IRZ, reducing salinisation risk in some catchments, however such risk should not be discounted even under a drying climate (Croton & Reed 2007, MacFarlane *et al*. 2020).

Streams in the IRZ tend to have naturally higher salinities than those in either the High Rainfall Zone (HRZ, > 1,100 mm/annum) or Low Rainfall Zone (LRZ, < 900 mm/annum). This is a result of the limited discharge of moderately saline groundwater combined with the diluting effect of rainfall on the perched groundwaters and overland runoff (Bari & Ruprecht 2003). DWER and Alcoa monitoring in Myara North indicates that surface water is fresh (0 - 500 mg/L TDS) in the surface water tributaries west of the 1100 mm isohyet, with maximum TDS of 486 mg/L reported at the Jack Rocks monitoring site on 39 Mile Brook (GHD 2020). For tributaries east of the 1,100 mm isohyet, the maximum TDS typically exceeds 500 mg/L (GHD 2020).

DWER and Alcoa monitoring in Myara North indicates median turbidity is typically below 1 NTU, with maximum values exceeding 25 NTU at some locations on Gooralong Brook, 39 Mile Brook and Banksia Gully (GHD 2020).

The highly permeable soils and related lack of surface runoff, the generally low relief, the high amounts of litter and understorey vegetation all contribute to low sediment loads. Organic material from the natural decay of vegetation and disturbance due to logs falling naturally into stream channels have been the major sources of suspended material measured in undisturbed catchments. Roads constructed for moving machinery and transport vehicles also play some role in generating sediment loads.

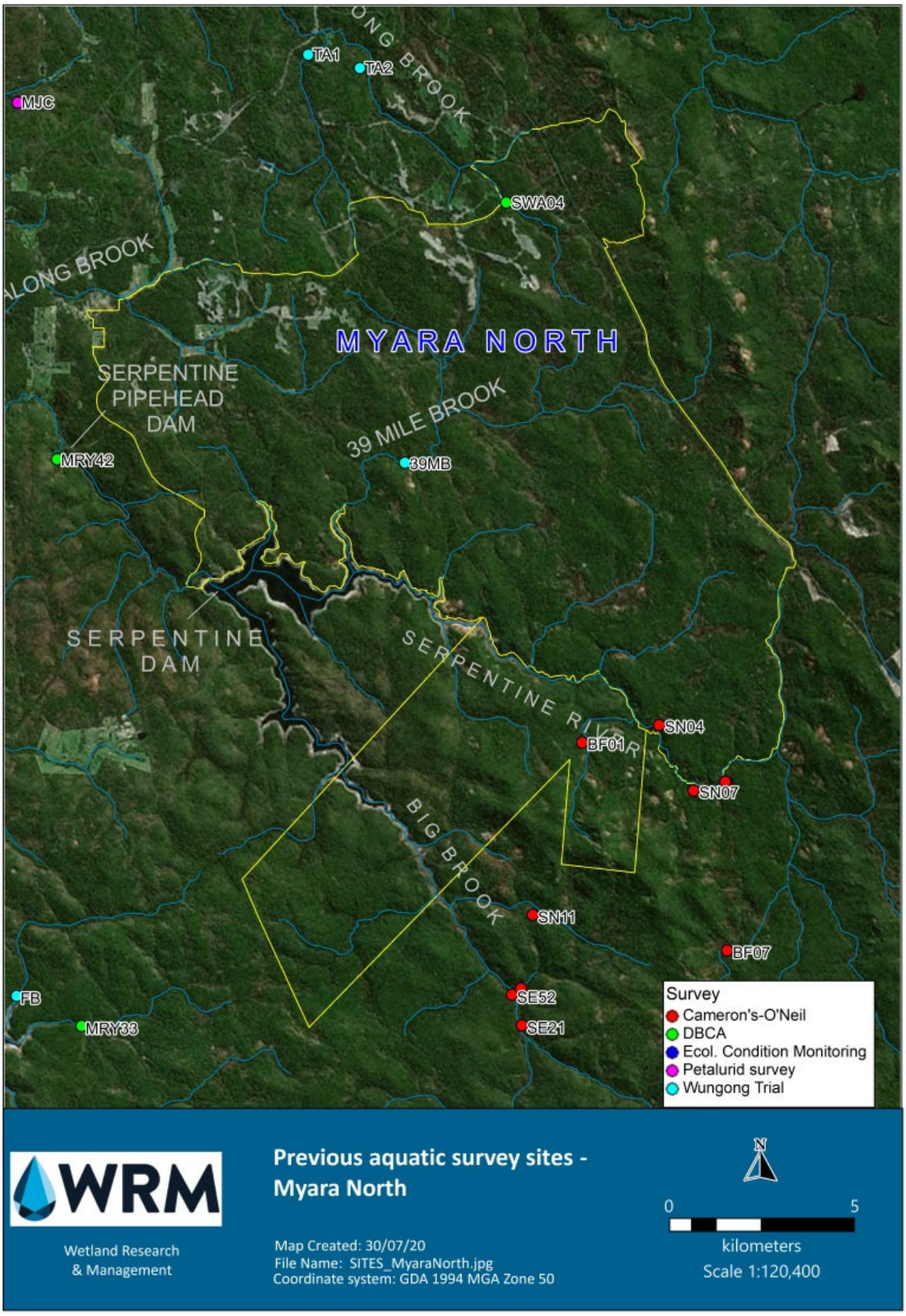

Figure 2. Myara North study area.

4.2 Aquatic Fauna Records

4.2.1 Summary of Previous Studies

Few previous survey sites fall within the boundaries of Myara North, thus there is a paucity of information on extant aquatic communities from which to assess potential impacts of mining developments. A summary of relevant studies is provided in Table 4 and sampling locations are shown in Figure 2 and Appendix 1.

Previous studies including sites within the boundaries of the Myara North region and adjacent conveyor corridor (hereafter Myara North) are limited to Streamtec Pty Ltd and WRM aquatic monitoring sites for the Huntly Mine, together with one reference site surveyed by ARL/WRM for the Water Corporation Wungong Catchment Trial (WCT), and one DWER forest stream monitoring site. These studies are discussed further below.

Additionally, there are records for Carter's freshwater mussel (Vulnerable, EPBC Act and BC Act) for the Serpentine River (see section 4.2.3.1), and stocking of exotic trout species (1970 - 2015) by Fisheries WA (DBIRD).

4.2.1.1 Pre-1990 surveys of macroinvertebrates and fish

The Aquatic Research Laboratory (ARL; The University of Western Australia) was commissioned to conduct surveys of macroinvertebrate community composition across the western portion of the NJF between 1984 and 1989 (various reports 1988 - 1989, here cited as ARL 1989). The surveys encompassed adjacent areas of the Swan Coastal Plain, including the Canning, Serpentine and North Dandalup catchments and sub-catchments of Dirk Brook and Gooralong Brook. The aim was to provide baseline information ahead of construction of several dams. Though no sites were sampled in the Myara North or Holyoake regions, they offer comprehensive historic information of macroinvertebrate communities of the IRZ and HRZ of the Darling Scarp.

Pusey *et al.* (1989) surveyed freshwater fish across headwater and downstream reaches of the Canning and North Dandalup Catchments between 1985 and 1986. Although the surveys did not include Myara North or Holyoake, they provide a useful summary of native fishes expected to be present in similar upland streams of the regions (acknowledging distributions may now be affected by climate change and dam regulation).

4.2.1.2 Cameron and O'Neill areas stream zone monitoring 1995 - 2019

Macroinvertebrates and fish were surveyed in the Camerons (IRZ) area between 1995 and 2007 (Streamtec 1997, 2000, 2001, Creagh *et al.* 2004, WRM 2006a, 2008) as part of streamzone monitoring for the Huntly Mine. Further monitoring for macroinvertebrates was conducted in the Camerons, Jayrup and O'Neill areas in 2009, 2011, 2014 and 2019 (WRM 2010, 2013a, 2015, 2020). Study sites within the Myara North region include SN04 and SN07 on the upper reaches of the Serpentine River, and BF01 on a nearby tributary (Figure 2 and Appendix 1). Long term aquatic biomonitoring during and post-mining aimed to track changes physical and biological attributes in response to mining, particularly in response to secondary salinisation (Croton & Dalton 2010). No detrimental impact on macroinvertebrate communities in response to mining was found, however communities did respond to consistent downward trends in rainfall over the study period (see WRM 2020).

Table 4. Summary of aquatic fauna studies and database records relevant to Myara North.

Program	Date	Sampled by	Locations sampled	Fauna	Methods used
Surveys that include sites within the study area					
IRZ Streamzone monitoring	1997 - 2019	Streamtec; WRM	Myara, Camerons, Jayrup, McCoy, O'Neil mine areas (Alcoa)	Macroinvertebrates, fish	Kick sampling, seine & barrier netting
Wungong Catchment Trial	2005 - 2012	ARL/WRM	Wungong; Serpentine; North Dandalup	Macroinvertebrates; Fish	Surber
Forest stream monitoring	2004 - 2011	DBCA	Southwest WA forests	Macroinvertebrates	Kick sampling
Petaluridae survey	2007	Dr J. Taylor (WA Insect Study Society); WRM	Kesner Swamp, Mandejal Brook and surrounds	*Petalura hesperia*	Targeted
Database/Mussel Watch results	pre-1992 to 2012	Analysed by Klunzinger *et al.* 2015	Southwest WA	*Westralunio carteri*	DPAW and WAM database searches; Sampling method 10 - 20 min of visual and tactile searching
Mussel translocation	2012	Klunzinger *et al*.	Serpentine pipehead dam; translocation d/s main dam	*Westralunio carteri*	Targeted
Trout stocking	1970 - 2019	Fisheries (DBIRD)	Serpentine River	*Salmo trutta*	Stocking
Trout stocking	1970 - 2019	Fisheries (DBIRD)	Davis Brook, Gooralong Brook, Serpentine River	*Oncorhynchus mykiss*	Stocking
Historic surveys in proximity to study area or with sites similar habitats of NJF					
Stream fauna studies (for proposed dams)	1985 - 1988	ARL	Western side of: Canning/Lower canning, Serpentine/Gooralong Brook, Nth Dandalup	Macroinvertebrates	Surber
Fish fauna of Canning and Nth Dandalup rivers	1985 - 1986	Pusey *et al*. 1989	Canning and Nth Dandalup	Fish	Seine and hand netting
Other relevant studies					
Serpentine River ecological health assessment	2012, 2019	WRM	Serpentine River, downstream of pipehead dam	Fish, crayfish and mussels	Fyke, box traps, electrofishing

4.2.1.3 DBCA forest stream monitoring 2005 - 2012

DBCA (formerly Department of Environment and Conservation; DEC) conducted stream faunal monitoring across southwest forests between 2005 and 2012. The Australian River Assessment System (AusRivAS) method was used to track changes in macroinvertebrates through time associated with the changing climate (Pennifold 2013a,b, 2018). The monitoring included one site, SWA04, at the northern boundary of Myara North. Raw data are publicly available through NatureMap (http://naturemap. dpaw.wa.gov.au) and provided in Appendix 2.

4.2.1.4 Wungong Catchment Trial 2005 - 2012

The Water Corporation undertook experimental forest thinning within the upper Wungong Brook catchment between 2005 and 2012, in an attempt to increase streamflow generation under a drying climate (the Wungong Catchment Trial; WCT). Baseline surveys for macroinvertebrates commenced in 2005 (ARL 2009) and annual sampling continued to 2012 (see WRM 2013d). One reference site on 39 Mile Brook (39MB, in the Serpentine catchment) is within the boundaries of Myara North (Figure 2). Other sites included treatment and reference sites within the Wungong catchment, and two reference sites in the North Dandalup catchment. Forest thinning was not found to alter aquatic biotic communities, which instead responded to declining rainfall, and subsequent declines in streamflow, which was not ameliorated by the WCT.

4.2.1.5 Targeted surveys of relictual Gondwanic western petaltail dragonfly, 2007

In 2007, targeted surveys for the Petaluridae dragonfly *Petalura hesperia* (western petaltail dragonfly) were conducted at several localities along the Darling Scarp (WRM 2007). The 2007 surveys are the most recent surveys for this rare dragonfly since 1998 (see Brown *et al.* 1996, Barrett & Williams 1998). The Petaluridae are an ancient family of dragonfly, and *P. hesperia* is the only species found in WA, where it is endemic and restricted in distribution. In the 2007 surveys, three sites were identified as suitable breeding habitat, including one previously known site in Kesner Swamp, off Kesner Road, upstream and east of the Pinjarra Alumina Refinery (Appendix 1). Petaluridae dragonflies are of great scientific interest due to their ancient lineage, and unusual breeding ecology. The larvae make burrows above the active channel in boggy or marsh substrate under streamside vegetation. Burrows can be found along both permanent or seasonally flowing streams, provided permanently damp marsh substrate, where nymphs emerge after 5 to 6 years into a very large (wingspan 13 cm) adult (Watson 1957, Barrett & Williams 1998, Jan Taylor, pers. obs. cited in WRM 2007). Endemism, specific habitat requirements, and known threatening processes (including habitat loss due to development, prescribed burns and climate drying) means *P. hesperia* likely warrants elevation to a conservation listed species for management, however due to their highly cryptic nature, little information exists on their population or distribution (Hawking & Theischinger 2004, WRM 2007).

4.2.1.6 Serpentine River ecological condition assessments 2012 & 2019

On behalf of the Water Corporation, WRM conducted ecological condition assessments for the Serpentine River downstream of the Serpentine Pipehead Dam (PHD) to determine whether upstream impoundment and abstraction was having impact on downstream ecological health. Fish and crayfish were surveyed at a limited number of sites upstream and downstream of the Serpentine Pipehead Dam, downstream of the main dam (WRM 2013e, 2019b). The assessment included opportunistic observations for Carter's freshwater mussel.

4.2.2 Summary of Aquatic Fauna

4.2.2.1 Fish and crayfish

Very little information exists for native fish and crayfish of Myara North (and none for Holyoake). Western minnows (*Galaxias occidentalis*) were opportunistically recorded at 39 Mile Brook during WCT monitoring (WRM 2013d). Two native freshwater crayfish, the gilgie and koonac, and one invasive exotic crayfish, the yabby (*Cherax destructor*) were also recorded at 39 Mile Brook (see WRM 2013d). The only other records of fish or crayfish were Fisheries WA (DBIRD) records for artificial stocking of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) in the Serpentine River and Gooralong Brook (Tables 5).

Fish assemblage data for systems proximate to the study areas include records from baseline and subsequent monitoring of the Huntly and Willowdale mines (Streamtec 1997, 2000, 2001, 2003a,b, Creagh *et al.* 2004). Western minnow was the only species recorded, in low numbers in the Cameron Corridor area. Willowdale monitoring recorded western minnow, gilgies, and introduced gambusia, rainbow trout and yabbies. In the Wungong catchment to the north, three native fishes (western minnow, western pygmy perch *Nannoperca vittata*, and nightfish *Bostockia porosa*) and three native crayfish (gilgie, koonac and smooth marron) were recorded during the WCT monitoring (2005 - 2012). Prior to this, Pusey *et al*. (1989) reported western minnow, western pygmy perch and nightfish from upland reaches of the Canning and North Dandalup catchments.

No fish or crayfish species currently listed for conservation significance were recorded for the one site surveyed in Myara North, or for the wider Huntly or Willowdale mine areas.

Table 5. Fish and crayfish species from NJF upland streams within 20 km of Myara North and Holyoake regions.

Project	Dates	Surveyed within Myara North	Surveyed outside Myara North	Species recorded
Alcoa IRZ Streamzone Monitoring	1995-2003	--	Cameron Corridor	• western minnow
Alcoa HRZ Streamzone Monitoring	1995-2003	--	Willowdale	• western minnow • gambusia • rainbow trout • yabbies
Wungong Catchment Trial	2005-2012	39 Mile Brook	--	• western minnow • gilgie • koonac • yabby
		--	Wungong Brook (TA1, TA2, Vardi Road)	• western minnow • pygmy perch • nightfish • gilgie
		--	Wungong Brook (Waterfall Gully)	• western minnow • gilgie
		--	Foster Brook and Wilson Brook in the North Dandalup catchment	• western minnow • pygmy perch • nightfish • trout • gilgie
		--	31 Mile brook	• western minnow • nightfish • gilgie

Project	Dates	Surveyed within Myara North	Surveyed outside Myara North	Species recorded
Pusey *et al*. (1989) fish surveys	1985-1986	--	Canning Widespread in upland streams	• western minnow • western pygmy perch • nightfish • rainbow trout • gambusia
		--	North Dandalup Widespread in upland streams	• western minnow • western pygmy perch • nightfish • gambusia
Fisheries WA (DBIRD) trout stocking	1970-2019	--	Serpentine river	• rainbow trout • brown trout
			Davis Brook	• rainbow trout
			Gooralong Brook	• rainbow trout

4.2.2.2 Aquatic invertebrates

Records of aquatic invertebrate fauna within Myara North are sparse. They are mostly limited to aquatic macroinvertebrate records for three sites sampled periodically between 2001 and 2019 (SN04, SN07, BF01) for Huntly Mine streamzone monitoring, site (39 Mile Brook) sampled annually between 2007 and 2012 for the WCT, and one DBCA forest stream monitoring site (SWA04) (Figure 2).

No species currently listed for conservation significance were recorded. Faunal assemblages included a diversity of south-west endemic epigean[2] (stoneflies, alderflies, caddisflies, non-biting midges) and stygal (paramelitid amphipods) species, characteristic of undisturbed upland forest steams. By way of example, a summary of taxa recorded by DBCA for SWA04 is given in Appendix 2.

Beyond the boundaries of the Myra North region, macroinvertebrate community data exists for the Cameron and Willowdale areas sampled by Streamtec and WRM for Alcoa streamzone monitoring programs (1997 - 2019), the Wungong catchment monitored for the WCT (2005 - 2012), historic ARL studies (1988, 1989), and various published literature and DBCA records (Appendix 1). Approximately 150 macroinvertebrate species have been collected from each of the Cameron and Willowdale areas, and 180 from the Wungong catchment. The number of species is likely far higher as not all taxa could be identified to species-level, owing to lack of published keys and/or immature life stages. An exhaustive summary is not provided here, other than for species of conservation and/or scientific significance.

Macroinvertebrates have received considerably less attention than other freshwater macro-fauna (*i.e.* crayfish and fish) in regards to conservation listings, which are currently biased towards particular groups (*i.e.* molluscs and dragonflies). Several authors flag species or groups which warrant further investigation as to conservation status (*e.g.* Sutcliffe 2003, Pennifold 2018). At time of writing, Carter's freshwater mussel is the only Commonwealth or WA listed macroinvertebrate known to occur in the vicinity of Myara North and Holyoake (see Appendices 3 to 5). This species is discussed further in section 3.3.3

The minute predatory aquatic snail *Glacidorbis occidentalis* (IUCN Vulnerable, DBCA Priority 3) is known from SN07 on the boundary of Myara North, as well as sites within the McCoy, O'Neil and Willowdale areas (see Appendices 3 to 6). This species is discussed further in section 3.3.3. No other macroinvertebrates within the

[2] Epigean = surface dwelling (*e.g.* in surface waters), as opposed to hypogean (subterranean).

relevant geographical range appear on DBCA Priority fauna listings, although this is under review (Pennifold *et al.* 2018, A. Pinder, DBCA, pers. comm. 2020).

Three species of Odonata (dragonflies and damselflies) which are red listed by IUCN as Vulnerable, potentially occur within the regions, including the spiny tigertail (*Archaeosynthemis spiniger*), the armourtail (*Armagomphus armiger*) and the western swiftwing (*Lathrocordulia metallica*), and three species red listed as Near Threatened, including the tiny flatwing (*Archiargiolestes pusillissimus*), the midget flatwing (*Archiargiolestes parvulus*) and the orange streamcruiser (*Hesperocordulia berthoudi*) (see section 4.2.4)

The Petaluridae dragonfly *Petalura hesperia* has been recorded from Kesner Swamp, off Kesner Road, upstream and to the east of the Pinjarra Alumina Refinery (Appendix 1). While currently it is not formally listed for conservation significance, several authors have highlighted this species as being of conservation concern (Barrett & Williams 1998, Sutcliffe 2003, Hawking & Theischinger 2004) (see section 4.2.4).

4.2.3 Conservation Significant Fauna

Conservation significant aquatic fauna known or likely to occur in Myara North are summarised in Table 6 and described in sections 4.2.3.1 to 4.2.3.4.

Table 6. Conservation significant aquatic fauna currently listed under the EPBC Act and WA BC Act 1950, and likely to occur in Myara North.

Species	Common name	Conservation status	Likelihood of occurrence within Myara North
Westralunio carteri	Carter's freshwater mussel	EPBC Vulnerable, WA BC Vulnerable	**High chance of occurrence** near reservoirs.. Recorded from the Serpentine River on the southern boundary of Myara North (Mussel Watch), and upper Wungong Brook ~10 km north of Myara North (ARL 2007). Restricted to permanent and seasonal stream and riverine habitats (Klunzinger 2012).
Glacidorbis occidentalis	Minute freshwater snail	DBCA Priority 3, IUCN Vulnerable	**High chance of occurrence** in gravel riffles in seasonal headwater tributaries. Recorded from the upper Serpentine River (WRM 2019a) on the southern boundary of Myara North, and upper Wungong Brook ~10 km north of Myara North (WRM 2013d).
Hydromys chrysogaster	Rakali or water rat	DBCA Priority 4	**High chance of occurrence** near reservoirs. Recorded from Vardi Road gauging station in the upper Wungong catchment ~10 km north of Myara North (WRM 2012). Widespread throughout the NJF but requires permanent water to survive.
Wesniphargus nichollsi	Amphipod	Stygal - potential SRE	**Known to occur**. Recorded from sites within (BF01) and immediately adjacent to (BF07, SN07) Myara North (WRM 2020). Also known from hyporheos in McCoy area (SE06) (WRM 2020).
Uroctena sp.	Amphipod	Stygal - potential SRE	**High chance of occurrence.** Recorded from one site (BF07) immediately adjacent to Myara North (WRM 2020). Indeterminate amphipods of the same family (Paramelitidae) recorded from Myara North (BF01), Myara (BF07), and a number of sites in the Cameron-McCoy (SE12, SE13, SE14, SE19, SE21) and Willowdale areas (DK06, SM46) (WRM 2016b, 2020).

Species	Common name	Conservation status	Likelihood of occurrence within Myara North
Hyperoedesipus plumosus	Isopod	Stygal - potential SRE	**Moderate chance of occurrence**. Closest recent record is for Willowdale area (BG01, BG02, NG09, SM01) (WRM 2016b). Historically known from the Dandalup catchment and McKnoe Brook (Knott 1986).
Geotria australis	Pouched lamprey	DBCA Priority 1	Highly unlikely to occur. Restricted to riverine habitats with marine connections. Closest recent record is for a Murray River tributary ~ 30 km south-west of Myara North and ~5 km south-west of Holyoake (DBCA 2016 record).

4.2.3.1 Carter's freshwater mussel *Westralunio carteri*

Carter's freshwater mussel is currently listed as Vulnerable under the EPBC Act and WA *Biodiversity and Conservation Act 2016* (BC Act) and by the IUCN. This species is known from recent (post-2010) mussel watch surveys and historic (1900 - 1959) WAM records for the Serpentine River along the southern boundary of the Myara North region (Appendix 5). It was also recorded from upper Wungong Brook (Vardi Road gauging station) approximately 10 km north of Myara North during WCT monitoring (Appendix 5; ARL 2007). The method used for the WCT was quantitative quadrat (Surber) sampling which is not designed to target mussels, so mussels may actually be more widespread throughout the upper Wungong catchment than recorded during field sampling for the WCT.

The current conservation listing is based on an estimated decline of 49% in south-west populations over the last 60 years, with a trend of continuing decline. The former range for this species extended from Moore River in the north to King George Sound in the south and inland to the Avon River. Current distribution is limited to within 50-100 km of the coast from Gingin Brook in the north, to the Kent River and Waychinicup River along the southern coast (Klunzinger & Walker 2014, Klunzinger *et al*. 2015).

Primary threats are salinisation, water extraction and climate change. Secondary threats are habitat destruction, trampling by cattle, changes in water quality and possible loss of suitable host fishes for larval stages (glochidia). Confirmed native host species for glochidia are freshwater cobbler, western minnows, western pygmy perch, nightfish, Swan River goby and southwestern goby, and exotic gambusia and one-spot livebearer (Klunzinger *et al.* 2012, 2015).

Barriers to upstream movement of fish may therefore also restrict gene flow between mussel populations, limit upstream-downstream recruitment of mussels, restrict distributions and prevent recolonisation. As well as weirs and dams, barriers include low flow regimes that make natural barriers (waterfalls, riffle zones) impassable for fish.

Freshwater mussels are filter feeders and vulnerable to water pollutants and sedimentation. The species prefers shallow water habitats with stable, sandy or muddy bottoms and inhabits both permanent and seasonal rivers and lakes. They can survive prolonged periods of drought by burrowing into bottom muds in shaded reaches and sealing the bivalve. It may thus survive potential drawdown of river pools, however they are unable to withstand extreme drying without shade for more than 5 days (Klunzinger *et al.* 2014). Burial by deep loose sands and silts will also kill mussels. Freshwater mussels also appear intolerant of average salinity levels > 1,500 mg/L (~3,000 µS/cm).

Mussels also provide a food source for native rakali (water rats) and freshwater cobbler (*Tandanus bostocki*).

4.2.3.2 Minute freshwater snail *Glacidorbis occidentalis*

The minute freshwater snail *G. occidentalis* is currently listed by DBCA as Priority 3 and by IUCN as Vulnerable. Recent formal assessments for *Glacidorbis occidentalis* in the vicinity of Myara North are limited to those of WRM for the upper Serpentine River (see WRM 2019a) and upper Wungong Brook (see WRM 2013d) (Appendix 6). *G. occidentalis* is also known from the O'Neil, McCoy and Willowdale areas (WRM 2016a, 2020). In all locales it is spatially and temporally variable in distribution, and typically only collected in low abundance.

The current listing is based on the fact that this snail has only been rarely collected and even when present, only occurs in low numbers, making it highly vulnerable to disturbance.

G. occidentalis occurs almost exclusively in gravel riffle habitats in less disturbed, vegetated, seasonal headwater tributaries where salinity is low (< 500 µS/cm), turbidity is low (< 5 NTU) and slightly acidic pH (5 - 7). Its former range included jarrah forest streams in the upper catchments of the Canning, Wungong, Serpentine, North Dandalup and Harris rivers on the edge of the Darling Scarp (Bunn & Stoddart 1983, Bunn *et al.* 1989, Streamtec 1997, WRM 2013d and unpub. data). The full extent of its current distribution within and outside the Myara North and Holyoake regions is not known. While it appears to have once been widespread throughout the NJF, climate change and declining stream flow are expected to have reduced habitat availability.

4.2.3.3 Rakali *Hydromys chrysogaster*

Rakali, or water rats (*Hydromys chrysogaster*), are currently listed by DBCA as Priority 4 and by IUCN as Least Concern. There is little available data on the current spatial distribution of rakali within the vicinity of Myara North and Holyoake regions as there have been no targeted studies, only opportunistic sightings, and none from within the regions (see Appendices 2 and 3). Nearest most recent records are for Wungong Brook (Vardi Road gauging station) where rakali feeding platforms were observed in all years (2005 - 2012).

The current listing is based on the species having a wide but sparse distribution and presumed large population. However, population decline has been recorded in some parts of Australia and current population trends are unknown, particularly in south-western Australia. *H. chrysogaster* occurs throughout Australia, Indonesia and Papua New Guinea, in a wide variety of habitats from permanent freshwater rivers and lakes to brackish-water environments (Olsen 2008, Valentine *et al.* 2009, Smart 2009, Smart *et al.* 2011).

Most recent surveys of rakali in the south-west have focused on the greater Perth region (Valentine *et al.* 2009, Smart 2009, Smart *et al.* 2011) and Upper Collie catchment (WRM 2016b). Results from night-time trapping suggest rakali prefer areas with a high percentage of vegetation cover, stream cover, bank stability and habitat diversity. There was also some evidence from these recent studies to support early findings (Watts & Aslin 1981, Scott & Grant 1997) that rakali require access to permanent water sources and suffer from heat stress if access to permanent pools is lost. This would limit their distribution in seasonal and ephemeral headwater streams of the Myara North region.

Other than loss of access to permanent pools, threats include clearing and secondary salinisation, though they can survive in areas that are brackish or polluted, including urban areas (Lee 1995). Rakali are omnivores and their diet include freshwater mussels, crayfish, insects, fish, birds, reptiles and small mammals (see Smart *et al.* 2011). Breeding can occur throughout the year, but more typically in spring. They build nests at the

ends of tunnels dug into banks near tree roots or in hollow logs. Therefore, there is a requirement for stable stage heights that inundate banks, tree roots and large woody debris.

4.2.3.4 Stygal amphipods and isopods

A number of stygal amphipod and isopod species have been recorded from surface waters during aquatic macroinvertebrate sampling within and adjacent the Myara North region. There is a paucity of knowledge on their taxonomy, biology, distribution and abundance. These species are of conservation interest because at least some are potentially SREs, but genetic analysis is required to first confirm their taxonomic status.

Stygal amphipods *Wesniphargus nichollsi* (Neoniphargidae) and *Uroctena* sp. (Paramelitidae) have most recently been recorded from BF01, BF07 and SN07 during Alcoa streamzone monitoring (Figure 2). These species, together with indeterminate juvenile paramelitid specimens, have also been collected from a number of stream sites in the McCoy and Willowdale areas, and are likely to occur more widely (see Appendix 7).

The stygal isopod *Hyperoedesipus plumosus* (Phreatoicidae) has been recorded from streamzone monitoring sites in the Willowdale area, but not in the immediate vicinity of Myara North (Appendix 7). Historically, *H. plumosus* was known from Finlay Brook (North Dandalup River catchment), Little Dandalup Creek (South Dandalup River Catchment), McKnoe Brook (near Wagerup), and two seasonal spring sites; one at Lesmurdie and the other in the Avon Valley (Bunn 1985, Knott 1986). Knott (1986) surmised the Lesmurdie and Avon Valley spring populations were likely extinct as a result of increasing salinity levels in groundwater, given the last successful collection of *H. plumosus* at these sites was in 1955.

These amphipods and isopods require strong connectivity between ground and surface waters if they are to frequent surface waters in search of food, particularly during wetter months. Temporal variability in their abundance in NJF streams appears closely linked to rainfall patterns (WRM 2020). Their presence is considered indicative of Groundwater Dependent Ecosystems (GDEs) in the area, if not necessarily at the point of collection. Downstream drift with streamflow will likely influence their distribution, though the propensity for, and longitudinal extent of drift in these species has not been studied. Nor is it known if hyporheic and epigean habitats are critical for survival. Knott (1986) considered *H. plumosus* should more appropriately be considered a groundwater species that has re-invaded surface waters, and now only takes refuge in interstitial waters of gravel-bed channels as a short-term strategy to survive seasonal dry periods. The same may be true of at least some of the stygal amphipod species, and if so, increases their vulnerability to physical disturbance and sedimentation. Both *Uroctena* sp. and *H. plumosus* appear sensitive to increased sediment levels (Gazey 1994), but otherwise the physico-chemical tolerance of stygal amphipods and isopods of the NJF is unknown.

4.2.3.4 Pouched lamprey *Geotria australis*

Pouched lampreys (*Geotria australis*) are currently listed by DBCA as Priority 1. While there are historic records of pouched lampreys within the Myara North region (1914 WAM; see Appendix 3), it seems unlikely this species still inhabits the upland streams within the area, given they undergo obligate migration, spending their adult lives at sea returning to freshwater upland reaches to spawn and die. The eyeless larvae filter feed in shaded, well-oxygenated freshwater streams, before migrating to the ocean. Construction of Serpentine Main Dam and Pipehead Dam has blocked migration pathways between the ocean and upland streams within the Myara North region, likely extirpating any previously occurring populations.

4.2.4 Candidate Priority Species of South-West WA

Pennifold (2018), under the direction of DBCA, developed a protocol for assessing how many freshwater invertebrates from the entire south west of WA, a broad area defined as west of a line between Shark Bay and Cape Arid, may be candidates for listing on the Western Australian Priority Fauna list, and provided an overview on a selection of those species for listing. Using DBCA records, a search was conducted to find species which only occurred west of a line between Shark Bay and Cape Arid, with restricted distributions. This process yielded a set of 49 aquatic invertebrate species, determined to be candidates for listing as priority species in need of further investigation. From this list, WRM identified a subset of nine species with habitat preferences that may include conditions similar to the study area (*i.e.* not restricted to permanent or lentic water), and were not restricted to one location (*i.e.* short-range endemic). These species are listed, along with their known distribution and nearest record of occurrence to the study area in Table 7.

Table 7. Candidate priority aquatic fauna identified by Pennifold (2018) with habitat preferences that might include conditions similar to Myara North, and their known distribution and nearest record to Myara North.

Scientific name	Common name	Known distribution	Nearest record to Myara North
Lectrides sp. AV1	Long-horned caddisfly	Large distribution range extending from Northam area to Lake Muir area, but is rarely collected and considered at risk of extinction Sutcliffe (2003).	Helena River ~50km north east (NatureMap 2011)
Armagomphus armiger IUCN (VU)	Western armourtail dragonfly	Restricted to streams on the Darling Scarp, from Wungong Brook to the Shannon NP. Rare.	Waterfall Gully ~30km north (Carey unpubl. data).
Archaeosynthemis spiniger IUCN (VU)	Spiny tigertail dragonfly	Southwest forests, from Perth to Albany and westward.	Finlay Brook, ~10km south west (NatureMap 2010)
Archiargiolestes pusillissimus IUCN (NT)	Tiny flatwing damselfly	Southwest; distribution uncertain.	All records pre-1970
Archiariolestes parvulus IUCN (NT)	Tiny flatwing damselfly	Southwest; distribution uncertain.	Most recent record 1978
Hesperocordulia berthoudi IUCN (NT)	Orange stream cruiser dragonfly	Southwest forests, from Perth to Albany and westward. Monotypic genera restricted to SWA. Sutcliffe (2003) identifies this species as warranting conservation listing.	Stirling Dam ~80km south (NatureMap 2009); Waterfall Gully ~30km north (Carey unpubl. data).
Lathrocordulia metallica IUCN (VU)	Western swiftwing dragonfly	Southwest forested streams.	Big Brook ~30km south (NatureMap 2008); Waterfall Gully ~30km north (Carey unpubl. data).
Petalura hesperia	Western petaltail dragonfly	Restricted to permanently damp stream zones near the Darling Scarp. Not presently listed, but several authors note that it is warranted.	*Petalura* targeted surveys < 10km west (WRM 2007)
Zephyrogomphus lateralis	Lilac hunter dragonfly	Southwest forests, appears restricted to small, fast flowing, permanent streams.	Waterfall Gully in Wungong catchment ~30km north (Carey unpubl. data).

4.3 Aquatic Fauna Values

Habitats that are known to be present within the Myara North region include ephemeral and seasonally flowing first order streams, as well as higher-order riverine channels (*e.g.* Jack Rocks on 39 Mile Brook) likely with long-term or possibly permanent pools. Seasonal drought refuges include permanent pools and channels in higher order streams (*e.g.* main channel of the Serpentine River). Spring-fed waterbodies possibly occur but would require field survey to confirm. These habitats have been demonstrated to support recovery of aquatic fauna following seasonal and supra-seasonal drought (Chester & Robson 2011) and will become increasingly important as climatic drying progresses. Hyporheic zones are also important ecological values in intermittent streams.

A summary of known and potential aquatic habitat and fauna values is provided in Table 8.

Table 8. Myara North region aquatic habitat and fauna values.

Known Values	• Inflow Dependent Ecosystems • Groundwater Dependent Ecosystems • Seasonal connectivity of headwaters for reproductive migration of native fish (western minnow) and habitat for native freshwater crayfish (gilgies and koonacs) • Minute freshwater snail *Glacidorbis occidentalis* (P3) • Hyporheic zone affords seasonal feeding habitat for stygal amphipods (*Uroctena* sp., *Wesniphargus nichollsi*) that are potential SREs
Potential Values	• Forested catchment maintains high water quality, particularly low salinity and sediment loads • High beta diversity - characteristic of interconnected ephemeral, seasonal and permanent (*e.g.* Serpentine reservoir) waterways • Drought refuges in headwater streams • High endemicity in macroinvertebrate fauna • Carter's freshwater mussel *Westralunio carteri* (EPBC Act Vulnerable, WA BC Act Vulnerable) • Rakali *Hydromys chrysogaster* (P4) • Habitat for candidate priority dragonflies and damselflies with rare and/or restricted distributions • Potential seasonal spawning habitat for western pygmy perch and nightfish

5. HOLYOAKE REGION

5.1 Hydrological Setting and Water Quality

The Holyoake region (Figure 3) comprises approximately 10,100 ha, from approximately 5 km east of the town of Dwellingup, predominantly in the Shire of Murray, and extends eastward into to the Shire of Boddington. The mine region and adjacent infrastructure corridor encompass upstream reaches of the North and South Dandalup rivers, Conjurunup Brook. The south of the region encompasses tributaries of the Murray River. The Murray River is one of the few rivers in south-west WA that is not regulated by a large reservoir, and therefore movement of aquatic fauna between lowland and upland reaches is still possible (*e.g.* migrating fish). Tributaries of the South and North Dandalup rivers are likely to be seasonally connected, however presence of permanent pools or drought refuges requires field survey to confirm.

The Holyoake region is within the eastern boundaries of the HRZ where groundwater discharge has historically played a greater role in streamflow generation than in the IRZ. In undisturbed forested catchments, stream salinity is derived from discharge of groundwater which is diluted by overland and throughflow (Bari & Ruprecht 2003). However, groundwater contribution is not consistent across all areas of the HRZ, and in addition, many valley floors have become increasingly disconnected from groundwater as a result of climate change, leading to greater declines in streamflow (see McFarlane *et al.* 2020).

Monitoring by Alcoa at Davis Brook (1976 - 1979) indicated salinity levels of approximately 350 - 900 µS/cm and turbidity of approximately 0.7 - 3.5 NTU (GHD 2020). Monitoring by DWER at South Dandalup sites (1970s - 1980s) indicated salinity ranged from less than 50 µS/cm to 2,000 µS/cm (mean ~300 - 600 µS/cm) and turbidity ranged from 0.1 NTU to 65 NTU (GHD 2020). Monitoring at the South Dandalup Gordon catchment gauging station (1988 - 2000) (WIR site 614060) indicated a salinity range of approximately 100 – 800 µS/cm (mean ~175 µS/cm), with an outlier of 6880 µS/cm recorded on 22/10/1999 (GHD 2021). DWER monitoring on the South Dandalup River at the eastern end of Holyoake (DWER site 6141350) recorded higher peak turbidity events of up to 1,064 NTU with a mean of approximately 260 NTU (GHD 2020).

5.2 Aquatic Fauna Records

5.2.1 Summary of Previous Studies

As mentioned in section 4.2 for the Myara North region, there is a paucity of information on aquatic fauna communities of the Holyoake region. Based on the general north to south increasing rainfall gradient, a greater probability of permanent aquatic habitats would be expected within the boundaries of the Holyoake region compared to Myara North. However, more detailed analyses conducted by Alcoa (A. Grigg, pers. comm., 2020) indicate comparable rainfall for both regions, in part because the Myara North region extends closer to the Darling Range escarpment to the west. Streamflow and the presence of pools is negatively correlated with forest cover, which is greater in Holyoake. Available data provide no evidence of more permanent flows, rather, seasonal flow is evident for Davis Brook within Holyoake, and similarly Pindalup and Chadoora catchments to the immediate east, and for several gauged catchments to the immediate north and south of the Holyoake region (A. Grigg, Alcoa, pers. comm.). The presence or otherwise of permanently damp hyporheic zones and small springs/seeps that may support hyporheos is unknown.

Figure 3. Holyoake study area.

There is only known study that includes sites in the Holyoake region; DBCA forest stream monitoring (2005 – 2012) which included one site (MRY44) on the eastern boundary of the region (Figure 3). This and other relevant studies are briefly described below and summarised in Table 9. All sampling locations are shown in Figure 3 and Appendix 1.

Additionally, there are records for Carter's freshwater mussel (Vulnerable, EPBC Act) for adjacent upland reaches of the Murray River (see section 5.2.3), historic surveys by ARL (1989) and Pusey *et al*. (1989) for the upper North Dandalup River, and other studies as described in section 4.2.1 for the Myara North region.

5.2.1.1 DBCA forest stream monitoring 2005 - 2012

DBCA (formerly DEC) conducted stream faunal monitoring across southwest forests between 2005 and 2012. The Australian River Assessment System (AusRivAS) method was used to track changes in macroinvertebrates through time associated with the changing climate (Pennifold 2013a, b, 2017). The monitoring included one site, MRY44, on the eastern boundary of the Holyoake region (Figure 3). Raw data are publicly available through NatureMap (http://naturemap. dpaw.wa.gov.au) and provided in Appendix 2.

5.2.1.2 Willowdale streamzone monitoring 1995 - 2019

Surveys of fish and macroinvertebrates were conducted in streams within the Willowdale Mine area as part of baseline (1995, 1996) and subsequent monitoring (2003, 2005, 2011, 2015). Post-2003, macroinvertebrates only were included in the monitoring program. All surveys were undertaken in spring (see Streamtec 1997, Creagh *et al*. 2003, WRM 2016a). The aim was to monitor for any potential ecological and/or physico-chemical response to mine operations, such as salinisation, sedimentation, reduction in biodiversity, *etc*. To date, no response in the aquatic fauna has been detected (WRM 2016b).

5.2.1.3 Targeted surveys of relictual Gondwanic western petaltail dragonfly, 2007

Targeted surveys for Petaluridae dragonfly *Petalura hesperia* (western petaltail dragonfly) are described in section 4.2.1.5 for Myara North. Potential breeding habitat for this species was identified upstream and to the east of the Pinjarra Alumina Refinery Development Envelope, at Kesner Swamp, off Kesner Road, (Appendix 1). Though not currently listed, *P. hesperia* is considered a potential candidate species for Priority listing, given its ancient lineage, fragmented distribution, and unusual breeding ecology which makes *P. hesperia* highly vulnerable to disturbance (see sections 4.2.1.5 and 4.2.4).

5.2.1.3 North and South Dandalup rivers ecological condition assessment 2012 & 2019

The Water Corporation commissioned WRM to conduct the ecological condition assessments for the North and South Dandalup dams and Conjurunup Brook Dam in 2012 and 2019 (WRM 2013e; WRM 2019b). The aim was to examine the efficacy of dam releases in maintaining ecological values downstream of impoundments. Sites were located on above and below the main dams and pipehead dams (Appendix 1). Only one site was located within forested catchment on the Scarp; SD1A below South Dandalup main dam (Figure 3). Sites were sampled for fish and crayfish, with opportunistic visual observations for any freshwater mussels and rakali. Historic connectivity between lowland river reaches and headwaters is now restricted by the dams and pipehead dams. However, the species recorded from these studies may be encountered in other watercourses within Holyoake, that do retain longitudinal connectivity, such as tributaries of the Murray River.

Table 9. Summary of aquatic fauna studies and database records relevant to Holyoake.

Program	Date	Sampled by	Locations sampled	Fauna	Methods used
Surveys that include sites within the study area					
Forest stream monitoring	2004 - 2011	DBCA	Southwest WA forests	Macroinvertebrates	Kick sampling
Historic surveys in proximity to study area or with sites in similar habitats of NJF					
HRZ Streamzone monitoring	1995 - 2015	Streamtec; WRM	Willowdale mine area (Alcoa)	Macroinvertebrates, fish	Kick sampling, seine & barrier netting
Petaluridae survey	2007	Dr J. Taylor (WA Insect Study Society); WRM	Kesner Swamp, Mandejal Brook and surrounds	*Petalura hesperia*	Targeted visual observations
Database / Mussel Watch results	pre-1992 to 2012	Analysed by Klunzinger *et al.* 2015	Southwest WA	*Westralunio carteri*	DPAW and WAM database searches; Sampling method 10 - 20 min of visual and tactile searching
North and South Dandalup dams ecological condition assessment	2012, 2019	WRM	North and South Dandalup rivers and Conjurunup Brook	Fish, crayfish and mussels	Fyke nets, box traps and electrofishing
Stream fauna studies (for proposed dams)	1985 - 1988	ARL	Canning/Lower Canning River, Serpentine River, Gooralong Brook, and North Dandalup River	Macroinvertebrates	Surber sampling
Fish fauna of Canning and Nth Dandalup rivers	1985 - 1986	Pusey *et al*. 1989	Canning and North Dandalup rivers	Fish	Seine and hand netting
Other relevant studies					
Refer Table 4 section 4.2.1 for additional studies discussed for the Myara North region					

5.2.2 Summary of Aquatic Fauna

5.2.2.1 Fish and crayfish

There is no information on fish or crayfish species within the Holyoake region. Based on studies in adjacent catchments, the region is expected to support suitable habitat for at least three species of native fish (western minnows, western pygmy perch and nightfish) and two species of native freshwater crayfish (gilgies and koonacs). The region potentially supports habitat for three additional species; smooth marron, freshwater cobbler (*Tandanus bostocki*) and migratory pouched lamprey (*Geotria australis* Priority 1) for the portion within the Murray River catchment.

A recent (2016) record of pouched lamprey from the Murray River suggests this species may potentially occur in connected tributaries within the Holyoake region (Appendix 4). Pouched lampreys are difficult to survey, due to their cryptic nature and complex life history, and often require targeted survey methods to obtain population information beyond opportunistic sightings. Lampreys require sandy substrates in shaded, well-oxygenated freshwater streams to breed, where the larvae primarily live in the sediments, emerging at night to filter feed on algae and entrained organic matter (see also section 4.2.3.4 for Myara North).

Tributaries of the unregulated Murray River offer potential additional spawning habitat for fish species that are otherwise restricted from upland tributaries by dam construction on the North and South Dandalup rivers. There are few unregulated (un-dammed) rivers in the NJF and therefore local populations of fish, crayfish and freshwater mussels are vulnerable. Pre-regulation, native freshwater fishes would have undertaken seasonal spawning migration from lowland reaches into seasonal upland creeks. This is no longer possible in the majority of NJF systems due to barriers posed by large dams for drinking water supply on the Darling Scarp. Populations of fish (and crays and mussels) above the dams are now isolated from populations below the Scarp, and genetic flow between these populations is compromised. In addition, larvae of freshwater mussels are parasitic of native fish, and rely on fish migration for dispersal. Regulation has also had an adverse effect on local lamprey populations, as lampreys can't complete their life cycle in freshwater, requiring access to the ocean. Being anadromous, lampreys migrate from the ocean into upland rivers to spawn, then migrate back to the sea in order to mature to adults. The absence of a major dam on the Murray River is therefore considered a significant attribute.

While there are other large south-west rivers that are not damned for drinking water supply, these are either severely degraded due to catchment clearing and secondary salinisation (*e.g.* the Avon River in the NJF), or are located outside the NJF with limited genetic connection to rivers within the NJF (*e.g.* the Blackwood and Denmark rivers in the southern jarrah forest subregion).

5.2.2.2 Aquatic invertebrates

Records of aquatic invertebrate fauna within Holyoake region are limited to aquatic macroinvertebrate records for one site (MY44) on the eastern boundary, sampled by DBCA. No macroinvertebrate species currently listed for conservation significance were recorded (Appendix 2). The faunal assemblage included only a moderate diversity of south-west endemic epigean (stoneflies, alderflies, caddisflies, non-biting midges) species, more characteristic of a disturbed upland forest steam (Pennifold 2013). The extent to which aquatic fauna assemblages and habitats in other parts of the Holyoake region are similarly impaired is unknown. Based on previous studies for surrounding areas, the region is expected to support a relatively high diversity of macroinvertebrate species typical of both seasonal and perennially flowing upland streams and headwater swamps. This includes potential habitat for Carter's freshwater mussel (EPBC Vulnerable, WA BC Vulnerable), the minute freshwater snail *Glacidorbis occidentalis* (P3), and candidate priority dragonflies and

damselflies, all of which are described above in sections 4.2.3 and 4.2.4 for Myara North (see also Appendices 4, 5 and 6).

The hyporheic zones within Holyoake potentially support habitat for stygal isopod and amphipod species, that are potentials SREs. The stygal isopod *Hyperoedesipus plumosus* (Phreatoicidae) has been recorded from a number of streamzone monitoring sites in the Willowdale area (BG01, BG02, NG09, SM01; Appendix 7). Elsewhere, *H. plumosus* has historically been recorded from Finlay Brook (North Dandalup River catchment), Little Dandalup Creek (South Dandalup River Catchment) and McKnoe Brook (near Wagerup), and probably occurs more widely throughout the NJF (Knott 1986). The genus is in need of taxonomic revision, requiring genetic analysis to confirm taxonomic status of populations present in various catchments. Further discussion on *H. plumosus* is provided above in section 4.2.3.4. Indeterminate juveniles of stygal paramelitid amphipods have also been recorded from the Willowdale area (DK06, SM46), and stygal amphipods *Uroctena* sp. (Paramelitidae) and *Wesniphargus nichollsi* (Neoniphargidae) are known from Myara, O'Neil and McCoy areas to the north (see section 4.2.3.4). Genetic analysis is also required to confirm the taxonomy of these specimens, and hence their status as potential SREs.

5.3 Aquatic Fauna Values

Habitats that are likely to be present within the Holyoake region include ephemeral and seasonally flowing first order streams, as well as higher-order riverine channels. The availability of permanent surface waters and permanently damp hyporheic zones that might afford drought refuges is unknown, though it is likely surface-groundwater connectivity is less than in Myara North. A summary of known and potential aquatic habitat and fauna values is provided in Table 10.

Table 10. Holyoake region aquatic habitat and fauna values.

Known Values	• Inflow Dependent Ecosystems • Connectivity to one of the last remaining unregulated rivers in south-west WA (Murray River)
Potential Values	• Groundwater Dependent Ecosystems • Seasonal connectivity of headwaters for reproductive migration of several native fish species and habitat for native freshwater crayfish (gilgies, koonacs, smooth marron) • Forested catchment maintains high water quality, particularly low salinity and sediment loads • High beta diversity - characteristic of interconnected ephemeral, seasonal and permanent waterways • Drought refuges in headwater streams • High endemicity in macroinvertebrate fauna • Carter's freshwater mussel *Westralunio carteri* (EPBC Act Vulnerable, WA BC Act Vulnerable) • Pouched lamprey *Geotria australis* (P1) • Minute freshwater snail *Glacidorbis occidentalis* (P3) • Rakali *Hydromys chrysogaster* (P4) • Stygal amphipods (*Uroctena* sp., *Wesniphargus nichollsi*) and isopods (*Hyperoedesipus plumosus*) that are potential SREs • Habitat for candidate priority dragonflies and damselflies with rare and/or restricted distributions • Potential seasonal spawning habitat for western pygmy perch and nightfish

6. KNOWLEDGE GAPS

A number of knowledge gaps are identified as part of this desktop review, and the priority issues that pertain to both the Myara North and Holyoake regions are listed in Table 11.

Table 11. Knowledge gaps for aquatic fauna of Myara North and Holyoake.

	Gap	Description
1	No comprehensive, coordinated sampling programs for either Myara North or Holyoake	• There have been no comprehensive, coordinated sampling programs for aquatic fauna in Myara North or Holyoake. • Most recent data collated for the current review are from annual macroinvertebrate surveys for the Huntly and Willowdale mines, and for the Wungong Catchment Trial. • Available data is spatially and/or temporarily inconsistent, affording only a 'snapshot' of the Myara North region based on a few sites. • A number of aquatic fauna species of conservation interest and/or conservation significance are known from Myara North and are likely to occur in Holyoake. However, true extents of distribution within the regions are unknown.
2	Past surveys mostly restricted to spring	• Species assemblages in NJF streams are known to display distinct seasonality. Most previous aquatic fauna surveys within and adjacent to the regions were conducted in mid-late spring in order to capture periods of highest diversity and when specimens are sufficiently mature to allow correct taxonomic identification. Dependent on rainfall many species may have completed their life cycles or reproductive migration earlier in the year. Therefore, alternative assemblages may be recorded by sampling at other times. Stygal fauna are also more likely to be captured under higher flow conditions, if there is upwelling of groundwaters into surface creeks, or low flow periods when remaining flows are groundwater dependent.
3	Paucity of baseline data specific to Myara North and Holyoake	• Data are largely restricted to 'grey' literature, and are from irregular temporal sequences that are limited in scope and application, and often focused on broader-scale monitoring, rather than characterising baseline aquatic habitat and aquatic fauna values. In many cases, the data from consultancy reports have been gathered using sampling designs that are suited for detecting gross impacts, but tend to be more vulnerable to confounding variables, and less statistically robust owing to the practicalities of time and budget. • Very little information on hydro-ecological relationships for aquatic fauna that would be required to help predict potential impacts of future hydrological change or disturbance by development. There are few studies on how aquatic fauna in the NJF have responded to climate change. • Replicated sampling across multiple years would be required and the implementation and subsequent publishing/uploading of data and records is limited by funding and resource constraints across industry, university, government and community sectors, and the hesitancy of some project proponents (including private industry and government) to share potentially sensitive information relating to developments. • It is likely there are additional studies on comparable habitats in the NJF which are not publicly available.

	Gap	Description
4	Ecological values used to assign conservation significance are based on species-level identifications	• Most ecological values used to assign conservation significance for fauna are based on species-level identifications, as individual species are listed under various legislation and policies, and not families or genera. As immature/damaged specimens of potentially significant species have been previously collected and identified to broad family groups for many records listed in NatureMap and ALA, it is likely the conservation significance of invertebrate assemblages, and in turn individual species has been underestimated due to taxonomic resolution and data deficiency. • Aquatic species are generally under-represented in assessments of conservation status, and those of ephemeral and seasonal systems in particular.

7. CONCLUSIONS

A review of literature and existing knowledge of the aquatic ecosystem of the Myara North and Holyoake regions of the Huntly Mine has been undertaken in this desktop assessment. Aquatic habitats and aquatic fauna values within of Myara North and, in particular, Holyoake are virtually unknown, though numerous studies have been undertaken in surrounding areas of the NJF. Distributions of native fish (western minnow, pygmy perch, nightfish), crayfish (gilgies, koonacs) and many south-west endemic macroinvertebrate species are known to overlap the Myara North and Holyoake regions, however few have actually been reported, owing to spatial gaps in the available literature.

Recent records of Carter's freshwater mussel (EPBC Vulnerable, WA BC Vulnerable) and the minute freshwater snail *Glacidorbis occidentalis* (P3) show populations of these conservation significant species occur within Myara North. No records exist for Holyoake, however the presence of populations nearby suggests freshwater mussels and the minute snail likely also occur within this region. Two other conservation significant species potentially occur; rakali (P4) in both regions, and pouched lamprey (P1) in Murray River tributaries in Holyoake.

No fish or crayfish species currently listed for conservation significance are known to have been recorded in the Huntly or Willowdale mine areas to date, including the limited records for Myara North and Holyoake regions.

There are few macroinvertebrate records for the regions, especially for Holyoake. Several species of conservation interest occur in proximity to the regions, notably stygal amphipods and isopods, and candidate priority dragonflies and damselflies, and there is potential for populations to occur in seasonal streams and headwater swamps within both Myara North and Holyoake.

The aquatic biota of seasonal and ephemeral headwater streams in the NJF have been historically understudied. As such, very little information exists for stygal species and candidate priority species, in terms of their distribution and conservation status, and their hydro-ecological relationships. The effective sampling of seasonal and ephemeral streams is also complicated by uncertainties around the presence and persistence of surface water, which is largely dependent on variables that are challenging to predict or characterise, such as climate patterns, underlying geology and surrounding landscape/catchment. At a higher level, potential impacts of future hydrological change or disturbance by the Proposal can be inferred based on the longitudinal studies of macroinvertebrates for the Huntly and Willowdale mines. These studies found no detrimental impact from mining, though communities did respond to consistent downward trends in rainfall over the study period (WRM 2020).

Native fish move into seasonally flowing headwater streams to spawn (*e.g.* western minnow, pygmy perch, nightfish) using aquatic or riparian (streamside) vegetation as spawning habitat. Macroinvertebrates have adapted life histories to flourish in seasonally flowing streams, freshwater mussels can withstand periodic drying by closing their bivalve, and crayfish burrow to avoid seasonal drying. Thus, although perennial water supports many taxa that are obligates, seasonally flowing waterways support a rich biodiversity of aquatic fauna and ecosystem services. Seasonally dry streams also provide important habitat services to terrestrial fauna including invertebrates (Datry *et al*. 2017).

Globally, in a generalistic sense, permanently flowing rivers and streams harbour higher species richness (alpha diversity) than do rivers and streams that undergo seasonal drying (Soira *et al*. 2017). However, intermittent rivers and ephemeral streams support a high diversity of species that have evolved life history and drought resistance traits, and contribute regional biodiversity where such intermittent and episodic

systems are present, including south-west WA (Bonada *et al*. 2006; Davies & Stewart 2013, Datry *et al.* 2017). Ephemeral and seasonal streams provide the same ecological and hydrological functions as perennial streams by facilitating the transport of energy, water, nutrients and sediment throughout the catchment (Levick *et al.* 2008). Catchments with both intermittent and perennially flowing systems have greater beta-diversity (species richness between streams) due to the mosaic of habitat types and niches available for aquatic taxa (Bonada *et al*. 2006, Soira *et al.* 2017). Furthermore, expansion and contraction of habitat throughout the cycles of wetting and drying provide seasonally available habitat resources to fauna including fish, crayfish and macroinvertebrates, which utilise seasonal streams for migration and breeding, and reside in drought refuges within such as permanent pools (Chester & Robson 2011, Strachan *et al.* 2015). Whilst permanently flowing waterways in south-west forested catchments are undeniably important, and increasingly so under a drying climate, ecosystem values of seasonally dry rivers and streams should not be overlooked in ecological assessments.

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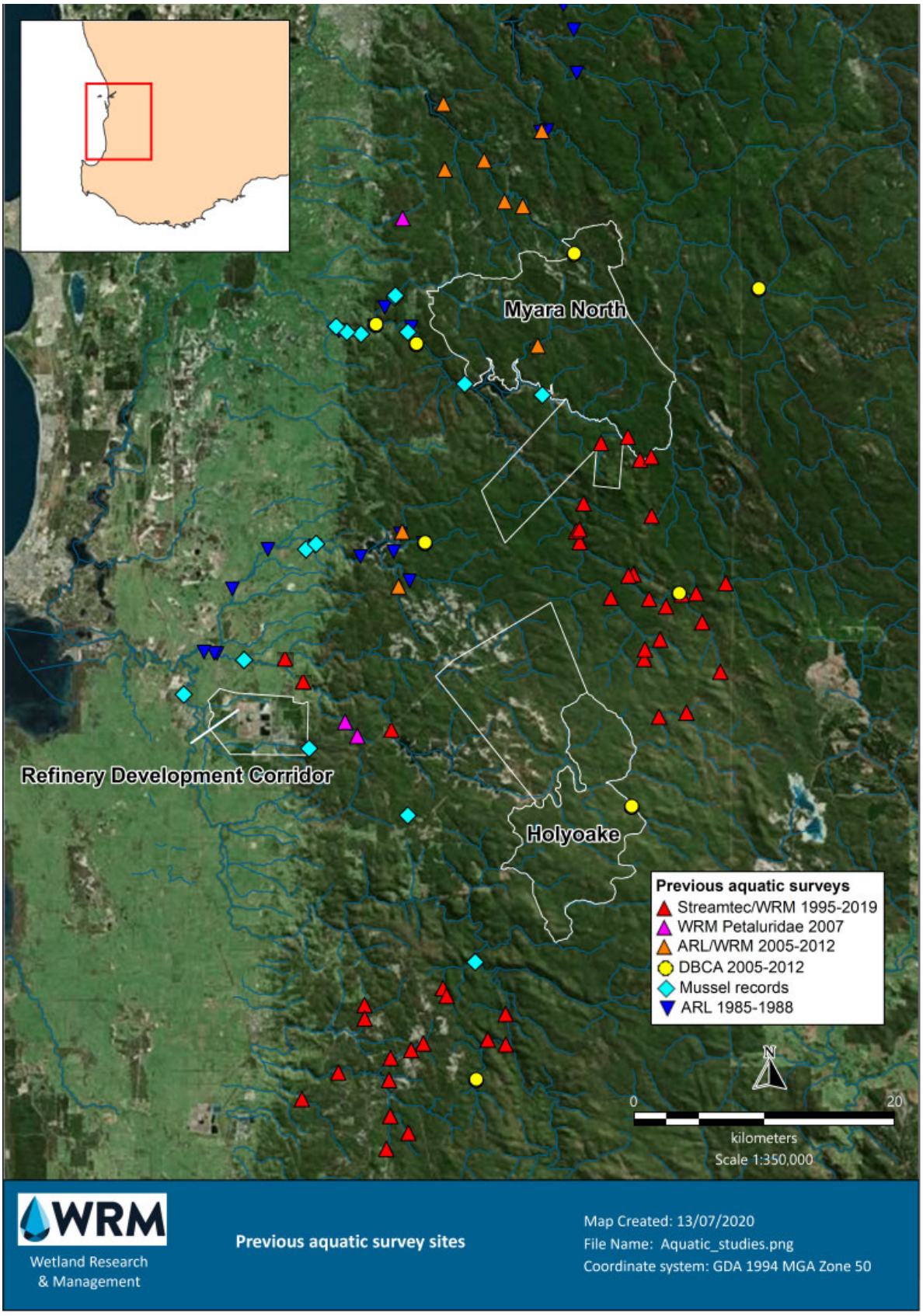
APPENDICES

Appendix 1. Previous Aquatic Survey Sites



Appendix 2. DBCA Forest Monitoring Records

Site SWA04 (Myara North region)		
Class/Order	Species Name	SWA endemic (where known)
Acarina	Arrenuridae sp.	UN
Acarina	Aturidae sp.	UN
Acarina	Hydryphantidae sp.	UN
Acarina	Hygrobatidae sp.	UN
Acarina	Limnesiidae sp.	UN
Amphipoda	Perthiidae sp.	LIKELY
Annelida	Hirudinea sp.	UN
Cladocera	Cladocera (unident.)	UN
Coleoptera	*Allodessus bistrigatus*	NO
Coleoptera	Chrysomelidae sp.	UN
Coleoptera	*Limbodessus inornatus*	NO
Coleoptera	*Necterosoma* sp.	UN
Coleoptera	*Paracymus pygmaeus*	NO
Coleoptera	*Platynectes* sp.	UN
Coleoptera	Scirtidae sp.	UN
Coleoptera	*Sternopriscus browni*	YES
Coleoptera	*Sternopriscus* sp.	UN
Decapoda	Parastacidae sp.	UN
Diptera	Athericidae sp.	UN
Diptera	*Botryocladius freemani*	YES
Diptera	*Botryocladius petrophilus*	NO
Diptera	Ceratopogonidae sp.	UN
Diptera	*Chironomus* aff. *alternans* (V24) (CB)	UN
Diptera	*Cricotopus 'parbicinctus'*	UN
Diptera	*Cryptochironomus* aff. *griseidorsum*	NO
Diptera	*Cryptochironomus griseidorsum*	NO
Diptera	Culicidae sp.	UN
Diptera	*Dicrotendipes pseudoconjunctus*	UN
Diptera	Dicrotendipes sp. A (V47) (SAP)	UN
Diptera	Ephydridae sp.	UN
Diptera	*Limnophyes vestitus* (V41)	UN
Diptera	Orthocladiinae 'woodminer' (SAP)	UN
Diptera	Orthocladiinae SO3 sp. A (SAP)	YES
Diptera	*Parakiefferiella variegatus*	UN
Diptera	*Paralimnophyes pullulus* (V42)	UN
Diptera	*Paramerina levidensis*	YES
Diptera	Pentaneurini genus V20	UN
Diptera	*Podonomopsis* sp. 1	UN
Diptera	*Polypedilum watsoni*	NO
Diptera	*Procladius paludicola*	NO

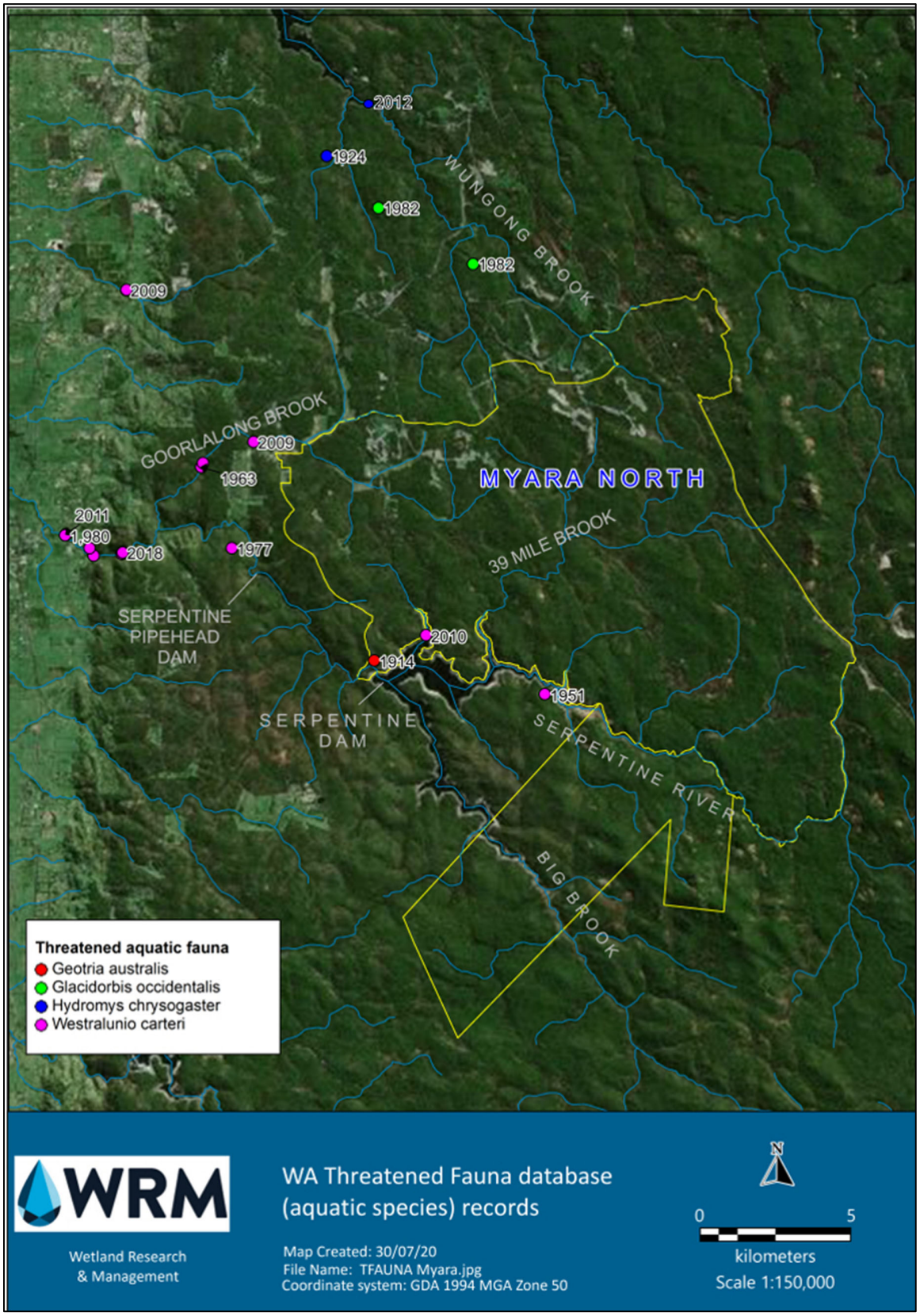
Site SWA04 (Myara North region)		
Class/Order	Species Name	SWA endemic (where known)
Diptera	Riethia v5	UN
Diptera	Simuliidae sp.	UN
Diptera	*Stictocladius occidentalis*	UN
Diptera	T*anytarsus* aff. *manleyensis*	UN
Diptera	*Tanytarsus fuscithorax/ semibarbitarsus*	UN
Diptera	*Tanytarsus* nr K5	UN
Diptera	*Tanytarsus palmatus*	UN
Diptera	*Thienemanniella* sp. (V19) (SAP)	UN
Ephemeroptera	*Nousia* sp. AV16	YES
Ephemeroptera	*Nyungara bunni*	YES
Nematoda	Nematoda sp.	UN
Odonata	*Archiargiolestes pusillus*	YES
Odonata	*Austrolestes analis*	NO
Oligocheata	*Ainudrilus nharna*	YES
Oligocheata	Enchytraeidae sp.	UN
Oligocheata	Naididae sp.	UN
Oligocheata	Opisthopora sp.	UN
Oligocheata	Phreodrilidae sp.	UN
Ostracoda	Ostracoda (unident.)	UN
Plecoptera	*Leptoperla australica*	YES
Plecoptera	*Newmanoperla exigua*	YES
Plecoptera	*Riekoperla occidentalis*	YES
Trichoptera	*Hydrobiosella michaelseni*	YES
Trichoptera	*Hydroptila losida*	NO
Trichoptera	*Maydenoptila baynesi*	YES
Trichoptera	*Maydenoptila* sp.	UN
Trichoptera	*Notalina* sp. AV15 (PSW)	UN
Trichoptera	*Notoperata tenax*	YES
Trichoptera	*Oxyethira* sp.	UN
Trichoptera	*Triplectides* sp. AV21 (SFM)	YES

Site MY44 (Holyoake region)		
Name ID	Species Name	SWA endemic (where known)
Acarina	Aturidae sp.	UN
Acarina	Mesostigmata sp.	UN
Amphipoda	Perthiidae sp.	LIKELY
Cladocera	Cladocera (unident.)	UN
Coleoptera	Curculionidae sp.	UN
Coleoptera	Exocelina ater	UN
Coleoptera	Hyderodes sp.	UN
Coleoptera	*Limbodessus inornatus*	NO
Coleoptera	*Necterosoma* sp.	UN
Coleoptera	*Platynectes* sp.	UN
Coleoptera	*Rhantus suturalis*	NO
Coleoptera	Scirtidae sp.	UN
Coleoptera	*Sternopriscus* sp.	UN
Copepoda	Copepoda sp.	UN
Diptera	*Ablabesmyia* sp. V37	UN
Diptera	Athericidae sp.	UN
Diptera	Ceratopogonidae sp.	UN
Diptera	*Chironomus aff. alternans* (V24) (CB)	UN
Diptera	*Corynoneura* sp. (V49) (SAP)	UN
Diptera	Culicidae sp.	UN
Diptera	*Dicrotendipes* sp. A (V47) (SAP)	UN
Diptera	*Gymnometriocnemus* sp. 1 (=V44)	UN
Diptera	*Harrisius* sp. A (SAP)	UN
Diptera	*Harrisius* sp. B (SFM)	UN
Diptera	*Kiefferulus martini*	NO
Diptera	*Paralimnophyes pullulus* (V42)	UN
Diptera	*Paramerina levidensis*	YES
Diptera	Pentaneurini genus V20	UN
Diptera	*Podonomopsis* sp. 1	UN
Diptera	*Polypedilum watsoni*	UN
Diptera	Simuliidae sp.	UN
Diptera	*Skusella*/"V12 ex-WA" (Cranston)	UN
Diptera	*Tanytarsus aff manleyensis*	UN
Diptera	*Tanytarsus* b1	UN
Diptera	*Tanytarsus fuscithorax/semibarbitarsus*	UN
Diptera	*Tanytarsus* nr K5	UN
Diptera	*Tanytarsus palmatus*	UN
Diptera	Tipulidae sp.	UN
Ephemeroptera	Leptophlebiid genus S sp. AV1	UN
Ephemeroptera	*Neboissophlebia occidentalis*	YES
Ephemeroptera	*Nousia* sp. AV16	YES
Ephemeroptera	*Nyungara bunni*	YES

Site MY44 (Holyoake region)		
Name ID	Species Name	SWA endemic (where known)
Gastropoda	Planorbidae sp.	UN
Megaloptera	*Archichauliodes* sp.	LIKELY
Oligochaeta	Naididae sp.	UN
Oligochaeta	Opisthopora sp.	UN
Oligochaeta	Phreodrilidae sp.	UN
Ostracoda	Ostracoda (unident.)	UN
Plectoptera	*Riekoperla occidentalis*	YES
Rotifera	Scaridiidae sp.	UN
Trichoptera	Triplectides sp. AV21 (SFM)	YES

Appendix 3. DBCA Threatened Fauna Species Records: Myara North

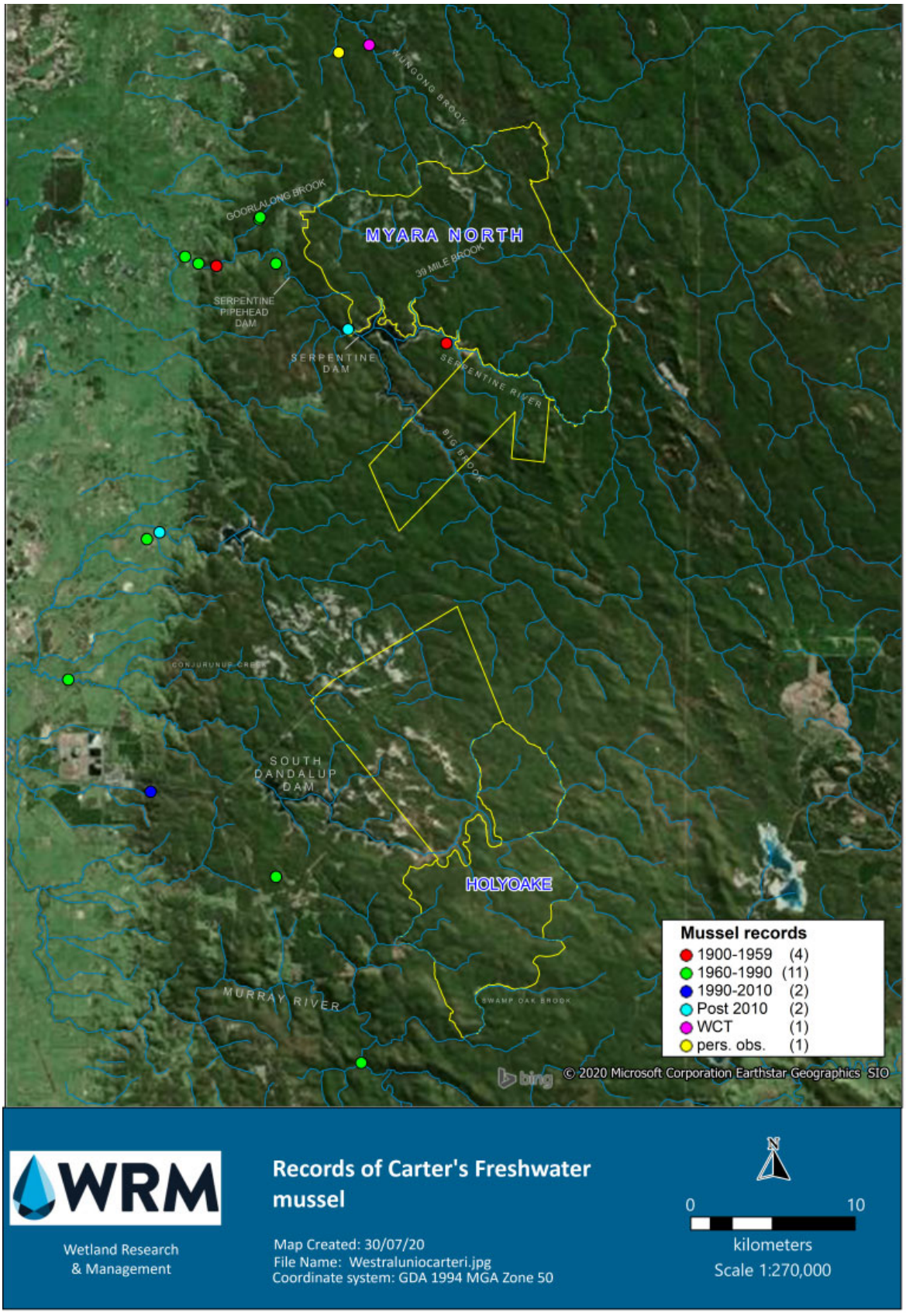
Year of record indicated.



Appendix 4. DBCA Threatened Fauna Species Records: Holyoake

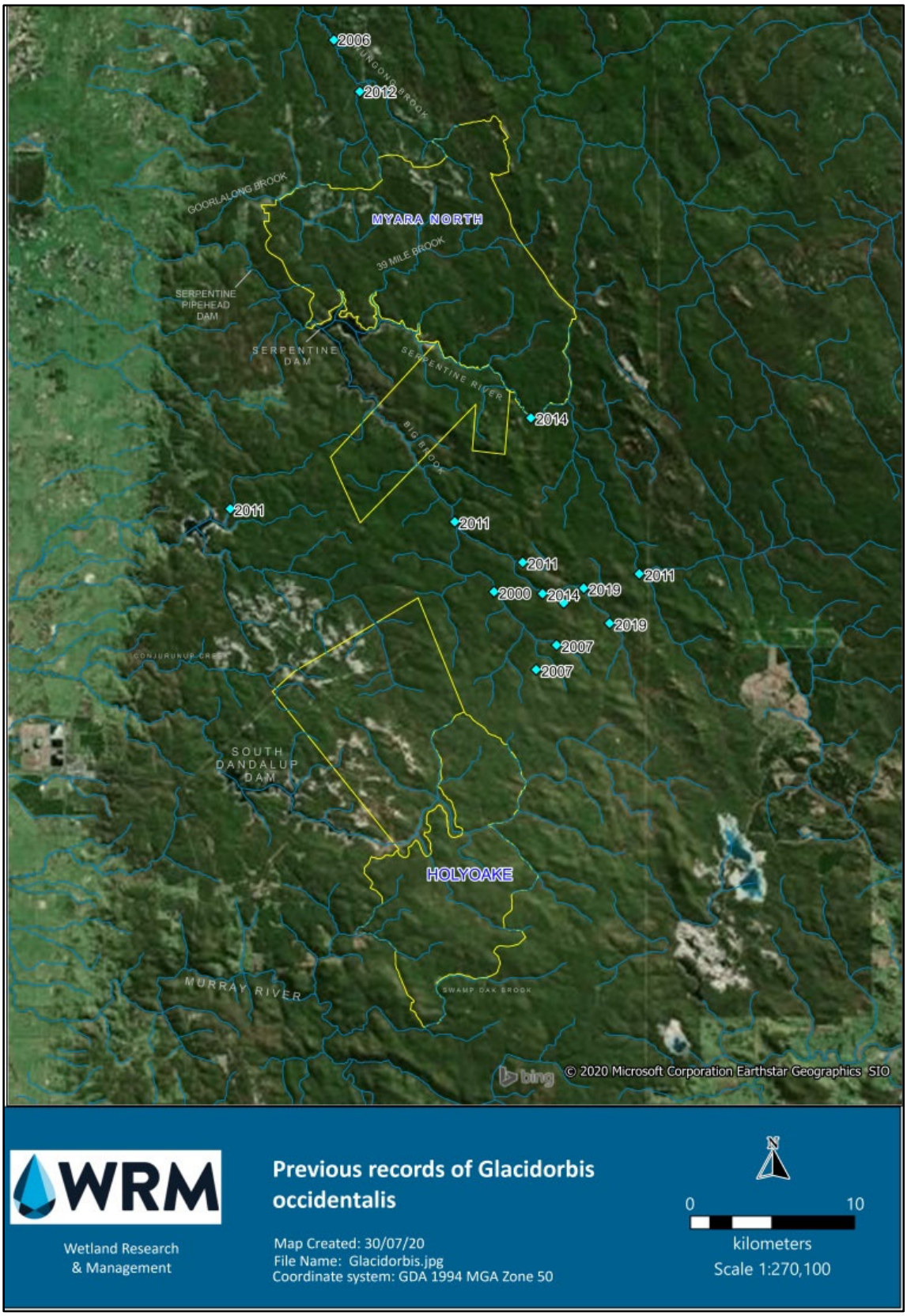
Year of record indicated.

Appendix 5. Records of Carter's Freshwater Mussel *W. carteri*



Appendix 6. Records of the Minute Freshwater Snail *G. occidentalis*

Year of record indicated.



Appendix 7. Records of GDE Species

Year of record indicated. NatureMap records where year was not specified indicated as 'ND'.