

LAKE ROE GOLD PROJECT: BASELINE AQUATIC ECOLOGY STUDY

PREPARED FOR **BREAKER RESOURCES**

September 2020

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Executive Summary

Breaker Resources NL (Breaker) are proposing to develop the Lake Roe Gold Project (the Project), associated with the Bombora gold deposit, on the south western edge of Lake Roe, located 100 km east of Kalgoorlie. The Project is expected to comprise a large open pit gold mine (approximately 2.5 km in length), a processing plant, waste rock landform (WRL), tailings storage facility (TSF) and other supporting infrastructure. In addition, it is likely that dewatering discharge will be required to Lake Roe.

Stantec Australia Pty Ltd (Stantec) were commissioned to undertake a baseline aquatic ecology study (the Study) of Lake Roe and surrounds, with the objective of increasing understanding of ecological values. The field survey of the lake and salinas was undertaken in dry conditions in May 2019. Sediment samples were collected for chemical analysis and to undertake rewetting trials (to simulate a flood event in the laboratory). Riparian vegetation was also assessed. A total of 18 sites were established, which included 14 sites on Lake Roe and four salina sites. Opportunistic collection of aquatic invertebrates was also undertaken prior to the field survey for this Study, from a in October 2018.

The Study provided preliminary baseline data on the aquatic and riparian ecology of the naturally saline Lake Roe and surrounding salinas. Water quality from the the rewetting trials indicated that the lake and salinas are likely to be alkaline (pH>7.5) and range in salinity from hyposaline to mesosaline, during the intital stages of flooding. Surface sediment was also typically alkaline (>pH 7.3) and saline, the latter being elevated in the salinas. Nutrient levels were variable, although substantially higher total nitrogen was also recorded in salinas in the north-eastern margin of the lake. For metals, chromium and nickel exceeded the ANZECC & ARMCANZ (2000) ISQG-Low trigger value at most Lake Roe and salina sites, while nickel also exceeded the ISQG-High trigger value within Lake Roe.

The rewetting trials undertaken for the Study were successful, and the results suggested that Lake Roe and the salinas are likely to support a productive and diverse biological assemblage during major flood events. A total of 106 taxa from the various biological groups were identified (**Table ES-1**), characterised by mostly well-documented, salt tolerant species. The taxa recorded collectively from Lake Roe and the salinas comprised 12 algae, two macrophytes, 24 diatoms, 15 aquatic invertebrates, six resting stages and 47 riparian plant taxa. Lake Roe supported the majority of the biodiversity (94 taxa), in comparison to the salinas (57 taxa), however, this disparity can likely be attributed to the unequal sample effort.

Similarities were evident in the biological assemblage observed between Lake Roe and the salinas. Both were characterised by common saline genera of algae such as *Hantzschia*, *Navicula*, *Planktolyngbya* and *Planktothrix* and macrophytes including *Ruppia tuberosa*. Charophyte oospores (*Lamprothamium* and *Nitella*) were also recorded in the sediment, which were particularly abundant at two salinas, located on the north-eastern margin of the playa, despite not germinating in the rewetting trials. Aquatic invertebrates included resident salt tolerant crustacean fauna recorded across the lake and salinas, including the ostracods *Diacypris phoxe* and *Patcypris outback*, while the brine shrimp *Parartemia serventyi* and *Parartemia veronicae* were predominantly associated with the lake. In contrast, *Triops nr australiensis* and *Caenestheia* sp. were characteristic of the peripheral claypan, indicative of freshwater or low salinity conditions. Riparian vegetation was characterised by chenopods, dominated by *Tecticornia*, *Frankenia* and *Atriplex* genera.

The majority of taxa recorded during the Study have been previously documented from the Coolgardie bioregion, and/or are known to occur more broadly throughout inland waters across Australia. There were no significant species of algae, macrophytes, or plants identified. However, three potentially new aquatic invertebrate taxa were recorded; the ostracods *Australocypris* 'BOS1364', *Reticypris* 'BOS1088' and *Reticypris* 'BOS1363' (**Table ES-2; Figure ES-1**). Of these, the former two species are currently only known from Lake Roe (although widespread throughout the playa and/or salinas), while the latter species (*Reticypris* 'BOS1363') has recently been identified from the Great Sandy Desert.

Table ES1: Summary of the taxa recorded per biota group during the Study.

Biota	Lake Roe Taxa	Salina Taxa	Total Taxa
Algae	12	10	12
Macrophytes	2	2	2
Diatoms	20	16	24
Aquatic Invertebrates	11	7	15
Resting Stages	5	4	6
Riparian Vegetation	44	18	47
Total Taxa	94	57	106

The potential exists for direct and indirect impacts on sensitive biological receptors inhabiting Lake Roe, the salinas, claypans and riparian zone, from development and mining for the Project (**Table ES-2**). Based on the findings of this Study, primary biological receptors were identified, which may be at risk of impacts, comprising:

- algae and macrophytes (including dormant propagules in sediment);
- aquatic invertebrates (including resting stages in sediment); and
- plants inhabiting the riparian zone.

Impacts from the Project may be associated with the location of infrastructure, development and mining of the deposit, and likely dewatering discharge to Lake Roe (**Table ES-2**). Direct impacts include the removal of habitat and release of contaminants, as well as inundation of the playa with hypersaline water, which may impact on aquatic biota and riparian vegetation. Indirect impacts include hydrological changes, drawdown and sedimentation, which may also adversely affect sensitive biological receptors on the playa and surrounds.

The level of risk to the sensitive biological receptors will be dependent on the final layout of infrastructure mining schedule, and associated requirements, as well as the location selected for the discharge outfall. There are several new aquatic invertebrate taxa known from Lake Roe and the salinas, although all species have also been recorded well-outside of the development envelope from numerous locations. It is also likely that these taxa occur in other lakes and salinas throughout the Roe Palaeodrainage system, due to the potential for connectivity and dispersal throughout the area during major flood events. This indicates that minimising impacts on the playa will ensure the persistence of these species.

There were no other new, listed or restricted taxa identified during the Study, including within the riparian zone (although several *Tecticomia* taxa remain unverified), reducing the potential risk from the Project. However, limiting the extent and duration of impacts still requires consideration, and appropriate risk assessment utilising a formal framework, as the Project progresses. A number of considerations and recommendations are provided at the rear of this report, to address knowledge gaps, improve understanding of potential impacts and risk and manage and mitigate Project impacts, to ensure the ecological integrity of the lake and surrounds is maintained.

Table ES-2: Summary of key findings and preliminary impact assessment for the baseline aquatic ecology study.

Ecological Aspects	Ecological Values				Preliminary Impact Assessment	
	Key Findings	Dominant Taxa	Total Taxa	Significant Taxa	Direct Impacts	Indirect Impacts
Water Quality	<ul style="list-style-type: none"> alkaline (pH>7.5) hyposaline to mesosaline, becoming hypersaline as the hydroperiod progresses 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<p>Infrastructure Layout:</p> <ul style="list-style-type: none"> removal of aquatic and riparian habitat due to clearing for development; surface water runoff, containing potential contaminants (elevated concentrations of salts and metals); and seepage of potential contaminants into groundwater and subsequent discharge to lake and/or riparian zone. <p>Dewatering Discharge:</p> <ul style="list-style-type: none"> change in hydroperiod from temporary to permanent for the duration of the discharge; erosion of lakebed and surrounds; increased salts and formation of a salt crust; and inundation of riparian zone with hypersaline discharge water causing adverse effects 	<p>Infrastructure Layout:</p> <ul style="list-style-type: none"> changes to surface hydrology, influencing water flow and pooling, adversely effecting persistence of aquatic biota and riparian vegetation; and sedimentation from runoff, smothering aquatic biota, riparian vegetation and propagules. <p>Dewatering Discharge:</p> <ul style="list-style-type: none"> reduced emergence and colonisation of aquatic biota due to: <ul style="list-style-type: none"> the presence of a thick salt crust (physical barrier); elevated salinities above potential tolerance limits; elevated concentrations of metals, causing toxicity; reduced recruitment of plants in the riparian zone due to increased salinity; smothering of aquatic biota, vegetation and propagules, due to drawdown and sediment mobilisation; and inundation of surrounding salinas, claypans, tributaries and/or riparian zone with hypersaline discharge water, causing adverse effects.
Sediment Quality	<ul style="list-style-type: none"> acidic to alkaline moderate to high salt loads variable nutrients variable metals, elevated chromium & nickel 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 		
Benthic Algae	<ul style="list-style-type: none"> Composition comprising diatoms, cyanobacteria and chlorophytes Species typical of saline waters 	<ul style="list-style-type: none"> <i>Hantzschia</i> <i>Navicula</i> <i>Planktolyngbya</i> <i>Planktothrix</i> 	<ul style="list-style-type: none"> 12 	<ul style="list-style-type: none"> None 		
Macrophytes	<ul style="list-style-type: none"> Patchy distribution of species typical of saline waters 	<ul style="list-style-type: none"> <i>Chara</i> sp. <i>Ruppia tuberosa</i> 	<ul style="list-style-type: none"> 2 	<ul style="list-style-type: none"> None 		
Diatoms	<ul style="list-style-type: none"> Composition typical of saline waters, including <i>Amphora</i>, <i>Hantzschia</i> and <i>Navicula</i> 	<ul style="list-style-type: none"> <i>Amphora coffeaeformis</i> <i>Hantzschia</i> sp. aff. <i>baltica</i> <i>Navicula</i> sp. aff. <i>incertata</i> 	<ul style="list-style-type: none"> 24 	<ul style="list-style-type: none"> None 		
Aquatic Invertebrates	<ul style="list-style-type: none"> Composition dominated by crustaceans including ostracods & anostracans Assemblage typical of saline waters 	<ul style="list-style-type: none"> <i>Diacypris phoxe</i> <i>Patcypris outback</i> 	<ul style="list-style-type: none"> 15 	<ul style="list-style-type: none"> <i>Australocypris</i> 'BOS1364' <i>Reticypris</i> 'BOS1088' <i>Reticypris</i> 'BOS1363' 		
Resting Stages	<ul style="list-style-type: none"> Patchy distribution of species typical of saline waters (crustaceans and charophytes) 	<ul style="list-style-type: none"> Ostracoda <i>Nitella</i> sp. <i>Lamprothamnium</i> sp. 	<ul style="list-style-type: none"> 6 	<ul style="list-style-type: none"> None 		
Riparian Vegetation	<ul style="list-style-type: none"> Composition dominated by salt tolerant chenopods Taxa recorded typical of salt lake riparian zone No declared rare or priority flora species recorded No introduced (weeds) species recorded 	<ul style="list-style-type: none"> <i>Tecticornia</i> spp. <i>Frankenia</i> sp. <i>Atriplex nana</i> 	<ul style="list-style-type: none"> 47 	<ul style="list-style-type: none"> None 		

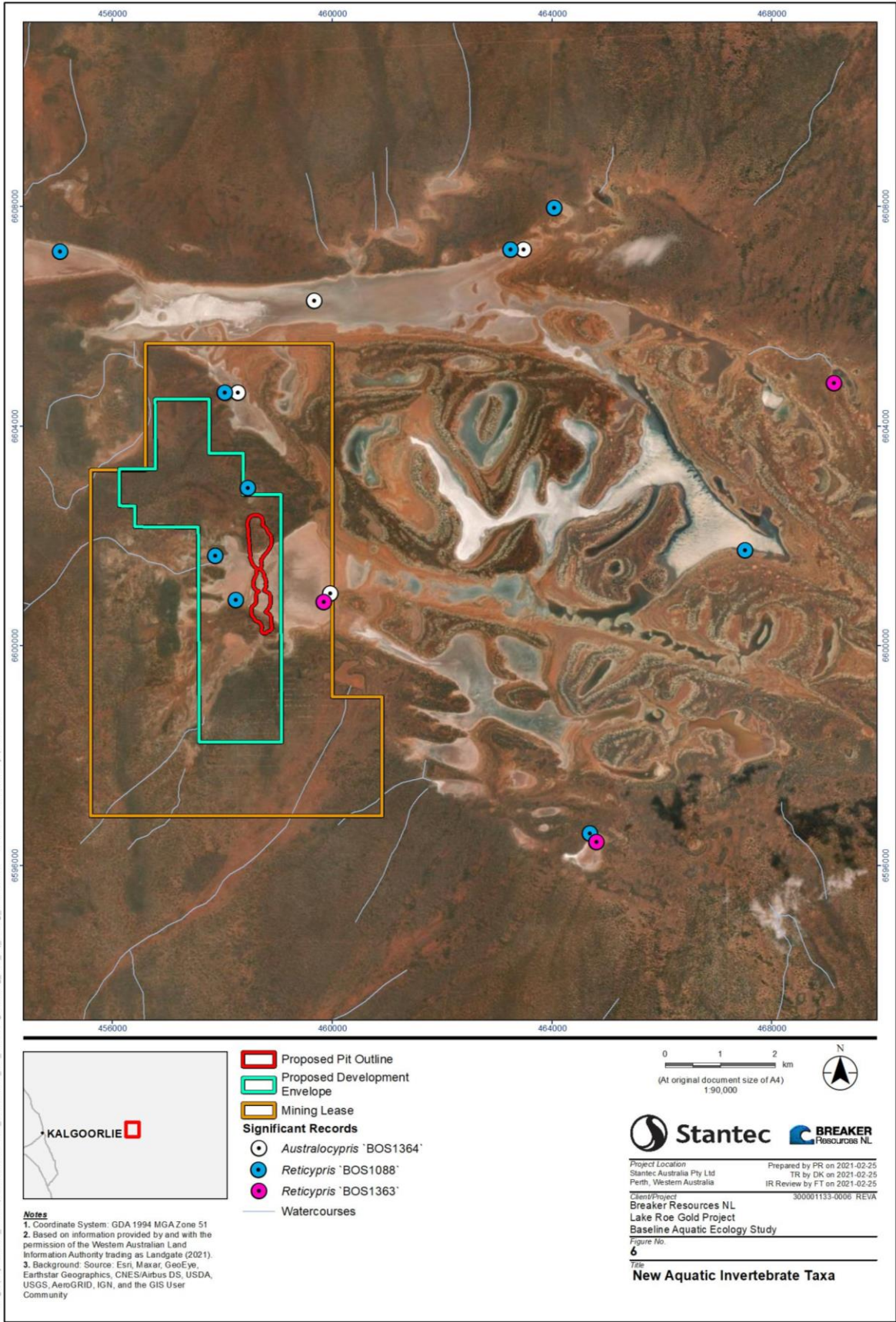


Figure ES-1: Location of new aquatic invertebrate taxa recorded during the Study.

Breaker Resources

Lake Roe Gold Project: Baseline Aquatic Ecology Study

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1. Introduction

1.1 Project Background

Breaker Resources NL (Breaker) are proposing to develop the Lake Roe Gold Project (the Project), comprising the Bombora deposit, and commissioned Stantec Australia Pty Ltd (Stantec) to undertake a Baseline Aquatic Ecology Study (the Study). The Project is located on the south western edge of Lake Roe, 100 km east of Kalgoorlie, in the eastern Goldfields region of Western Australia (**Figure 1-1**). It comprises six granted tenements across an area of approximately 550 km². Gold mineralisation typically occurs as a sulphide-impregnated lode along a north-south strike.

While currently in the prefeasibility phase, with ongoing exploration and definition of the resource, the Project will likely comprise the development of a large open pit gold mine approximately 2.5 km in length, which will be mined to approximately 200 m in depth. Supporting infrastructure will include a processing plant, waste rock landform (WRL), tailings storage facility (TSF), run of mine pad (ROM), laydown area, topsoil stockpiles, workshop, office and village, as well as linear infrastructure including access roads. In order to facilitate mining, dewatering of hypersaline groundwater from the pit will be required, with Lake Roe a likely discharge option.

Previously, in August 2018, Stantec completed an environmental and hydrological desktop assessment for the Project. Based on the findings and recommendations of this assessment, in May 2019, Stantec was commissioned to undertake this Study to investigate the ecological values of Lake Roe and its peripheral wetlands, addressing knowledge gaps.

1.2 Objective and Scope

The objective of the Study was to increase the understanding of the ecological values of Lake Roe and peripheral wetlands (salinas and claypans), to support environmental approvals for the Project. The following scope of works was undertaken:

- ecological assessment of the lake and peripheral wetlands (abiotic and biotic components) during dry conditions;
- collection of surficial sediments from the lake and peripheral wetlands to undertake rewetting trials, simulating flooded conditions, to determine the diversity of aquatic biota;
- determining the potential communities and species of significance inhabiting the lake and peripheral wetlands (excluding waterbirds);
- characterising important ecological habitats within the lake and peripheral wetlands, providing regional context; and
- identifying potentially sensitive environmental receptors, in relation to preliminary impacts associated with the Project.

1.3 Guidance and Legislation

The Study was undertaken in accordance with relevant legislation and regulatory guidelines. These include, albeit are not limited to:

Environmental Protection Authority (2018). Environmental Factor Guideline – Inland Waters; and

Department of Water and Environmental Regulation (2018). Goldfields Environmental Management Workshop: DWERs Approach to Assessment of Mine Dewatering Discharge to Salt Lakes and Claypan Environments.

Technical guidance was also considered for flora and vegetation (Environmental Protection Authority 2016a;c) and terrestrial fauna (Environmental Protection Authority 2016b;d;e), where applicable to the EPA's Inland Waters factor.

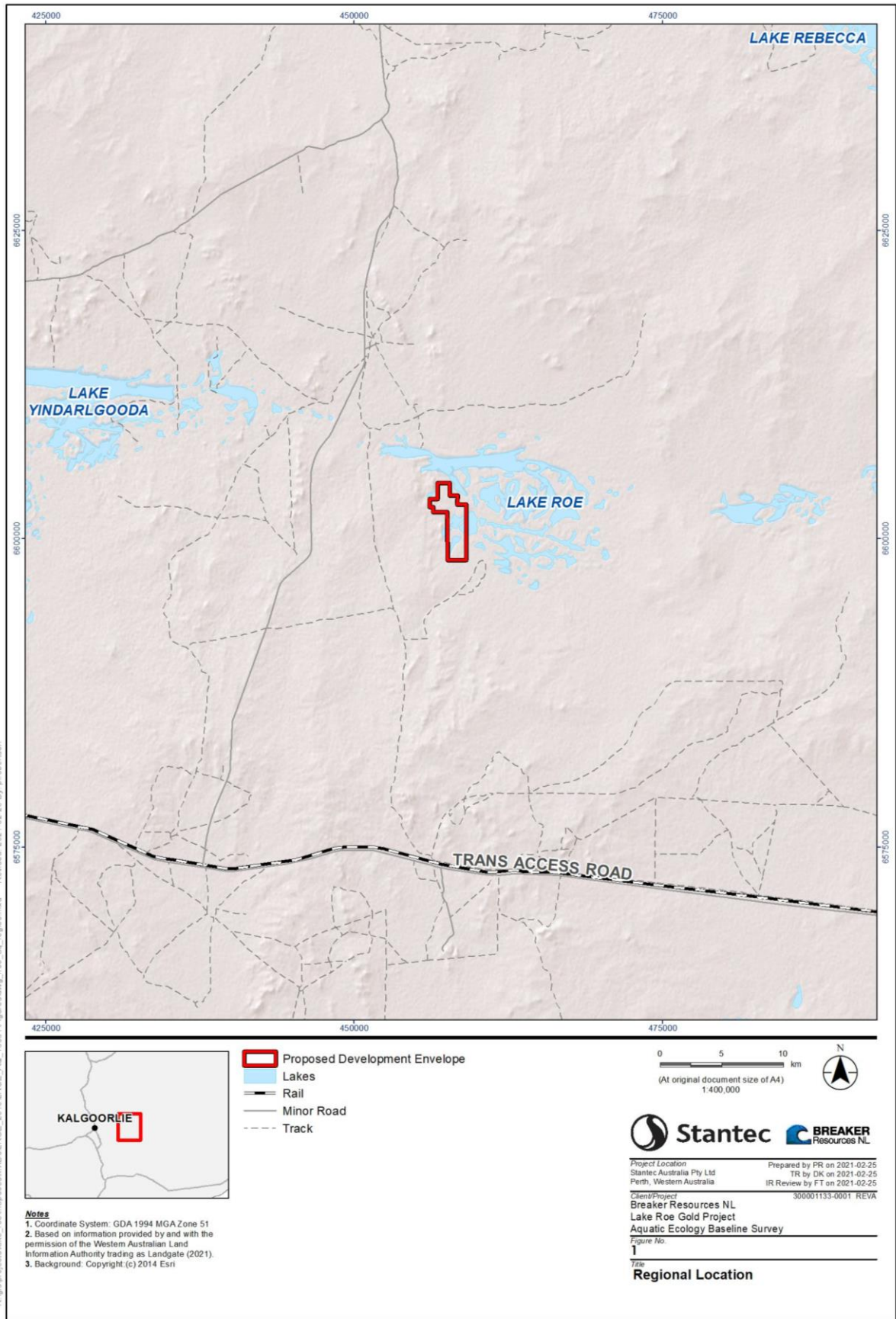


Figure 1-1: Regional location of Lake Roe in relation to the Project.

2. Existing Environment

2.1 Biogeographical Context and Land Use

The Project is located within the Eastern Goldfields Subregion (COO3) of the Coolgardie bioregion, in Western Australia (**Figure 2-1**), and covers an area of 5,102,428 ha (Cowan 2001). The subregion is underlain by the Yilgarn Craton, which forms a large section of the Western Shield geotectonic unit (Pilgrim 1979). It is characterised by gentling undulating plains interrupted in the west by low hills and ridges of Archaean greenstones, and in the east by a horst of Proterozoic basic granulite (Cowan 2001).

Topographic relief in the subregion is low, and the underlying strata are eroded flat and covered with Tertiary sand and gravel soils, scattered exposures of bedrock and plains of calcareous earths (Kern 1996b). Early Tertiary sediments are preserved in the palaeochannels within an infilled palaeodrainage system, concealed by thick sequences of Cainozoic deposits (Johnston *et al.* 1999). Soils in the subregion vary widely from deep sands to cracking clays, and most landforms are considered to be hard lime at depth. However, surface geology is typically characterised by neutral red earths on the plains, calcareous loams and brown calcareous earths in the hills and saline soils in around playa lakes McKenzie *et al.* 2003).

Vegetation is characterised by mallees, *Acacia* thickets and shrub-heaths on sandplains. *Eucalyptus* woodlands surround saline playas, occur on ranges and in valleys. There are numerous salt lake systems throughout the subregion; the remnants of ancient major drainage lines. These salt lakes support dwarf shrublands of samphires (*Tecticornia*). The Project area also lies in the Coolgardie Botanical Zone of the South Western Interzone (Beard 1979), and is located within the internationally significant Great Western Woodlands. This area supports more than 3,000 flowering plant species and is a centre of endemic *Eucalypt* species diversity (Department of Environment and Conservation 2010).

The primary land uses within the subregion comprise Unallocated Crown Land (UCL) and Crown reserves as well as native grazing pastures (37.8%) and freehold land (7.15%) (Cowan 2001). The Project area is situated on Pastoral Lease Yindi (PL N09512). Pastoralism, especially sheep grazing, has been the major land use over the past 100 years, resulting in degradation and erosion (McKenzie *et al.* 2003). As the subregion is rich in mineral deposits, especially gold and nickel, exploration and mining are also prevalent (Kern 1996b). The township of Kumalpi (65 km north-west of the Project), was a thriving gold centre from the late 1800's to the early 1900's, however, has since been abandoned.

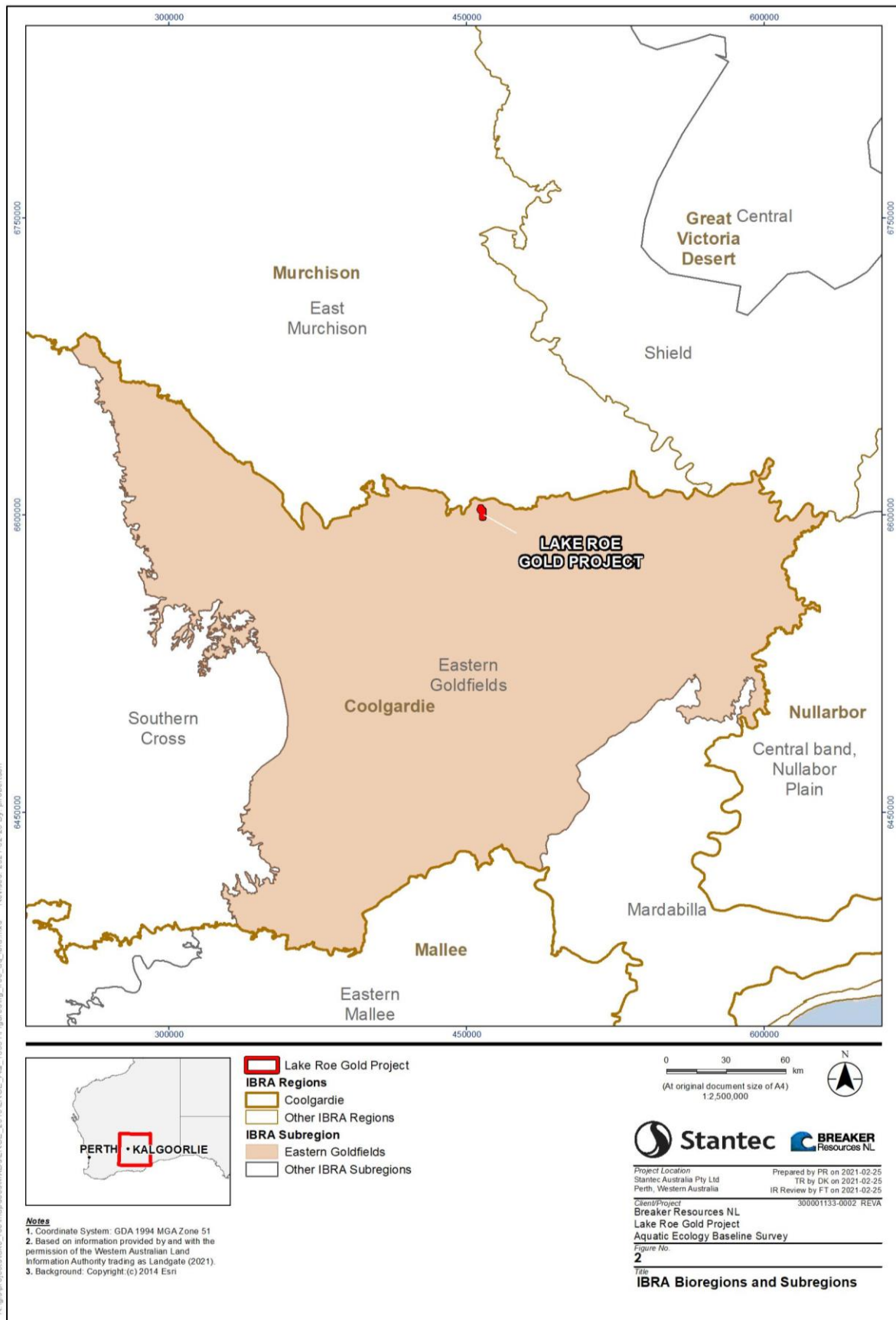


Figure 2-1: Location of the Project within the Eastern Goldfields subregion.

2.2 Hydrogeology

Drainage in the Yilgarn Craton is derived from an ancient river system that radiates from a broad drainage divide (Anand and Paine 2002). Over geological time scales extensive alluviation of valley floors has occurred forming chains of salt lakes (Kern 1995). These salt lakes are the deflated remnants of the palaeorivers (palaeochannels) and act as a basin for the accumulation of salts and sediment, often connected to local and regional groundwater systems (Salama 1997). The Project lies along the south western margin of Lake Roe, which is part of the Roe Palaeodrainage system (Kern 1996a).

The hydrogeology of the Project area (Kern 1996b) is underlain by weathered and fractured Archaean bedrock, overlain locally by palaeochannel deposits and widespread alluvium and lake deposits. The bedrock forms part of the Yilgarn Goldfields fractured-rock groundwater-province (Kern 1996a). The fractured bedrock is characterised by secondary permeability resulting from tectonic and decompression fracturing enhanced by chemical dissolution along fracture lines. Fractured-bedrock aquifers occur more commonly in mafic, ultramafic, and granitic rocks than in sedimentary or felsic volcanic and volcanoclastic rocks. Open fractures occurring to depths of 120 m and 150 m have been reported and similar depths could be expected along major faults and shear zones (Kern 1996a).

The Roe Palaeodrainage system is extensive (**Figure 2-2**), comprising three main tributaries extending from 80 km west northwest, to 60 km west of Kalgoorlie, through over 200 km east to northeast of Kalgoorlie, where the palaeodrainage feature becomes obscured by the Eucla Basin Coastal Barrier (Kern 1996a). The main trunk of the palaeochannel is in the vicinity of the Project area and Lake Roe (**Figure 2-3**). The key palaeochannel sediments comprise the Wollubar Sandstone, which is at least 30 m thick and consists of unconsolidated quartz sand, with minor conglomerate, silt, clay, and lignite. This is overlain, obscured and confined by the Perkollili Shale, a multicoloured clay with minor sandy clay beds up to 40 m thick (Kern 1996a).

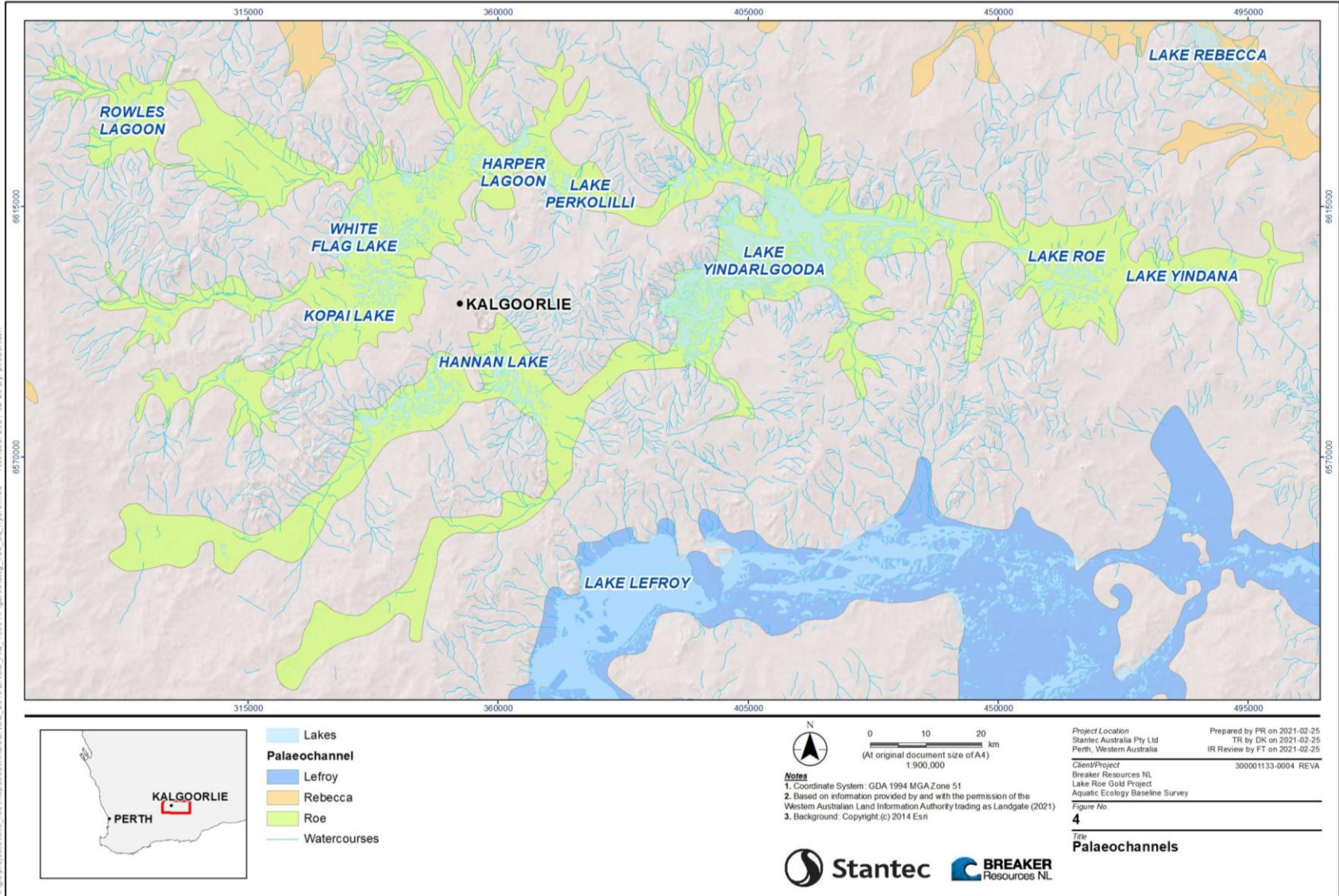
The Wollubar Sandstone is highly permeable and contains significant volumes of groundwater. Minor amounts of groundwater occur in the alluvial and lacustrine deposits. Minor mafic and ultramafic dykes occur in the southern half of the area. They are undeformed, typically appear to lack open fractures, and are possible hydraulic barriers to groundwater movement. However, no significant dykes are known in the immediate vicinity of the Project area. A regional water table occurs in the Project area, the depth to which ranges from less than 1 m in the vicinity of Lake Roe, to more than 50 m in elevated areas (Kern 1996a).

2.3 Surface Hydrology

The Lake Roe catchment area is approximately 1,515 km² and is located along the southern limit of the larger Raeside-Ponton Catchment (approximately 116,000 km²) (**Figure 2-4**). The Raeside-Ponton Catchment is part of the vast Salt Lake Basin (440,000 km²), which extends across much of central Western Australia and includes several large, sub-parallel, southeast trending salt lake drainage systems (Groundwater Resource Management 2018).

Lake Roe is an endorheic salt lake with a surface area of 90 km², of which approximately half comprises islands of low relief up to 10 m high. Surface gradients over the lake are low (typically <0.01%) and there are no significant river systems or watercourses in proximity. The lake is typically dry except following periods of substantial rainfall-runoff, which results in surface water pooling in discrete areas. This is most often associated with the remnants of tropical cyclones or intense summer storms. Within a 200 km radius of the lake, the frequency that remnant tropical cyclones influence the area, is on average, approximately once every six years (Groundwater Resource Management 2018).

The last major flood event occurred in April 2017. Natural flow within the lake is from the northwest to southeast, although this is interrupted by the presence of islands throughout the playa. There are two sub-catchments upstream of the lake, limited to approximately 178 km²; the Southwestern and Southern Sub-catchments, which are 165 km² and 13 km² in size, respectively. Runoff from these sub-catchments reports to Lake Roe via two distinct drainages (**Figure 2-5**), the discharge points of which are approximately 700 m apart along the lake shore (Groundwater Resource Management 2018).



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Figure 2-2: Palaeodrainage systems in the vicinity of the Project.

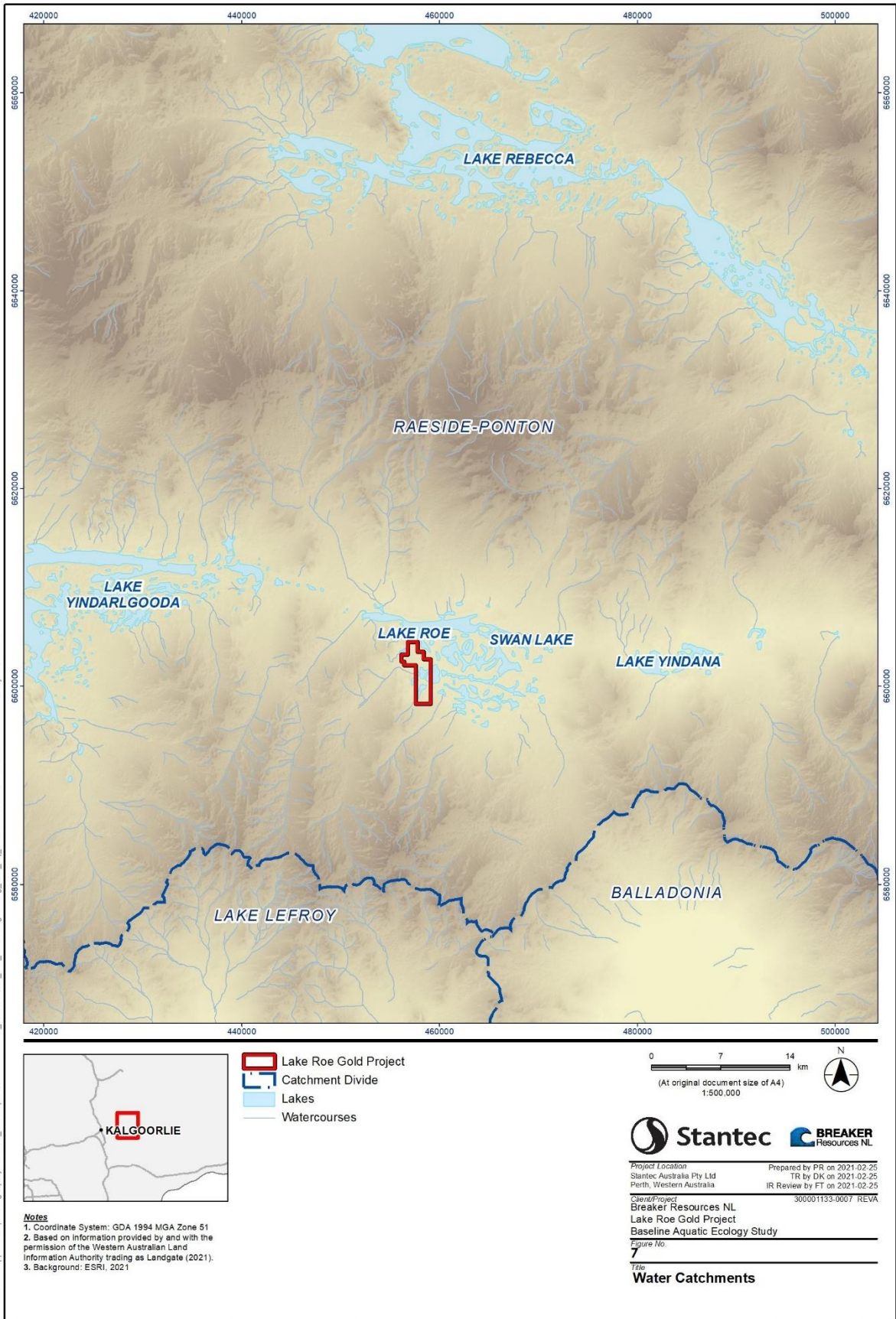
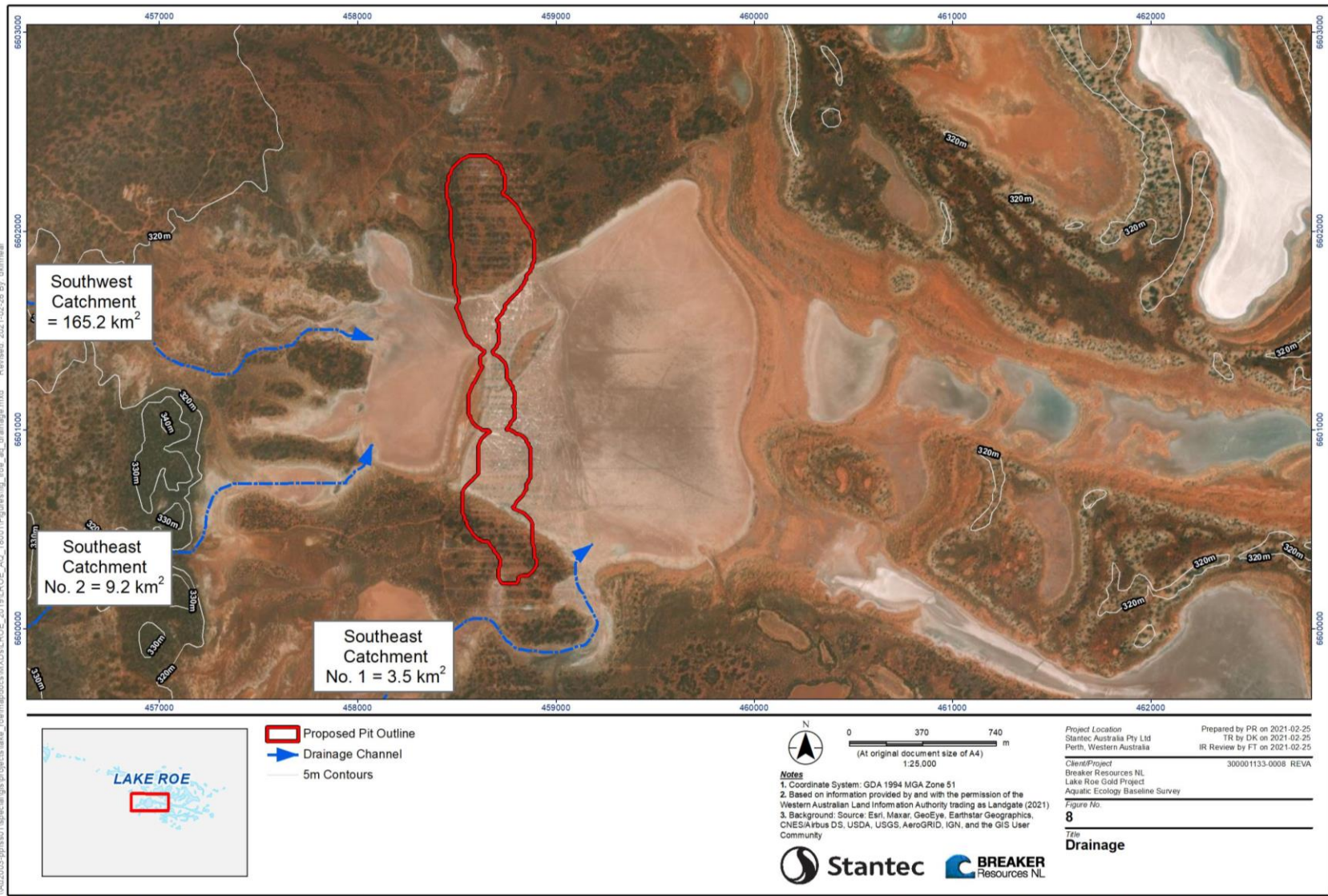


Figure 2-4: Surface water catchments in the vicinity of the Project.



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Figure 2-5: Sub-catchments and drainage lines associated with the Project. Source (Groundwater Resource Management 2018).

2.4 Climate

The Project is located approximately 100 km east of Kalgoorlie, and has a semi-arid climate, characterised by hot summers and cool winters (Pringle *et al.* 1994). Temperatures range from below zero in winter, to in excess of 40°C during summer. Rainfall is variable, with an average of approximately 300 mm per annum, most of which is associated with winter or summer weather systems. Evaporation in the area is high at approximately 2400 mm per year (Johnston *et al.* 1999), exceeding rainfall in all months.

Mean annual rainfall recorded from Kalgoorlie-Boulder Airport weather station (Bureau of Meteorology site number 12038; 100 km to the west), is approximately 267 mm, based on reliable records from 1943 to 2018. The highest mean monthly rainfall, in excess of 30 mm, occurs in February; coinciding with high mean monthly temperatures (Figure 2-6). In the twelve months prior to the Study rainfall was below average (250 mm), although substantially above average rainfall was recorded in October 2018 (69 mm), November 2018 (62 mm) and April 2019 (36 mm).

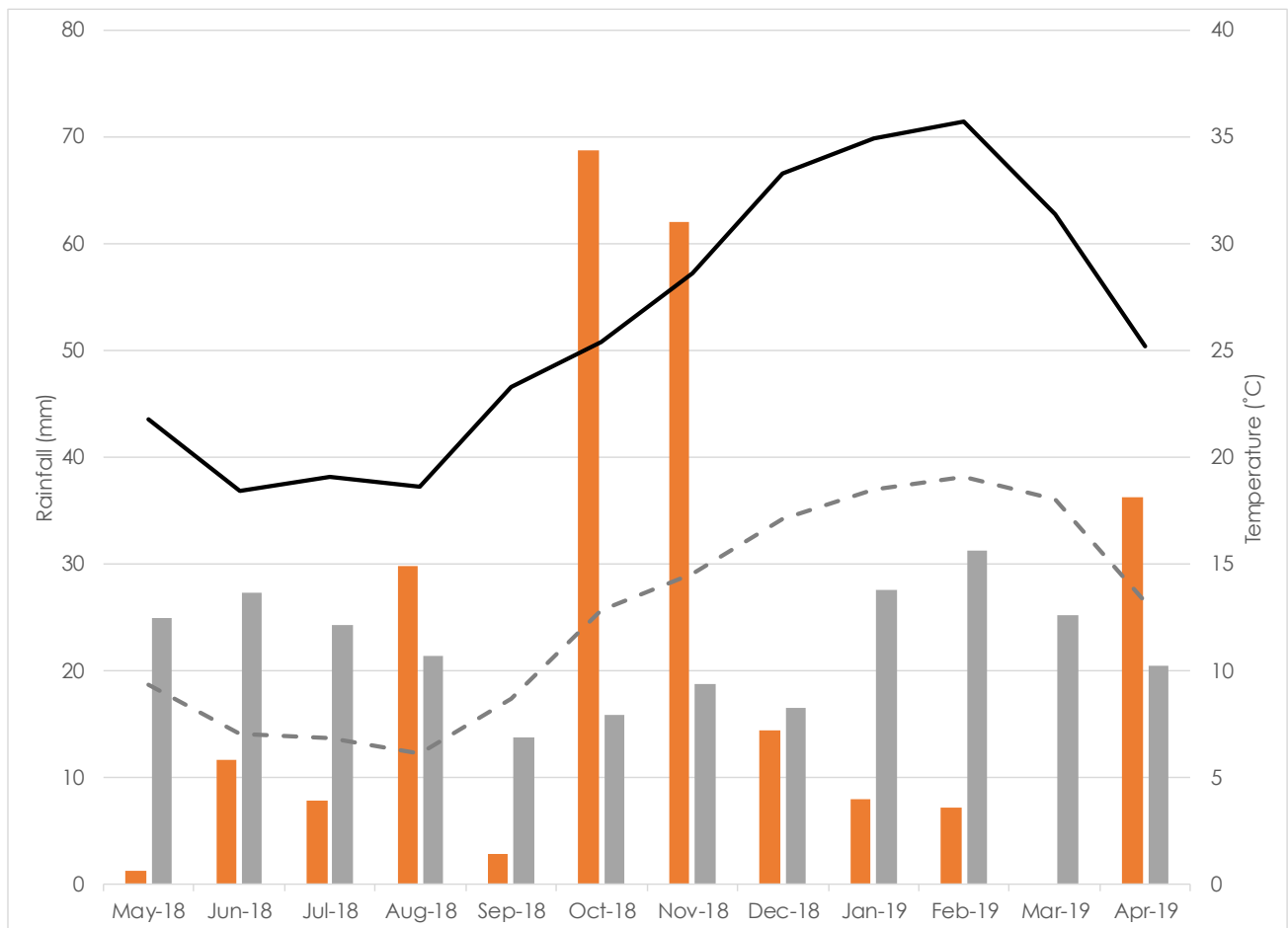


Figure 2-6: . Monthly rainfall (■), compared to long-term mean monthly rainfall (■), with mean minimum (---) and mean maximum (—) temperatures recorded at the Kalgoorlie-Boulder Airport weather station (#12038) (Bureau of Meteorology 2020).

3. Methods

3.1 Survey Design

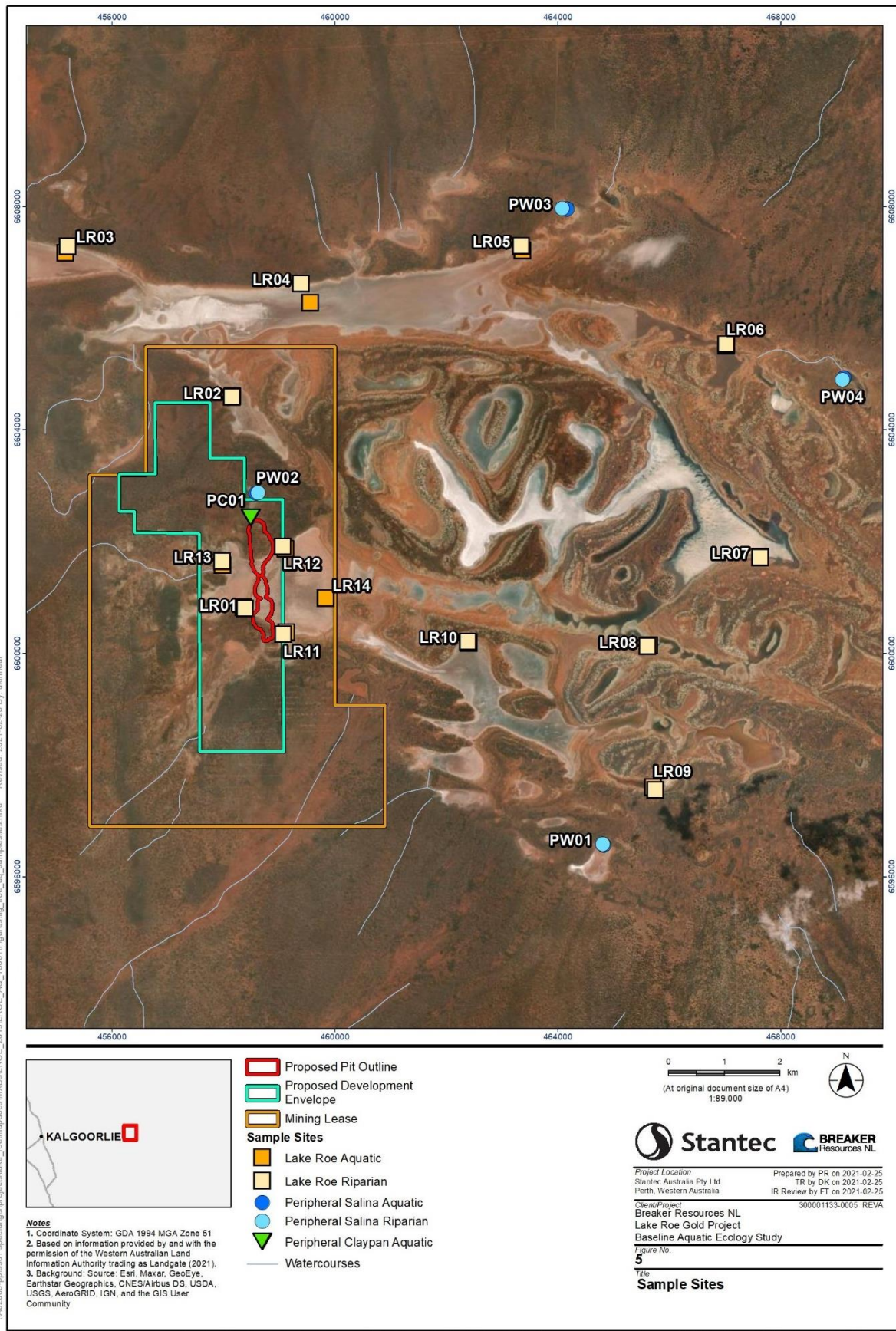
A field survey of Lake Roe and peripheral wetlands (salinas and claypans) was undertaken for the Study over a five-day period in May 2019, during dry conditions. A total of eighteen sites were established, incorporating 14 sites on the lake and four salinas (**Figure 3-1**). Sampling was undertaken by two highly experienced Stantec ecologists, Dr Nicholas Stevens and Emma Dobinson. A Licence for fauna taking (biological assessment) Regulation 27 (Licence Number BA27000066) was obtained from the Department of Biodiversity Conservation and Attractions (DBCA).

During the field survey, the habitat was characterised at each site, sediment samples were collected for chemical analysis and riparian vegetation was assessed (**Table 3-1**). Sediment was also collected for the purpose of undertaking laboratory rewetting trials (simulating a flood event). In addition, an opportunistic aquatic invertebrate sample was collected from one inundated peripheral claypan in a prior survey during October 2018.

Table 3-1: Summary of the sampling program (●) for the Study.

Sites	GPS Coordinates (UTM, Zone 51 J)		Habitat Characterisation	Sediment Quality	Rewetting Trials	Riparian Vegetation	Aquatic Invertebrates
Lake Roe							
LR01	458363	6600832	●	●	●	●	●
LR02	458163	6604611	●	●	●	●	
LR03	455161	6607176	●	●	●	●	
LR04	459554	6606285	●	●	●	●	
LR05	463365	6607217	●	●	●	●	
LR06	467022	6605518	●	●	●	●	
LR07	467636	6601735	●	●	●	●	
LR08	465642	6600138	●	●	●	●	
LR09	465772	6597648	●	●	●	●	
LR10	462407	6600183	●	●	●	●	
LR11	459129	6600378	●	●	●	●	
LR12	459112	6601876	●	●	●	●	
LR13	457990	6601633	●	●	●	●	
LR14	459839	6600949	●		●		
Salinas							
PW01	464806	6596577	●	●	●	●	
PW02	458585	6602867	●	●	●	●	
PW03	464160	6607970	●	●	●	●	
PW04	469134	6604936	●	●	●	●	
Claypans							
PC01*	458486	6602436					●

Note: * sampled opportunistically in October 2018.



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Figure 3-1: Location of the sites sampled during the Study, in relation to the Project.

3.2 Sediment Quality

Sediment sampling was undertaken at all sites (excluding LR14) during the field survey for the Study. The top 2 cm of sediment was scraped into a sterilised glass jar (excluding voids), which was then sealed and sent to ALS (Wangara), for the analysis of a suite of parameters (**Table 3-2**). Samples were collected and stored using containers and instructions provided by ALS. Holding times were breached for pH at all sites and for moisture content at LR01, LR02, LR09, LR11, PW01 and PW02, and these results should be considered indicative only.

Analytical sediment quality results were compared to the ANZECC & ARMCANZ (2000) interim sediment quality guideline (ISQG)-Low and ISQG-High trigger values. Sediment pH was also classified according to Hazelton and Murphy (2007), which ranges from very strongly acidic (<5.0) to very strongly alkaline (>9.0).

Table 3-2: Sediment quality parameters analysed during the Study.

Basic	Anions and Cations	Metals and Trace Elements	
pH	Chloride (Cl)	Aluminium (Al)	Lead (Pb)
Total Suspended Solids (TDS)	Sulphate (SO ₄)	Arsenic (As)	Manganese (Mn)
Total Kjeldhal Nitrogen (TKN)	Carbonate (CO ₃)	Barium (Ba)	Mercury (Hg)
Nitrite + Nitrate (NO ₂ + NO ₃)	Bicarbonate (HCO ₃)	Beryllium (Be)	Nickel (Ni)
Total Nitrogen (TN)	Sodium (Na)	Cadmium (Cd)	Selenium (Se)
Total Phosphorus (TP)	Magnesium (Mg)	Chromium (Co)	Silicon (Si)
Total Organic Carbon (TOC)	Calcium (Ca)	Cobalt (Co)	Vanadium (V)
	Potassium (K)	Copper (Cu)	Zinc (Zn)
		Iron (Fe)	

3.3 Resting Stages

Sediment samples were collected at all sites during the Study to assess resting stages (dormant propagules of aquatic biota). Surface sediment was scraped using a modified PVC pipe, across an area 25 x 25 cm and 1 to 2 cm deep, with the resultant sample placed into calico bags. In the Stantec laboratory, the samples were oven dried at 40°C. Once dry, a 200 g sub-sample was passed through 500 µm and 106 µm stacked Endecott® brass sieves. Material (1 g) retained in the 106 µm sieve was examined using a dissecting microscope. Resting stages were enumerated and identified using appropriate literature by experienced aquatic scientist Emma Dobinson. The abundance of resting stages was calculated per 100 g of sediment.

3.4 Aquatic Invertebrates

A single aquatic invertebrate sample was collected opportunistically from surface water at one site (PC01) in October 2018. The sample was collected by hand using a 250 mL polycarbonate vial and refrigerated to preserve specimens. Sorting of the sample was completed under a dissecting microscope, on return to the Stantec laboratory. The abundance of aquatic invertebrates was recorded, with invertebrate specimens separated into their broad taxonomic groups and placed into microvials and preserved in 100% undenatured ethanol. Identification of taxa to species level was completed using appropriate literature and keys by invertebrate taxonomist Thomas de Silva of Stantec.

3.5 Rewetting Trials

Rewetting trials were undertaken using sediment samples collected during the field survey for the Study. These trials aim to simulate a flood event, to germinate algae and macrophytes, and hatch aquatic invertebrates. In the Stantec laboratory, dried sediment was placed into transparent 20 L containers, to which dechlorinated water was added. Artificial aerators increased dissolved oxygen levels in the containers and liquid fertiliser was added to the water to promote biological productivity. Albite® hydroponic lights were applied to increase light intensity and maintain heat within the containers, based on a diurnal cycle.

The rewetting trials were undertaken over 12 weeks, to allow aquatic biota to emerge, develop and mature, simulating various stages of the hydroperiod. Basic water quality (pH, electrical conductivity and temperature) was measured regularly, and aquatic biota were observed daily, with the emergence of new taxa recorded. During this time dechlorinated water was added as required and algal pellets were used as a food source for aquatic invertebrates.

Macrophytes were allowed to develop to maturity and were identified following methods outlined in **Section 3.5.2**. Aquatic invertebrates, once mature were manually collected from the containers and preserved in 100% undenatured ethanol. Specimens were sorted and identified using methods outlined in **Section 3.5.3**.

For the purposes of data analysis and reporting, aquatic biota recorded during the rewetting trials were combined with the results from the opportunistically collected aquatic invertebrates. Reference to salinity tolerance limits for taxa were typically converted from mg/L to $\mu\text{S}/\text{cm}$, to align with water quality results from the rewetting trials. It should be noted that laboratory conditions cannot fully replicate naturally flooded conditions and instead provide a likely representation of the resident algae and aquatic invertebrates that may emerge.

3.5.1 Benthic Algae and Diatoms

After approximately six weeks of the rewetting trials benthic algal samples growing in the containers were collected for identification. Filamentous algae were also collected opportunistically from containers throughout the rewetting trials. A small portion of each sample was mounted onto a slide and assessed using a compound microscope (40X). The abundance (using a broad ranking system) and diversity of algae was recorded for each site. Identification to genus level was completed by principal taxonomist Dr Erin Thomas (Stantec), using appropriate taxonomic guides.

Concurrently, sediment samples from each site were also collected from the rewetting trial containers for the processing of the microalgae diatoms (Bacillariophyta). Samples were treated in 70% nitric acid to remove organic material and permanent slides were prepared according to John (1983). One slide was made from each sample and enumeration was carried out at 100X magnification using a compound microscope. The abundance and diversity of diatoms was recorded for each site. A maximum of 100 diatoms were counted from each site, or at sites where diatoms were considered sparse, the total number of diatoms was counted. Species were identified using relevant literature by aquatic scientist Jake Daviot, with verification by principal taxonomist Dr Fiona Taukulis, both of Stantec.

3.5.2 Macrophytes

Macrophyte samples growing in rewetting trial containers were collected opportunistically throughout the rewetting trials for identification and typically require a longer period to mature than aquatic invertebrates. The specimens were examined under a dissecting microscope in the laboratory and identified to genus or species level using morphological and reproductive features. A relative macrophyte abundance ranking was provided. Verification of macrophytes was undertaken by principal taxonomists Dr Erin Thomas and Dr Fiona Taukulis, using appropriate taxonomic literature.

3.5.3 Aquatic Invertebrates

Aquatic invertebrates were collected from the rewetting trial containers at approximately five and eight weeks, using a 50 μm mesh net, with the resultant samples preserved in 100% undenatured ethanol. The samples were sorted, with an estimate of abundance recorded. The specimens were separated into their broad taxonomic rank, with identification to the lowest possible level completed by Dr Erin Thomas and Thomas de Silva of Stantec. Specialist taxonomist Dr Stuart Halse (Bennelongia Environmental Consultants) provided identification of ostracod species.

3.6 Riparian Vegetation

Riparian vegetation was assessed at all sites (excluding LR14) during the field survey of the Study. Transects, 30 m in length, were established perpendicular to the shoreline from the edge of the lake or peripheral wetland. Along each transect, ten quadrats (3 m x 3 m) were assessed and species diversity, plant health, cover (percentage) and abundance was recorded. Photographic monitoring was also undertaken to support the assessment.

Plant health was rated on a scale of 1 to 5 for each quadrat within a transect, based on the system by Keighery (1994), as follows:

1. = dead/no live vegetation;
2. = poor/declining vegetation health;
3. = good/improving vegetation health;
4. = very good vegetation health/no change from previous monitoring if relevant; and
5. = excellent health, new germinants.

Plant specimens collected in the field were identified by experienced Stantec botanists, excluding *Tecticornia* specimens. The latter were identified by specialist Dr Kelly A. Shepherd (Senior Research Scientist) of the Western Australian Herbarium (WAH).

3.7 Multivariate Statistical Analysis

Multivariate statistical analysis involves the analysis of more than one parameter at a time and was performed on data generated from the Study using PRIMER, Version 7.0. Principal component analysis (PCA) was used to assess sediment quality (abiotic) data, and hierarchical classification was used to investigate biological data.

For abiotic data, where values were below detection, a value equal to half the limit of reporting was substituted, while parameters with values mostly below detection were removed. Pre-treatment of the data involved removal of collinear variables and applying a square-root transformation to the data, to reduce skewness. PCA was undertaken on the refined dataset, the results of which are shown in the form of a plot, where sites with similar characteristics are located close together. Vectors radiate from the centre of the plot, representing the influence of parameters. Higher concentrations of a parameter tend to occur near the end point of the vector. The percentage variance is used to explain the strength of the PCA, presented over the first two axes of the plot. A value of more than 50% is considered a useful interpretation of the results (Clarke and Warwick 2001).

Hierarchical classification was used to determine trends in the community structure of biological data including benthic algae, diatoms, aquatic invertebrates and riparian vegetation. Data was square-root transformed as required, to reduce skewness. For each dataset, the Bray-Curtis coefficient calculated similarities between sites, with classification based on the group-average linking algorithm. The results of the hierarchical classification were then presented in the form of a dendrogram (link-tree), showing the percentage similarity between sites, based on biological community structure (Clarke and Warwick 2001).

4. Results and Discussion

4.1 Habitat Characterisation

4.1.1 Lake Roe

Lake Roe consists of a highly convoluted playa divided by a complex series of islands. During the Study sites were distributed throughout the playa (**Table 4-1, Plate 4-1, Plate 4-2**), with several sites located in proximity to the Project (LR01, LR11, LR12, LR14, LR13). Conditions were dry at the time of sampling. The lake is rarely subject to major flooding, typically after heavy rainfall during summer months. The most significant inflows are located along the lake's western margin, draining the two sub-catchments.

The geology of the lakebed is characterised by a clay to clay-loam sandy substrate (LR02 and LR09), overlain with quartz pebbles (LR01 and LR04) within some parts of the playa. While the lake is naturally saline, only the northwest (LR04) and south eastern areas (LR07) of the lake exhibit salt crusting. Low-lying sandy dunes fringe the lake, intermittently replaced by steep rocky rises. Dune sandplains are also evident on the lake's islands.

Aquatic and riparian habitat was assessed during the Study, with the former comprising open playa, embayments and the mouth of significant drainage lines. Within the riparian zone, chenopod shrubland dominated by a range of samphires (*Tecticornia*) was targeted. It should also be noted that the lake has been affected by various historic land use practices, including pastoralism (sheep grazing). Intensive mining exploration including drilling, has also impacted the western side of the lake within Breaker's mining lease.

4.1.2 Peripheral Wetlands

Along its periphery, Lake Roe is fringed by numerous ephemeral wetlands and drainage features, including creeks, floodplains, salinas and claypans. Several salinas were sampled during Study (**Table 4-1, Plate 4-3**), ranging from approximately 360 m (PW02) to 760 m (PW01) in length. The salinas typically consisted of well-defined playas separated from the lake. However, there is likely connectivity through diffuse drainage during major flood events. Conditions were mostly dry during the study, however, there was shallow surface water present at PW04.

The salinas comprised predominantly of clay, loam and sand, with evidence of salt deposition and accumulation, particularly at PW01. They are typically surrounded by a low-lying primary dune system and a riparian zone dominated by samphires (*Tecticornia*) and other chenopods. The salina site PW03 comprised small islets, which provide areas of low relief throughout the playa and were colonised by vegetation.

One vegetated claypan (PC01) was also sampled opportunistically in October 2018, prior to this Study, which was comparatively smaller (85 m length) than the salinas. The claypan was ill-defined and formed part of a wide floodplain adjacent to Lake Roe's western margin and characterised by *Tecticornia*. At the time of sampling it comprised a shallow body of water attributed to a minor rainfall event.

Aquatic and riparian habitat was assessed from the peripheral wetlands during the Study. In comparison to the playa, these wetlands may flood more regularly and hold water for longer, due to their comparatively smaller size and impervious clay base. Land use in the vicinity of the salinas and claypan was consistent with the broader lake and comprised pastoralism and exploration within Breaker's mining lease.

Table 4-1: Habitat characterisation for sites assessed during the Study.

Sites	Distance to Project (km)	Hydrology	Geology	Biology	Land use
Lake Roe					
LR01	0	Dry low-lying playa located in wide (approx. 500 m) embayment, created by a narrow peninsula to the east. Significant drainage inflow to the west.	Pustular sediment comprising sandy loam and silt with numerous quartz stones and pebbles.	Riparian vegetation characterised by sparse <i>Tecticornia</i> low-shrubland.	Previous disturbance evident from recent mining exploration (tracks and drilling) land uses.
LR02	0.4 (east)	Low-lying playa within narrow (approx. 200 m) embayment, adjoining main playa via a narrow (60 m) channel. Partially inundated with shallow film of surface water. Significant drainage inflow located to the south.	Sediment comprising clay-loam on playa and light-brown sand along shore and riparian zone.	Riparian vegetation characterised by <i>Tecticornia</i> and <i>Frankenia</i> low-shrubland.	Previous disturbance evident from recent mining exploration (tracks and drilling) land uses.
LR03	3.1 (north west)	Dry low-lying playa, within wide (approx. 600 m) embayment, adjoining main playa via a narrow (100 m) channel. Significant drainage inflows located to the west.	Sediment comprising red-brown clay, with fine salt crust, and light brown sand and quartz along shoreline and riparian zone.	Riparian vegetation characterised by <i>Tecticornia</i> low-shrubland. <i>Eucalyptus</i> woodland occurring with elevation.	Previous disturbance evident from pastoralism (livestock) land use.
LR04	2.5 (north)	Dry main playa, broad and open with significant drainage inflow located to the east.	Sediment comprising clay on playa, with fine salt crust, and light-brown coarse sand with quartz pebbles underlain by sand-loam along shoreline.	Riparian vegetation characterised by <i>Tecticornia</i> low-shrubland. <i>Eucalyptus</i> woodland occurring with elevation.	Previous disturbance evident from pastoralism (livestock) land use.
LR05	6.2 (north east)	Dry low-lying playa within narrow (approx. 200 m) embayment. Significant drainage inflow located to north-east.	Sediment comprising moist red-brown clay, with fine salt surface layer, and clay covered with light-brown sand along the shoreline.	Riparian vegetation characterised by <i>Tecticornia</i> low-shrubland. <i>Eucalyptus</i> woodland occurring with elevation.	Previous disturbance evident from pastoralism (livestock) land use.
LR06	8.4 (north east)	Dry low-lying playa, within narrow convoluted embayment. Drainage inflows located to south-east and north-west.	Sediment comprising clay, with a thin salt crust, on playa and sand loam along shoreline and riparian zone.	Riparian vegetation characterised by sparse <i>Tecticornia</i> low-shrubland.	Previous disturbance evident from pastoralism (livestock) land use.
LR07	8.6 (east)	Main playa, broad and open. Partially inundated with shallow film of surface water.	Sediment comprising clay, with a thin salt crust, on playa and coarse sand in riparian zone. Low-lying sandy dunes.	Riparian vegetation characterised by very sparse <i>Tecticornia</i> low-shrubland.	Previous disturbance evident from pastoralism (livestock) land use.
LR08	6.6 (east)	One of a chain of discrete playas separated from the main playa by low-lying convoluted islands.	Sediment comprising moist dark clay with organics on playa and coarse sand loam along shore and riparian zone. Low-lying sandy dunes.	Riparian vegetation characterised by very sparse <i>Tecticornia</i> low-shrubland.	Previous disturbance evident from historical pastoralism (livestock) land use.
LR09	6.9 (south east)	Part of a poorly connected and convoluted part of the Lake Roe playa. Thin surface layer of water present on playa.	Sediment comprising clay, with thin salt crust, on playa and gypsum and sand along shore and riparian zone. Low-lying sandy dunes.	Riparian vegetation characterised by sparse <i>Tecticornia</i> low-shrubland. <i>Eucalyptus</i> woodland occurring with elevation.	Previous disturbance evident from historical pastoralism (livestock) land use.
LR10	3.4 (east)	Dry playa, located in wide (approx. 600m) embayment.	Sediment comprising clay, with anoxic layer, over coarse sand on playa and soft loam and coarse light-brown sand along shore. Low-lying, gently rising sandy dunes, backed by steep rise.	Riparian vegetation characterised by <i>Tecticornia</i> low-shrubland. <i>Eucalyptus</i> woodland occurring with elevation.	Previous disturbance evident from historical pastoralism (livestock) land use.
LR11	0	Dry playa, broad and open. Drainage inflows located adjacent and further to the east.	Sediment comprising clay on playa and light-brown sand along shore and riparian zone.	Riparian vegetation characterised by <i>Tecticornia</i> low-shrubland. <i>Eucalyptus</i> woodland occurring with elevation.	Previous disturbance evident from recent mining exploration (tracks) land use.
LR12	0	Dry playa, broad and open.	Sediment comprising clay, silt and sand on playa and light-brown sand loam along shore and riparian zone.	Riparian vegetation characterised by <i>Tecticornia</i> low-shrubland.	Previous disturbance evident from recent mining exploration (tracks and drilling) land use.

Sites	Distance to Project (km)	Hydrology	Geology	Biology	Land use
LR13	0	Mouth of major drainage inflow, braided with small islands, terminating into a wide embayment of Lake Roe.	Sediment comprising clay on playa, surrounded by sandy loam with silt and quartz.	Riparian vegetation characterised by <i>Tecticornia</i> low-shrubland. <i>Melaleuca</i> shrubland over <i>Triodia</i> with elevation.	Previous disturbance evident from recent mining exploration (tracks) land use.
LR14	0.8 (east)	Dry playa, broad and open. Separated from an easterly chain of discrete smaller playas by a broad expanse of low-lying islands.	Sediment comprising clay, silt and sand on playa.	Riparian vegetation characterised by <i>Tecticornia</i> low-shrubland.	Previous disturbance evident from recent mining exploration (tracks and drilling) land use.
LR15	0	Dry playa, broad and open.	Sediment comprising clay on playa and light-brown sand along shore and riparian zone.	Riparian vegetation characterised by <i>Tecticornia</i> low-shrubland.	Previous disturbance evident from recent mining exploration (tracks) land use.
Salinas					
PW01	6 (south east)	Large open salina, located to the south of Lake Roe. Drainage inflow to the south-west.	Sediment comprising sandy loam, overlain with salt crust. Rising sand dunes along the southern shoreline. Narrow to no riparian zone along the north shoreline.	Riparian vegetation characterised by sparse <i>Tecticornia</i> low-shrubland.	Previous disturbance evident from pastoralism (livestock) land use.
PW02	0.1 (north)	Small lunette salina located approximately 750 m southwest of main northern playa. Small drainage inflows present to north and southwest.	Sediment comprising loam with quartz pebbles, becoming more abundant in the north. Elevated rocky shoreline on western margin. Eastern margin comprising low-lying sandy dunes.	Limited riparian zone in the western, comprising elevated rocky shore supporting <i>Eucalyptus</i> woodland. Riparian vegetation present on low-lying eastern bank, comprising <i>Tecticornia</i> low-shrubland.	Previous disturbance evident from recent mining exploration (tracks and drilling) land use.
PW03	7.3 (north east)	Small salina, characterised by numerous small low-relief islets and forming part of a small chain of pans with drainage towards Lake Roe. Located approximately 700 m northeast of main northern playa.	Sediment comprising clay, loam and light-brown coarse sand.	Narrow riparian zone supporting sparse <i>Tecticornia</i> low-shrubland, backed by <i>Melaleuca</i> shrubland and <i>Eucalyptus</i> woodland.	Previous disturbance evident from pastoralism (livestock) land use.
PW04	10.3 (north east)	Small salina, located approximately 2 km east of Lake Roe playa, connected by a meandering drainage channel. Drainage inflows to north and east of site. Thin surface layer of water present in the centre of the pan.	Sediment comprising soft, moist clay, with sand and silt, overlain with a speckled salt crust in the north.	Evidence of recent water bird activity around surface waters. Riparian vegetation comprising <i>Tecticornia</i> low-shrubland, with numerous seedlings along shoreline. <i>Melaleuca</i> shrubland with elevation.	Previous disturbance evident from pastoralism (livestock) land use.
Claypan					
PC01	0	Small low-lying vegetated claypan, located approximately 150 m south of PW02 of Lake Roe playa. Local terminus of a wide, diffuse floodplain. Surface waters present.	Sediment comprising clay, loam and light-brown coarse sand.	Pan vegetated by sparse <i>Tecticornia</i> low-shrubland. Aquatic invertebrates (<i>Triops</i> and ostracods) observed in surface water.	Previous disturbance evident from pastoralism (livestock) land use.

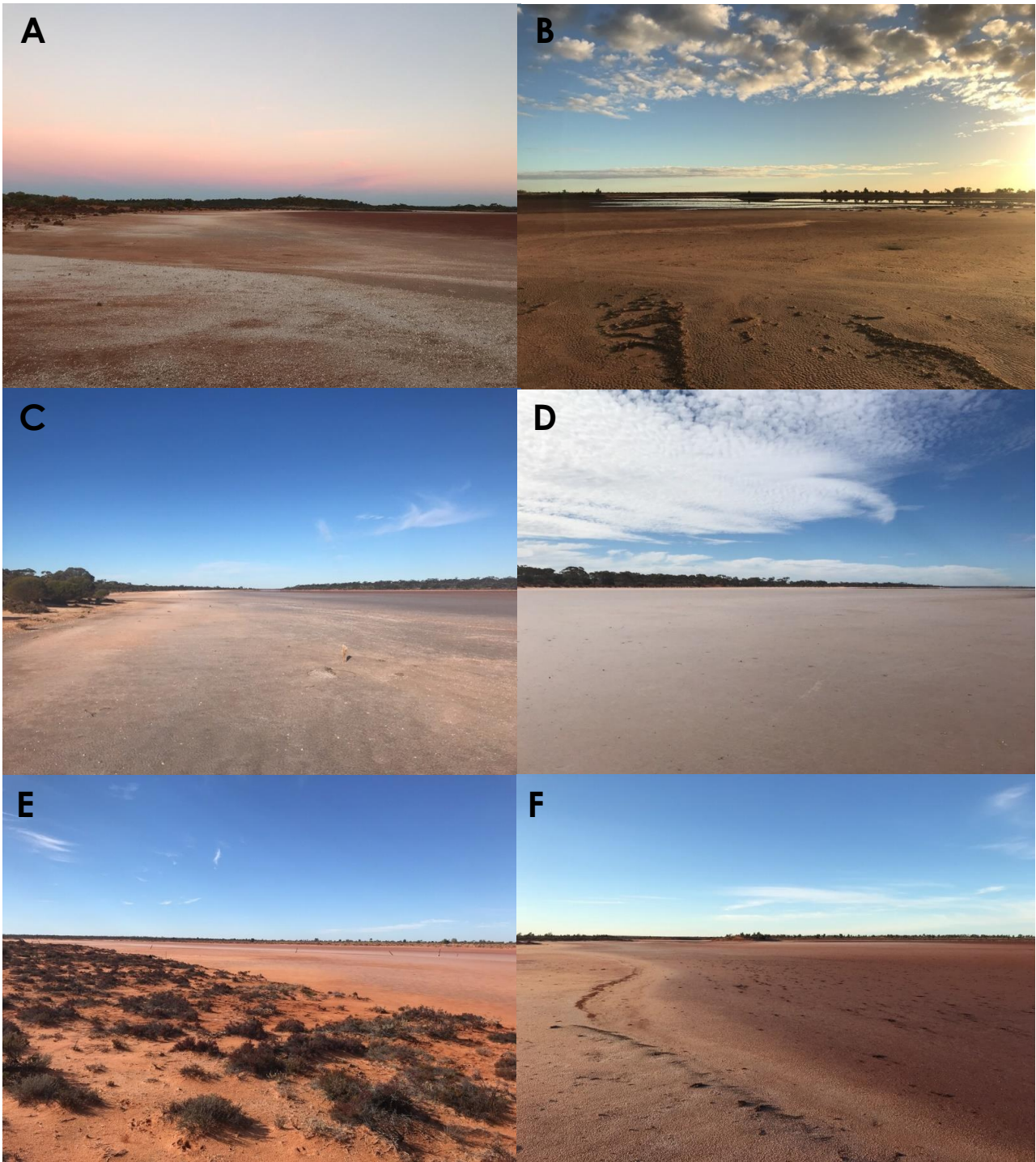


Plate 4-1: Lake Roe sites sampled during the Study; (A) LR01, (B) LR02, (C) LR03, (D) LR04, (E) LR05, and (F) LR06.

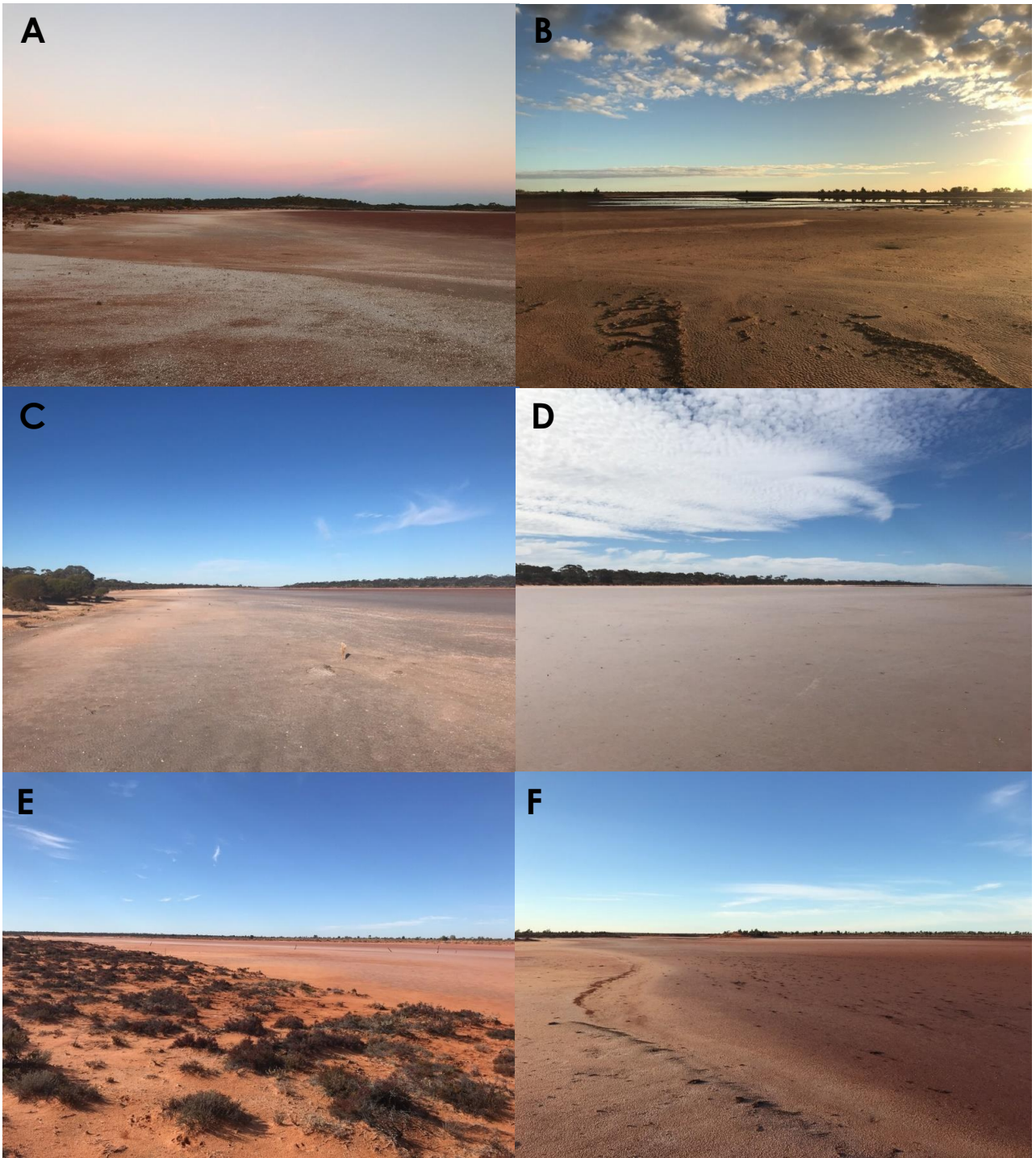


Plate 4-2: Lake Roe sites sampled during the Study; (A) LR07, (B) LR08, (C) LR09, (D) LR10, (E) LR11, and (F) LR12.



Plate 4-3: Lake Roe sites sampled during the Study; (A) LR13, and (B) LR14. Salinas sampled during the Study; (C) PW01, (D) PW02, (E) PW03, and (F) PW04.

4.2 Sediment Quality

The sediment quality of Lake Roe and the salinas were variable during the Study. The pH ranged from strongly acidic to moderately alkaline (Hazelton and Murphy 2007) (**Table 4-2**). The lake sites exhibited a broader pH range from 4.7 (LR09) to 8 (LR04 and LR12) (**Figure 4-1A**), while the salinas ranged from 6.4 (PW01) to 8 (PW04). Sediment pH was considered characteristic of wetlands in the Coolgardie bioregion (6.4 to 7.7) (Gregory 2008) and the acidic conditions at LR06 and LR09 may be related to the surface expression of low pH groundwater, which is associated with the south western section of the Yilgarn block (Commander 1999; Mann 1983). Sediment pH is also strongly influenced by changes in the hydroperiod, redox reactions and fluctuations in the concentration of carbonates and organic matter (Connell 2005; Reddy and DeLaune 2008).

Sediment salinity (measured in total soluble solids; TSS) during the Study (**Table 4-2**) ranged from 56,600 mg/kg at LR13 to 104,000 mg/kg at LR06 across the lake sites (**Figure 4-1B**). Sites located on the playa and adjacent to inflows (LR12 and LR13) also had comparatively lower salinities, likely attributed to sediment flushing following heavy rainfall. The salinas typically displayed higher salinities than the lake, ranging from 89,600 mg/kg at PW01 to 137,000 mg/kg at PW04, which was also reflected in the PCA (**Figure 4-3**). The spatial heterogeneity observed in the sediment salinity throughout the lake and salinas is typical of the Goldfields (Gregory 2008), and can be attributed to differences in bathymetry and local geomorphological processes.

The dominant cation in the sediment during the Study was sodium throughout the lake and salina sites (**Table 4-2**). However, the dominance of the minor cations (Ca, Mg and K) was interchangeable, likely a result of localised geology influencing sediment composition (Chakrapani 2002; Gorham 1961). Anions followed a more uniform $\text{Cl} > \text{SO}_4 > \text{HCO}_3$ at all sites (**Table 4-2**), considered typical of inland waterbodies in Western Australia (Gregory 2008; Hart and McKelvie 1986).

Total nitrogen was greater than total phosphorus in the sediment at the majority of sites during the Study (**Table 4-2**). The former ranged from 140 mg/kg to 630 mg/kg, while the latter ranged from 60 mg/kg to 386 mg/kg, respectively. Nutrient concentrations were relatively comparable throughout the lake and salinas, with the exception of elevated total nitrogen (>1,300 mg/kg) at PW03 and PW04 (**Figure 4-1C-D**). High nutrient levels in the sediment are related to the degradation of organic material by microbes in the sediment and changes in the hydroperiod (Boulton and Brock 1999). This is consistent with these results, with PW03 and PW04 having comparatively higher total organic carbon (>0.60%) and moisture content (>30%) (**Table 4-2**), trends also reflected in the PCA (**Figure 4-3**).

The majority of metals in the sediment were below the ANZECC & ARM CANZ (2000) ISQG trigger values (where available) during the Study (**Table 4-2**). However, chromium was elevated above the ANZECC & ARM CANZ (2000) ANZECC & ARM CANZ (2000) ISQG-Low trigger values at most sites (**Figure 4-2A**). The highest concentrations were recorded at LR02 (172 mg/kg) and LR12 (161 mg/kg) on the western side of Lake Roe, which were more than twice the ISQG-Low trigger value (80 mg/kg). In addition, nickel also exceeded the ISQG-Low trigger value at most sites and the ISQG-High trigger value at several lake sites. The latter included LR03 (54.6 mg/kg), LR05 (73.3 mg/kg) and LR11 (53 mg/kg), which at the maximum was more than 1.4 times the ISQG-High trigger value (52 mg/kg) (**Figure 4-2C**). In contrast, sites along the eastern side of the lake (LR07, LR08, LR09, LR10 and PW04) were typically low in all metal concentrations, also reflected in the PCA (**Figure 4-4**). Salt lakes in the Goldfields are often enriched with metals including chromium and nickel, attributed to natural mineralisation within their catchments (Förstner 1977; Gregory 2008) and therefore is unlikely to pose a toxicity risk to the aquatic biota that have evolved to cope with these conditions (Metals Environmental Risk Assessment Guidance 2007).

Table 4-2: Sediment quality during the Study, compared to the ANZECC & ARM CANZ (2000) guideline ISQG triggers.

Sediment Parameters		Lake Roe												Salinas				ANZECC Triggers		
		LR01	LR02	LR03	LR04	LR05	LR06	LR07	LR08	LR09	LR10	LR11	LR12	LR13	PW01	PW02	PW03	PW04	ISQG-Low	ISQG-High
Basic & Nutrients	pH (unit)	7.8	7.7	7.3	8	7.5	5.4	7.6	7.8	4.7	7.7	7.9	8	7.4	6.4	7.6	6.8	8	-	-
	Total Soluble Salts	91,500	70,200	69,200	74,000	96,200	104,000	58,900	82,200	77,200	100,000	63,300	88,300	56,600	89,600	102,000	115,000	137,000	-	-
	Moisture Content (%)	25.8	22.6	19	21.2	27.9	31.8	26.5	29.3	20.6	29	19.4	19.5	16.9	23.8	32.5	30.8	42	-	-
	Total Nitrogen	570	400	290	210	450	430	270	570	400	630	140	480	320	270	100	1,360	1,610	-	-
	Total Phosphorus	248	159	223	177	386	262	60	69	124	120	95	151	171	185	176	253	235	-	-
	Total Organic Carbon (%)	0.18	0.05	0.07	0.02	0.12	0.21	0.04	0.08	0.23	0.54	0.05	0.26	0.23	0.27	0.15	0.94	0.63	-	-
	Total Kjeldahl Nitrogen	570	400	290	210	450	430	270	570	400	630	140	480	320	270	100	1,360	1,610	-	-
	Nitrite + Nitrate	0.4	<0.1	0.1	<0.1	1.1	<0.1	<0.1	<0.1	0.1	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Anions & Cations	Sodium	34,800	26,200	26,600	28,700	42,700	44,200	23,600	31,100	25,500	45,500	24,200	33,600	23,700	33,800	47,900	51,100	76,600	-	-
	Calcium	3,260	4,340	750	1,480	3,850	8,590	7,480	8,390	950	8,730	850	7,070	1,300	7,490	1,700	8,340	11,900	-	-
	Magnesium	5,550	3,570	3,640	2,870	4,060	6,020	1,800	3,050	3,140	4,160	3,440	3,660	3,410	2,960	6,830	7,940	6,220	-	-
	Potassium	430	370	280	400	600	710	260	420	420	570	280	530	300	430	540	1,050	1,160	-	-
	Chloride	62,400	46,900	48,100	50,500	72,200	73,300	41,400	53,000	45,600	73,200	43,800	57,600	42,000	55,000	82,300	87,100	121,000	-	-
	Sulfate	16,400	18,100	8,180	10,000	19,100	32,600	20,400	24,700	6,950	29,300	8,850	24,000	8,860	25,100	16,600	35,300	37,500	-	-
	Bicarbonate	260	24	22	35	28	5	9	15	<1	14	36	25	6	2	16	7	31	-	-
	Carbonate	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-
Metals & Trace Elements	Aluminium	18,300	8,160	10,300	12,600	23,000	22,600	2,630	2,380	22,100	6,650	10,600	10,200	6,670	17,100	6,910	18,000	11,500	-	-
	Arsenic	4.14	5.96	5.23	4.03	6.15	4.72	<1.00	<1.00	1.47	1.32	3.69	4.18	13.3	4.16	2.44	4.69	2.53	20	70
	Barium	40	110	50	150	80	40	10	<10	60	20	140	180	130	60	30	50	30	-	-
	Beryllium	<1	<1	<1	<1	1	2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-
	Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	1.5	10
	Chromium	118	172	140	98.8	109	94.4	22.2	12	56.7	46.4	105	161	144	112	127	84.2	72.1	80	370
	Cobalt	16.7	10.1	61.4	10.8	29.3	10.5	1.4	1.1	3.7	4	18.3	10.6	11.9	19.6	27.7	10.6	16.4	-	-
	Copper	33.5	23.8	26.9	17.4	31.7	22.9	3.4	2.9	15.8	7.8	26.6	22.3	24.7	21.2	52	19.8	17.8	65	270
	Iron	42,300	64,000	52,300	34,300	42,500	31,900	5,790	3,160	21,200	11,500	39,700	48,000	51,200	31,800	78,000	29,400	20,400	-	-
	Lead	4.5	6.3	16.8	7.1	11.9	4	<1.0	<1.0	1.4	2.2	9.9	6	7	16.3	2.6	6.7	6.7	50	220
	Manganese	305	235	2,140	275	887	94	68	27	29	93	1,080	332	450	295	386	107	414	-	-
	Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	0.15	1
	Nickel	45.2	27.8	54.6	35.1	73.3	42.9	5.4	4.4	23.6	13.8	53	30.8	24.3	36.7	25.9	43.2	51.9	21	52
	Selenium	0.4	0.4	0.6	0.3	0.6	0.6	0.1	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.1	0.4	0.3	-	-
	Silicon	13	7	13	9	20	16	5	3	15	7	12	7	11	9	16	9	5	-	-
	Vanadium	105	167	150	81	97.9	80.7	14.7	8.8	47	30.8	98.4	135	155	94.7	197	62.9	46	-	-
Zinc	44.9	20.1	24.6	31.4	43.2	26.6	5	4.8	10.2	13.7	28.6	32.6	27.3	31.3	38.1	24	21.6	200	410	

Note: All units in mg/kg except where stated; yellow shading indicates exceedance of ANZECC & ARM CANZ (2000) ISQG-Low triggers; red shading indicates exceedance of the ANZECC & ARM CANZ (2000) ISQG-High triggers.

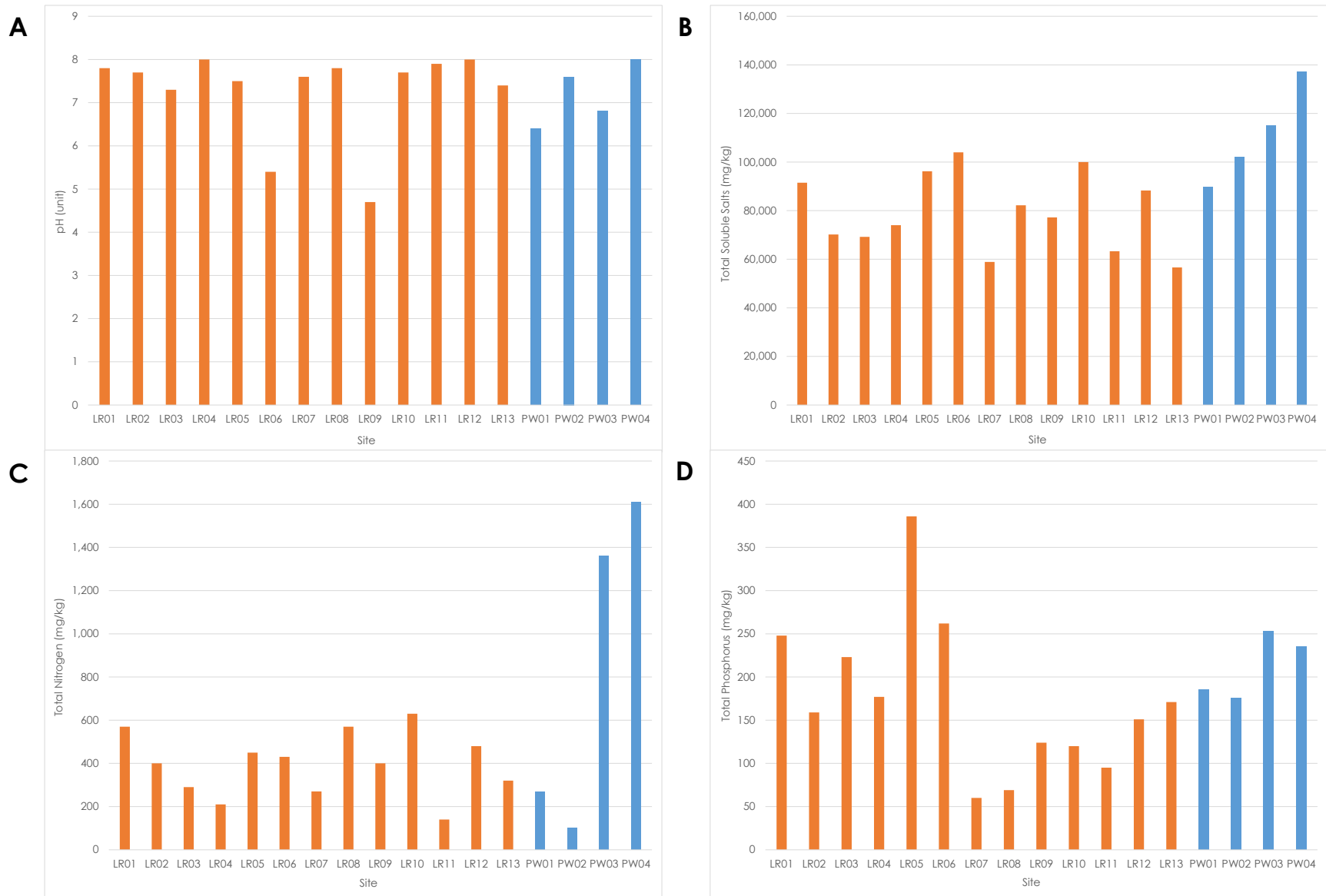


Figure 4-1: Sediment quality during the Study (■=Lake Roe and ■=salinas); (A) pH, (B) salinity, (C) total nitrogen and (D) total phosphorus.

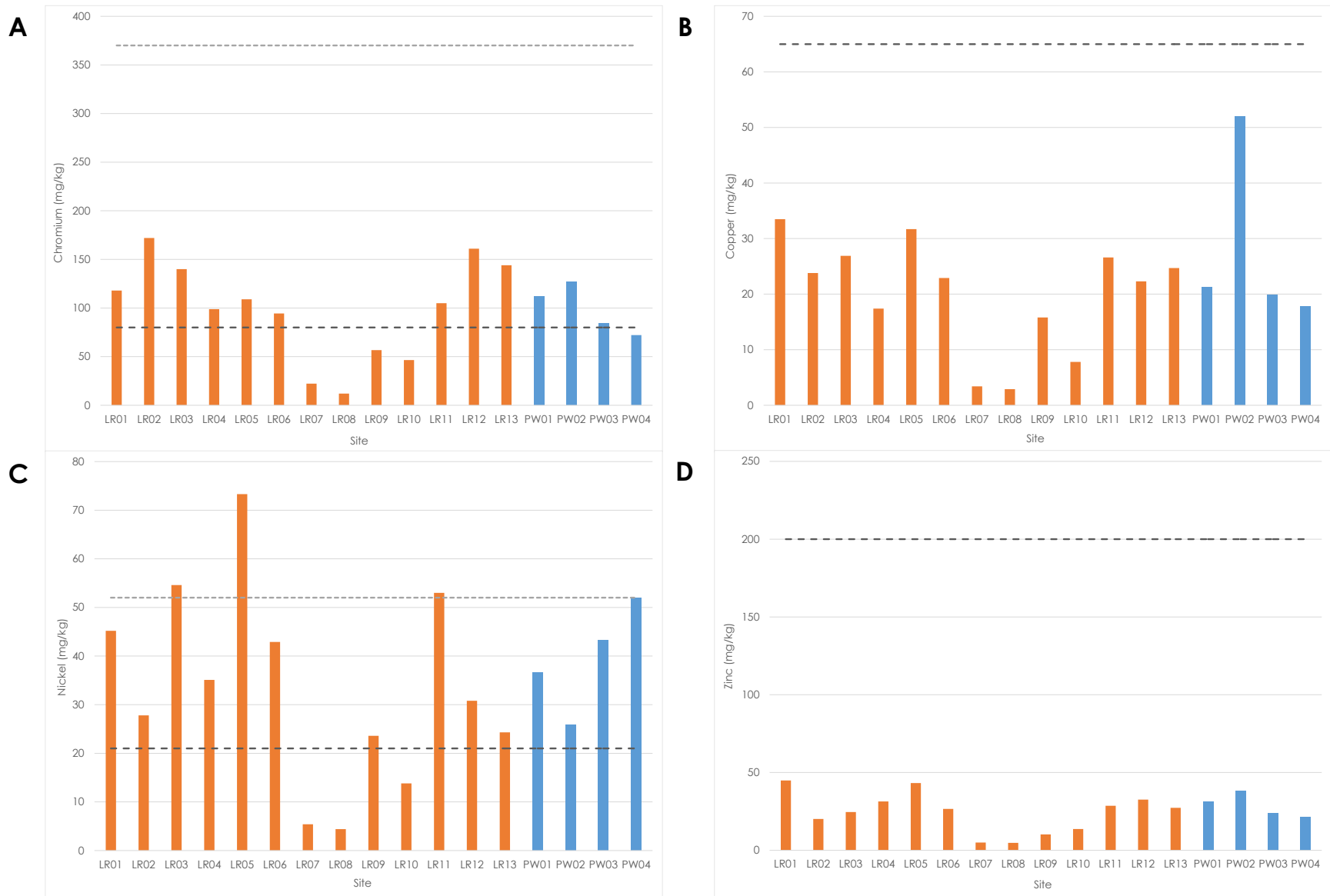


Figure 4-2: Sediment quality during the Study (■=Lake Roe and ■=salinas); (A) chromium, (B) copper, (C) nickel, and (D) zinc, compared to the ANZECC & ARMCANZ (2000) guideline ISQG Low (—) and ISQG-High (-) triggers.

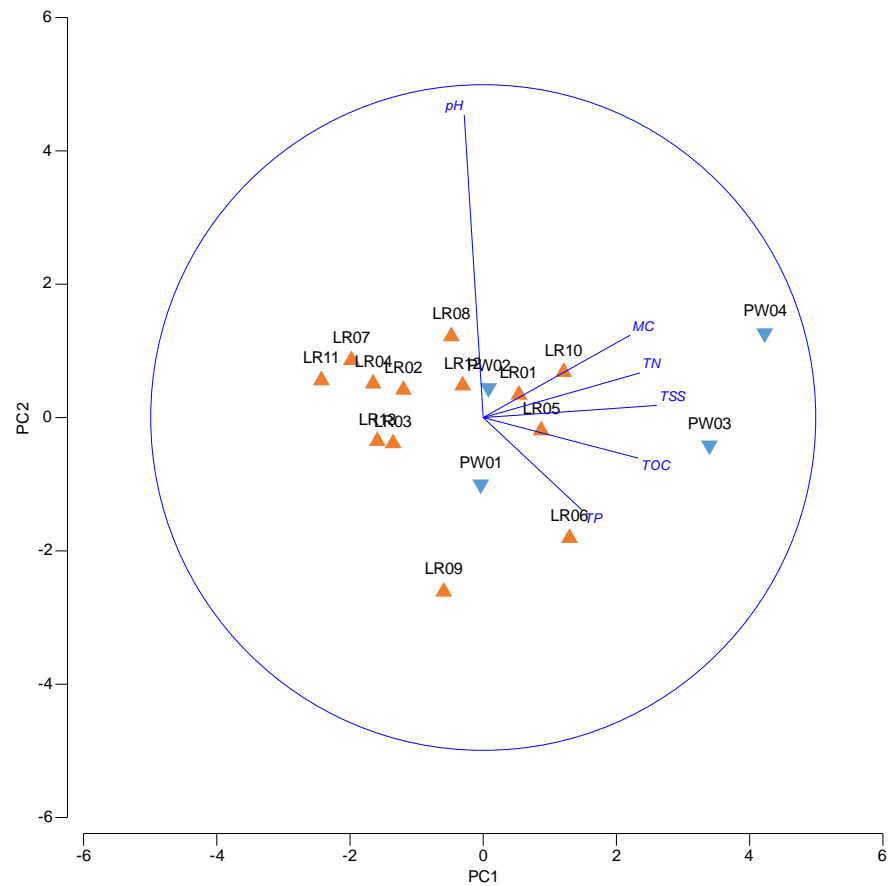


Figure 4-3: PCA of basic sediment quality of Lake Roe and salinas during the Study (▲=Lake Roe and ▼=salinas), with 72.7% variation in the data explained by the first two axes.

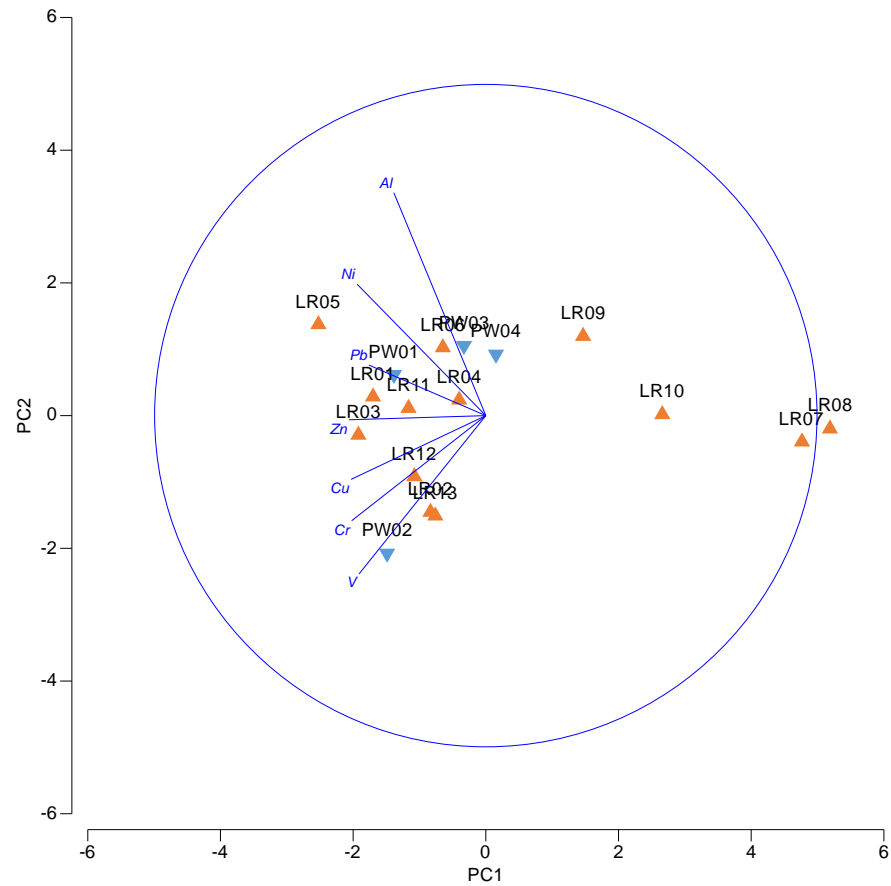


Figure 4-4: PCA of metal concentrations of Lake Roe and salinas during the Study (▲=Lake Roe and ▼=salinas), with 86.7% variation in the data explained by the first two axes.

4.3 Rewetting Trials

4.3.1 Water Quality

Water quality recorded during the rewetting trials of the Study (**Table 4-3**) indicated that Lake Roe and the salinas were alkaline (pH>7.5), with the highest pH associated with the salinas (8.6). Electrical conductivity was generally comparable between the lake and the salinas, ranging from 15,690 $\mu\text{S}/\text{cm}$ to 91,100 $\mu\text{S}/\text{cm}$, and 16,470 $\mu\text{S}/\text{cm}$ to 77,600 $\mu\text{S}/\text{cm}$, respectively. Water temperature was also similar across the sites with minima of close to 20°C and maxima over 30°C.

These results suggest that during a major flood event, the water quality of Lake Roe and the salinas is likely to be alkaline, with a salinity ranging from hyposaline with the onset of flooding, increasing to hypersaline (>70,000 $\mu\text{S}/\text{cm}$) as the hydroperiod progresses. While salt lakes in the Goldfields are subject to highly variable water quality conditions over the course of the hydroperiod, they generally exhibit a low salinity phase after major rainfall events that result in flooding. This initiates the emergence of aquatic biota and creates a productive biological community, which shifts to a more salt tolerant assemblage as salinity increases over time (Taukulis 2016; Taukulis *et al.* 2014).

Table 4-3: Summary of water quality ranges during the rewetting trials of the Study.

Rewetting Trials Water Quality Parameters		Lake Roe	Salinas
pH (unit)	Minimum	4.3	6.8
	Mean	7.6	7.7
	Maximum	8.2	8.6
	Standard Deviation	0.5	0.3
	Number of Records	363	104
Electrical Conductivity ($\mu\text{S}/\text{cm}$)	Minimum	15,690	16,470
	Mean	43,753	47,366
	Maximum	91,100	77,600
	Standard Deviation	11,766	134,959
	Number of Records	364	104
Temperature (°C)	Minimum	20.5	22.5
	Mean	25.9	27.0
	Maximum	37.0	33.1
	Standard Deviation	3.1	2.9
	Number of Records	364	104

4.3.2 Benthic Algae

A total of 12 algal taxa comprising three phyla (**Table 4-4**), were recorded during the rewetting trials of the Study. Diatoms (Bacillariophyta) were the most speciose phyla (10 taxa), followed by Cyanophyta (6 taxa), with Chlorophyta limited to a single taxon (**Figure 4-5**). The taxa recorded were considered widespread and the composition was consistent with the assemblage identified from inland waters throughout Western Australia (Campagna 2007; Handley 2003; Taukulis and John 2009). Diatoms and filamentous cyanobacteria are important constituents of benthic algal communities in Western Australia salt lakes (Handley 2003), providing a food source and structural complexity for aquatic invertebrates (Rautio and Vincent 2006).

During the rewetting trials of the Study, the total diversity was similar across Lake Roe (12 taxa) and the salinas (11 taxa), with the majority of sites recording between two and four taxa each (**Figure 4-6**). The salina PW04 had the highest site diversity (eight taxa), followed by Lake Roe site PW11 (six taxa); both of which were dominated by *Phormidium* spp. This genus is a salt-tolerant filamentous cyanobacterium (blue-green algae), typical of benthic communities throughout waterbodies in the wheatbelt and Pilbara regions of Western Australia (John *et al.* 2017; Paling *et al.* 1989). It is often dominant in salinities ranging from 70,000 $\mu\text{S}/\text{cm}$ to 125,000 $\mu\text{S}/\text{cm}$ (Borowitzka 1981), with some representative species reported from lakes with salinities in excess of 170,000 $\mu\text{S}/\text{cm}$ (Nagasathya and Thajuddin 2008).

Other representatives of the cyanophyta genera found during the rewetting trials of the Study included *Planktolyngbya* and *Planktothrix*. These genera were also relatively widespread, being identified from six sites each (**Table 4-4**). *Planktothrix* was abundant at two sites (LR04 and LR10) and was represented by two taxa (*Planktothrix* sp. 1 and 2). Both *Planktothrix* and *Planktolyngbya* are associated with marine conditions (Komarek and Komarkova 2004) and/or elevated salinities (>100,000 $\mu\text{S}/\text{cm}$) (Madkour and Gaballah 2012).

Two diatom taxa including *Hantzschia* (sp. aff. *baltica*) and *Navicula* (sp. aff. *incertata*) were widespread (in more than half of the sites) throughout Lake Roe and the salinas during the rewetting trials of the Study (**Table 4-4**). These taxa have been commonly recorded in salt lakes throughout the Roe Palaeoriver and are also known from the broader Goldfields and wheatbelt regions. They are associated with hypersaline conditions, and have tolerance limits that exceed 125,000 $\mu\text{S}/\text{cm}$ (Taukulis 2007).

The chlorophyte (green alga) *Dunaliella* sp., was recorded from three Lake Roe sites (LR07, LR08, LR10) and one salina (PW04) during the rewetting trials of the Study (**Table 4-4**). This taxon is considered a dominant component of benthic algal communities throughout Australia (Borowitzka 1981), and can develop a range of life stages in response to varying salinities (Oren 2005). It is extremely salt tolerant and has been documented from salinities in excess of 300,000 $\mu\text{S}/\text{cm}$ (Williams 1998).

While the structure of the benthic algal community varied across Lake Roe and the salinas during the rewetting trials of the Study, there was at least 20% similarity in composition, based on hierarchical classification (**Figure 4-7**). This was predominantly associated with the dominant cyanobacterial and diatom representatives. This suggests that during a flooding event, the salinas may exhibit a similar algal assemblage to the playa, dependent on the hydroperiod. Key factors responsible for differences in the algal assemblage are likely to be pH, salinity, nutrient concentrations, water depth, and substrate type, including the presence of macrophytes (Foged 1978; John 2002; Townsend and Gell 2005).

Table 4-4: Benthic algal taxa recorded during the rewetting trials of the Study.

Benthic Algal Taxa	Lake Roe														Salinas			
	LR01	LR02	LR03	LR04	LR05	LR06	LR07	LR08	LR09	LR10	LR11	LR12	LR13	LR14	PW01	PW02	PW03	PW04
Bacillariophyta																		
<i>Amphora (coffeaeformis)</i>					•			••	•						•			•
<i>Amphora (sp. aff. mira)</i>																		•
<i>Hantzschia (sp. aff. baltica)</i>		•			••	•	••			•	•		•	•	•		•	••
<i>Navicella (pusilla)</i>								•									•	
<i>Navicula (sp. aff. incertata)</i>				•	•			•	•	•	•	•	•					
<i>Nitzschia (sp. aff. virgata)</i>																	•	
<i>Pinnularia (sp. aff. intermedia)</i>										•								
<i>Pinnularia (sp. aff. divergentissima)</i>								••							••		•	
<i>Pleurosigma (longum var. elongatum)</i>																		•
<i>Tabularia (fasiculata)</i>																		•
Chlorophyta																		
<i>Dunaliella sp.</i>							•	•		•								•
Cyanophyta																		
<i>Cyanothece sp.</i>												•						
<i>Phormidium sp. 1</i>																		•••
<i>Phormidium sp. 2</i>										••		•••						
<i>Planktolyngbya sp.</i>										•	•		•	•	•			•
<i>Planktothrix sp. 1</i>			•	••					•••	•	•	•						
<i>Planktothrix sp. 2</i>			•	•••														
Diversity	0	1	2	3	3	1	2	3	4	4	6	4	4	2	4	1	4	8

Note: •=few, ••=common, •••=abundant.

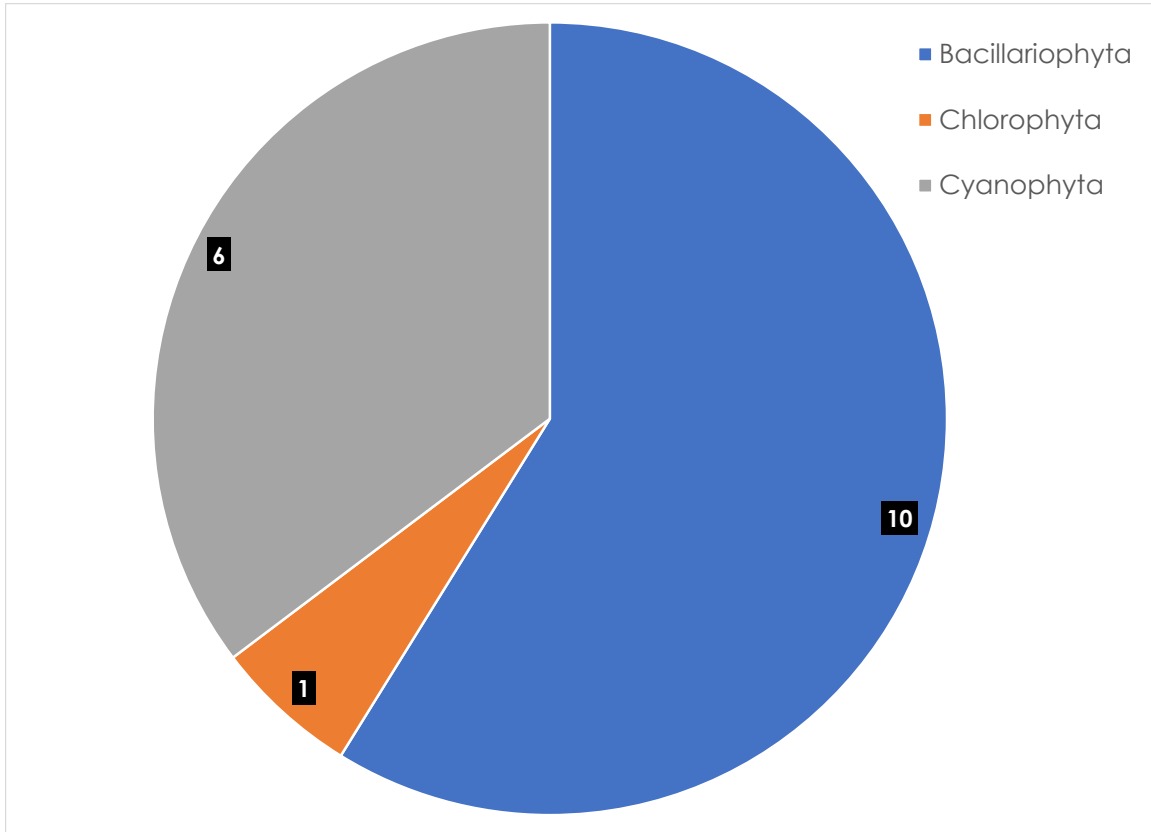


Figure 4-5: Benthic algal taxa per genus recorded during the rewetting trials of the Study.

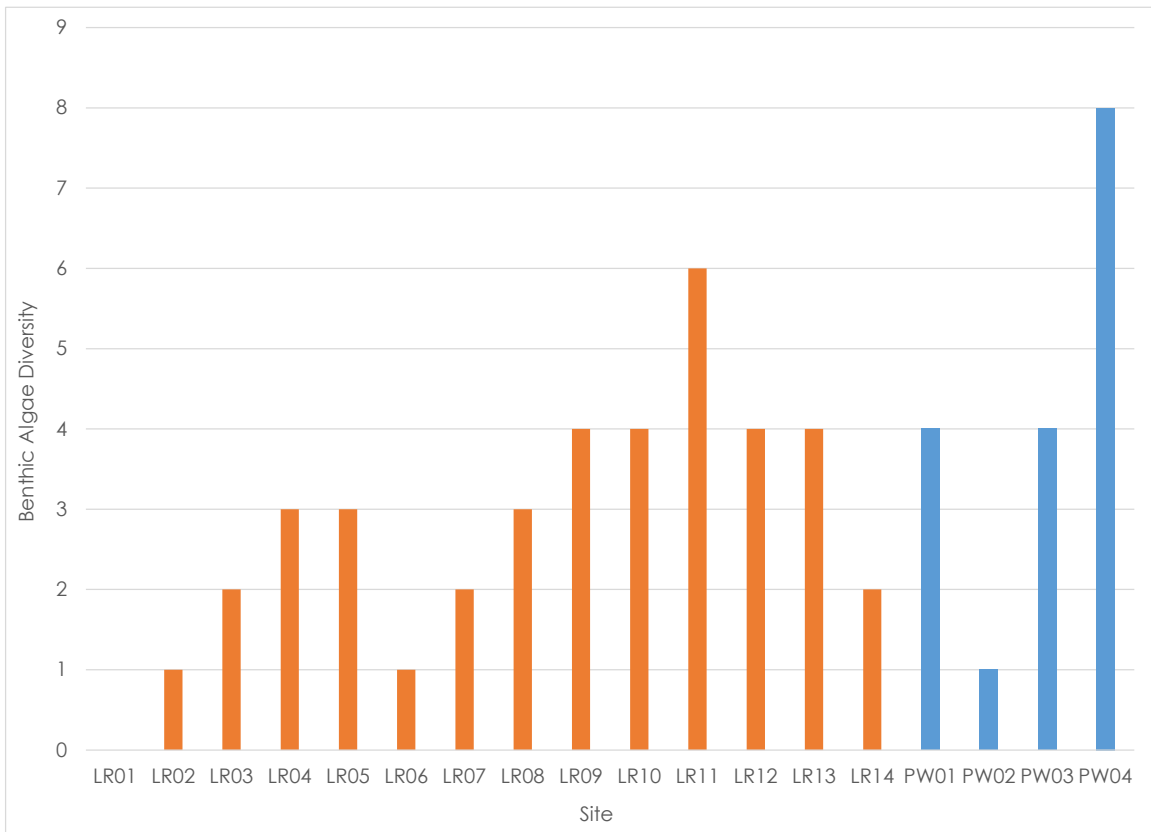


Figure 4-6: Diversity of benthic algal taxa recorded during the rewetting trials of the Study (■=Lake Roe and ■=salinas).

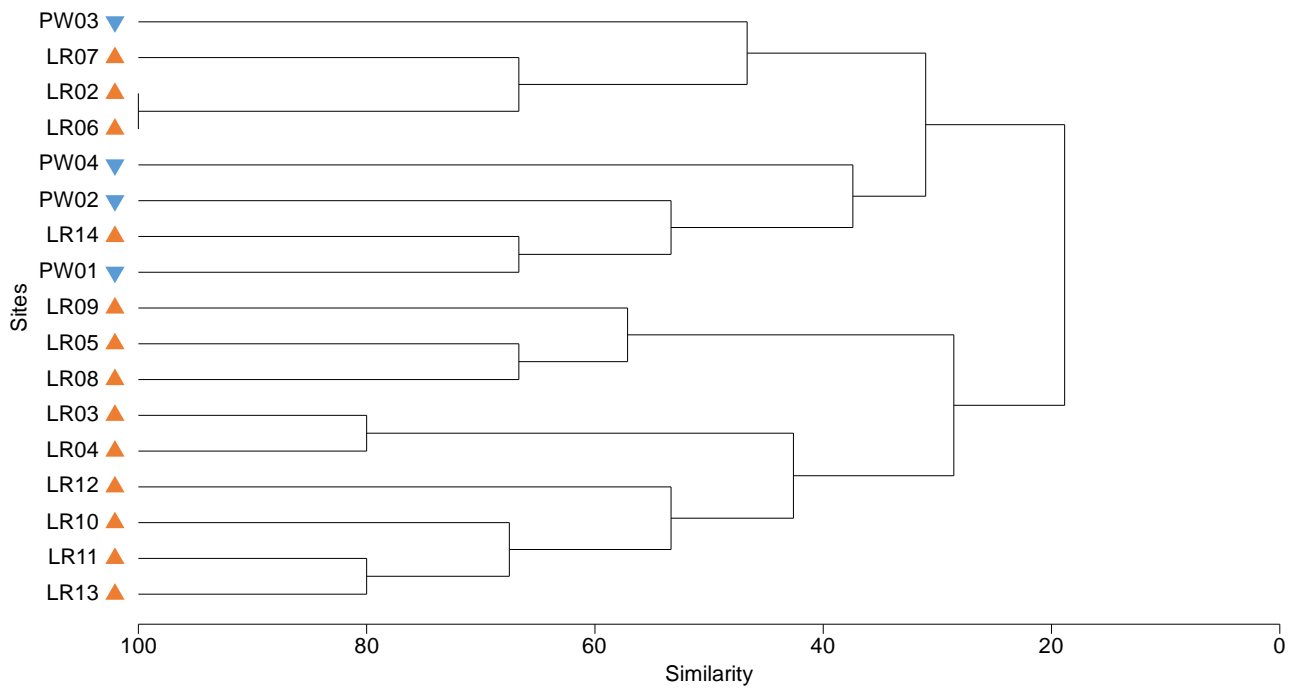


Figure 4-7: Dendrogram of the benthic algal assemblage recorded during the rewetting trials of the Study (▲=salinas and ▼=salinas).

4.3.3 Macrophytes

During the rewetting trials of the Study macrophytes (submerged aquatic plants) were successfully germinated from nine sites including Lake Roe sites and the salinas (**Table 4-5**). In addition to benthic algae, macrophytes are also important components of aquatic systems during flooding, contributing to primary productivity, as well as providing a food source and habitat for aquatic fauna and waterbirds (Bunn 1995; Canfield and Des Marais 1993; Porter *et al.* 2007; Sainty and Jacobs 2003).

Two macrophyte taxa, comprising one angiosperm and one macroalga were germinated during the rewetting trials for the Study (**Table 4-5**). The macroalga *Chara* sp. was widespread and abundant during the rewetting trials, germinating from six Lake Roe sites and three salinas. This taxon was most abundant at site LR14, located in the western portion of the lake. *Chara* sp. belongs to the class Charophyceae (stoneworts), common throughout Australia (Montoya 2009). It is often found in clear, alkaline waters and may be considered an indicator of healthy ecosystems (Casanova 2005; Coops 2002). Typically this genus is also associated with less saline (<15,000 $\mu\text{S}/\text{cm}$) waterbodies (Brock and Lane 1983), and therefore may have been washed into this part of the lake from surrounding creeks and claypans.

The angiosperm *Ruppia tuberosa* (**Plate 4-4**), belonging to the family Ruppiceae (sea tassels), was only germinated from three Lake Roe sites and one salina during the rewetting trials of the Study, and occurred in comparatively lower abundances. *Ruppia tuberosa* is a submerged macrophyte with a grass like appearance, and is found in shallow, saline waters throughout Australia (Rogers and Paton 2009). In contrast to most macrophytes, the germination of *Ruppia tuberosa* is stimulated by elevated salinity and once established this species can persist in salinities over 200,000 $\mu\text{S}/\text{cm}$ (Rogers and Paton 2009).

Table 4-5: Macrophyte taxa recorded during the rewetting trials of the Study.

Macrophyte Taxa	Lake Roe						Salinas		
	LR01	LR08	LR10	LR11	LR12	LR14	PW01	PW03	PW04
Algae									
<i>Chara</i> sp.	●	●	●●	●●	●●	●●●	●●	●	●
Charophyceae									
Angiosperms									
Ruppiceae									
<i>Ruppia tuberosa</i>			●●		●	●			●
Diversity	1	1	2	1	2	2	1	1	2

Note: ●=few, ●●=common, ●●●=abundant.

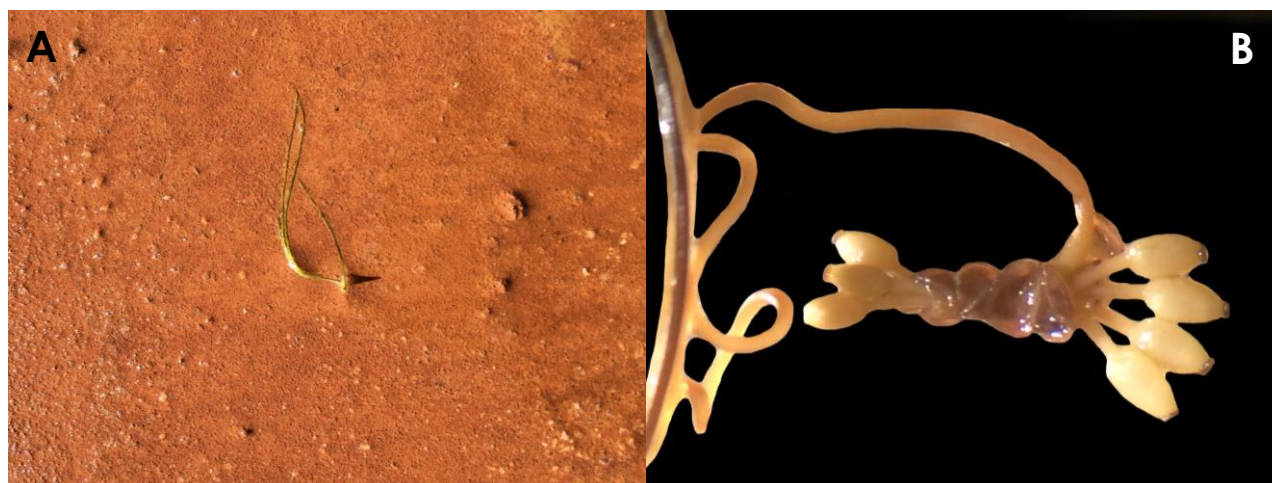


Plate 4-4: Images of *Ruppia tuberosa* comprising (A) plant habit, and (B) inflorescence with developing fruits.

4.3.4 Diatoms

Diatoms, a microalga belonging to the Bacillariophyta phylum, were recorded from all Lake Roe and salina sites during the rewetting trials of the Study (**Table 4-6**). A total of 24 taxa representing 13 genera were recorded (**Figure 4-8**). The most speciose genus was *Navicula* (five taxa) followed by *Nitzschia* (four taxa) and *Pinnularia* (three taxa) (**Figure 4-8**), considered a typical assemblage of inland salt lakes throughout the Goldfields and wheatbelt regions of Western Australia (Blinn 1995; Campagna 2007; John 1998; Taukulis 2007).

The diversity recorded from Lake Roe and the salinas during the rewetting trials of the Study was 20 and 16 diatom taxa, respectively (**Table 4-6**). Site diversity was also similar and at Lake Roe ranged from two (LR07) to 10 taxa (LR04), while the salinas ranged from five (PW02) to nine taxa (PW03) (**Figure 4-9**). This is most likely attributed to the likely similar salinity of these sites during flooding, which is a key factor influencing diatom community structure (Handley 2003; Taukulis 2007). Diatoms were also abundant during the rewetting trials of the Study, with 100 frustules recorded at almost all sites (**Table 4-6**), with the exception of LR01 (26 frustules) and LR08 (75 frustules).

The most widespread diatoms recorded from Lake Roe during the rewetting trials of the Study were *Amphora coffeaeformis* (15 sites), *Navicula* sp. aff. *incertata* (18 sites) and *Hantzschia* sp. aff. *baltica* (17 sites) (**Table 4-6**). Several taxa such as *Luticola mutica*, *Navicella pusilla* and *Navicula* sp. aff. *salinicola* were also identified from the lake and salinas (**Figure 4-10**). The community structure was consistent with other waterbodies throughout the Goldfields (Campagna 2007; Taukulis *et al.* 2012), comprising well known salt tolerant taxa with documented tolerance limits in excess of 70,000 $\mu\text{S}/\text{cm}$ (Taukulis 2007).

Representatives of the *Hantzschia* and *Luticola* genera were frequently identified from the lake and salinas during the rewetting trials of the Study (**Table 4-6**), and are considered aerophilic (Ehrlich 1995); associated with non-submerged habitat. The representatives of this genus are also associated with eroded sediment (John 2000), reflecting the typically dry conditions. Several *Pinnularia* taxa were also recorded from Lake Roe (LR09) and the salinas (PW01 and PW03) (**Figure 4-10**). This genus is associated with acidic conditions (Thomas 2007) and reflects the low pH of the sediments at these sites ($\text{pH}<7$), and is known from salt lakes in the Goldfields with acidic groundwater (Stantec 2018).

Comparable diatom community structure throughout Lake Roe and the salinas during the rewetting trials of the Study was demonstrated in the hierarchical classification (**Figure 4-11**), with most sites exhibiting more than 50% similarity. Key factors that typically influence species composition include salinity, nutrients, water depth, and substrate type (Deepa *et al.* 2010; Foged 1978; Townsend and Gell 2005). During predominantly dry conditions, the moisture content and microtopography (grain size) of the lake sediment can also affect diatom distribution (van Kerckvoorde *et al.* 2000). During major flood events, there is likely to be greater connectivity between the lake and salinas, with lower salinities and a more homogenous diatom assemblage. As the hydroperiod progresses surface water salinity increases, causing a decrease in diatom diversity, with a shift towards more salt tolerant taxa (Taukulis 2007).

Table 4-6: Diatom taxa recorded during the rewetting trials of the Study.

Diatom Taxa	Lake Roe														Salinas			
	LR01	LR02	LR03	LR04	LR05	LR06	LR07	LR08	LR09	LR10	LR11	LR12	LR13	LR14	PW01	PW02	PW03	PW04
<i>Amphora coffeaeformis</i>		46	14	31	1	19		10	16	6		14	7	38	51	85	19	4
<i>Amphora</i> sp. aff. <i>mira</i>	2											3						16
<i>Craticula cuspidata</i>	4		3		1	1					1							
<i>Cyclotella stelligera</i>											1							
<i>Entomoneis</i> sp. aff. <i>paludosa</i>				1							2			3	1			
<i>Hantzschia</i> sp. aff. <i>amphioxys</i>	2																	
<i>Hantzschia</i> sp. aff. <i>baltica</i>		7	32	18	26	21	96	4	6	12	32	8	8	35	3	7	15	56
<i>Luticola mutica</i>	1		1	1	4	2					1		3				3	
<i>Mastogloia pumila</i>																		1
<i>Navicella pusilla</i>	1	7	3	1					1	2		2	1			1	7	
<i>Navicula nivalis</i>			1		2	2							1				1	
<i>Navicula</i> sp. aff. <i>arvensis</i>									9									
<i>Navicula</i> sp. aff. <i>elegans</i>	1				1	1					4							
<i>Navicula</i> sp. aff. <i>incertata</i>	15	40	37	47	64	50	4	61	5	80	57	73	67	23	2	6	33	3
<i>Navicula</i> sp. aff. <i>salinicola</i>			4										11		6		5	
<i>Nitzschia ovalis</i>			2	1					6							1		
<i>Nitzschia pellucida</i>													1	1	9			
<i>Nitzschia punctata</i> former <i>minor</i>			3		1	4												
<i>Nitzschia</i> sp. aff. <i>virgata</i>																	1	1
<i>Pinnularia borealis</i>													1					
<i>Pinnularia</i> sp. aff. <i>divergentissima</i>									25						28		16	
<i>Pinnularia</i> sp. aff. <i>intermedia</i>									32		2							
<i>Pleurosigma longum</i> var. <i>elongatum</i>																		5
<i>Tabularia fasciculata</i>																		14
Abundance	26	100	100	100	100	100	100	75	100	100	100	100	100	100	100	100	100	100
Diversity	7	4	10	7	8	8	2	3	8	4	9	5	9	5	7	5	9	8

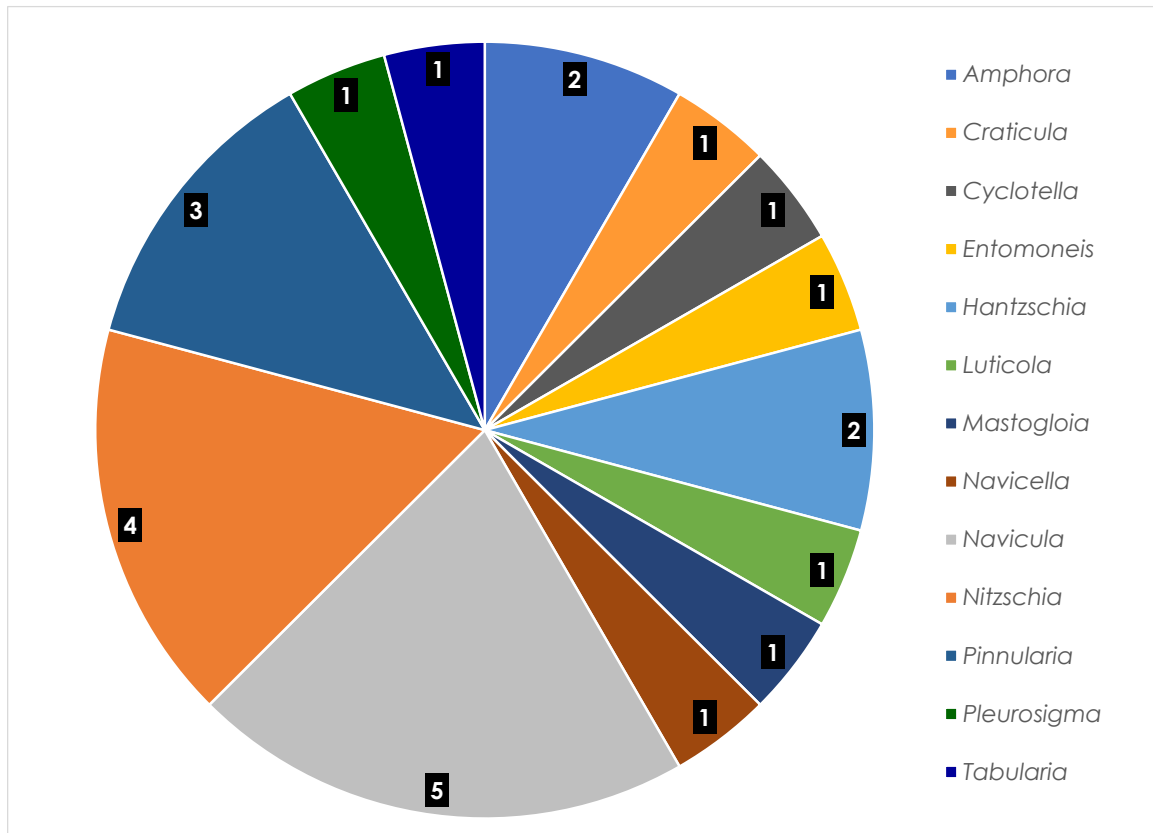


Figure 4-8: Diatom taxa per genus recorded during the rewetting trials of the Study.

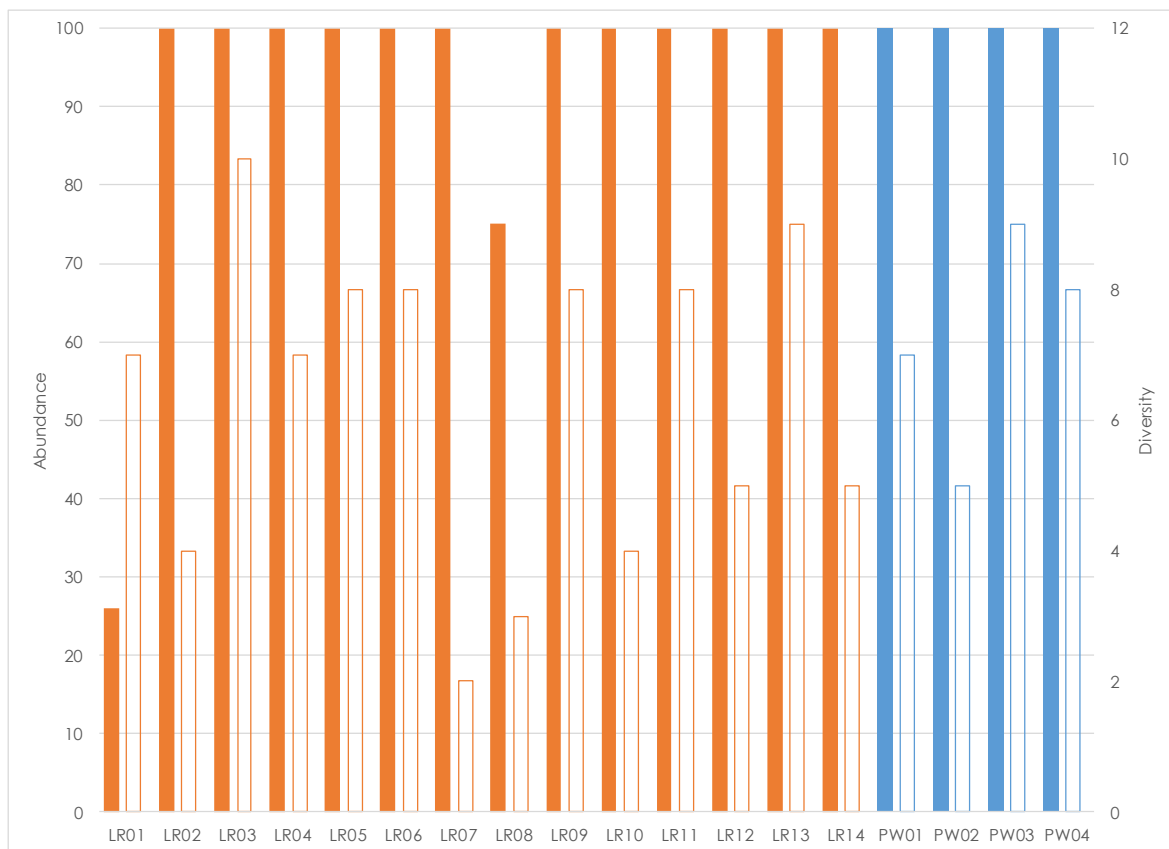


Figure 4-9: Abundance (solid fill) and diversity (no fill) of diatom taxa recorded during the rewetting trials of the Study (■=Lake Roe and ■=salinas).

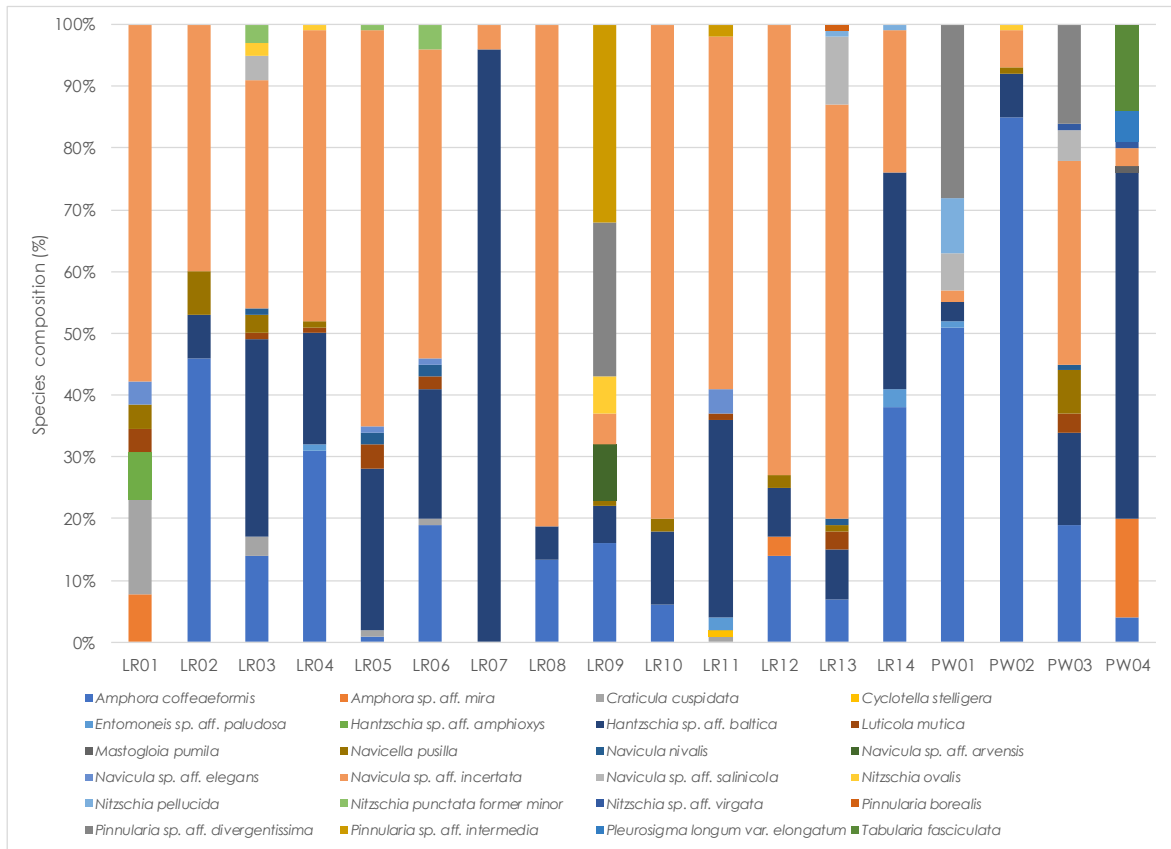


Figure 4-10: Percentage composition of diatom taxa recorded during the rewetting trials of the Study.

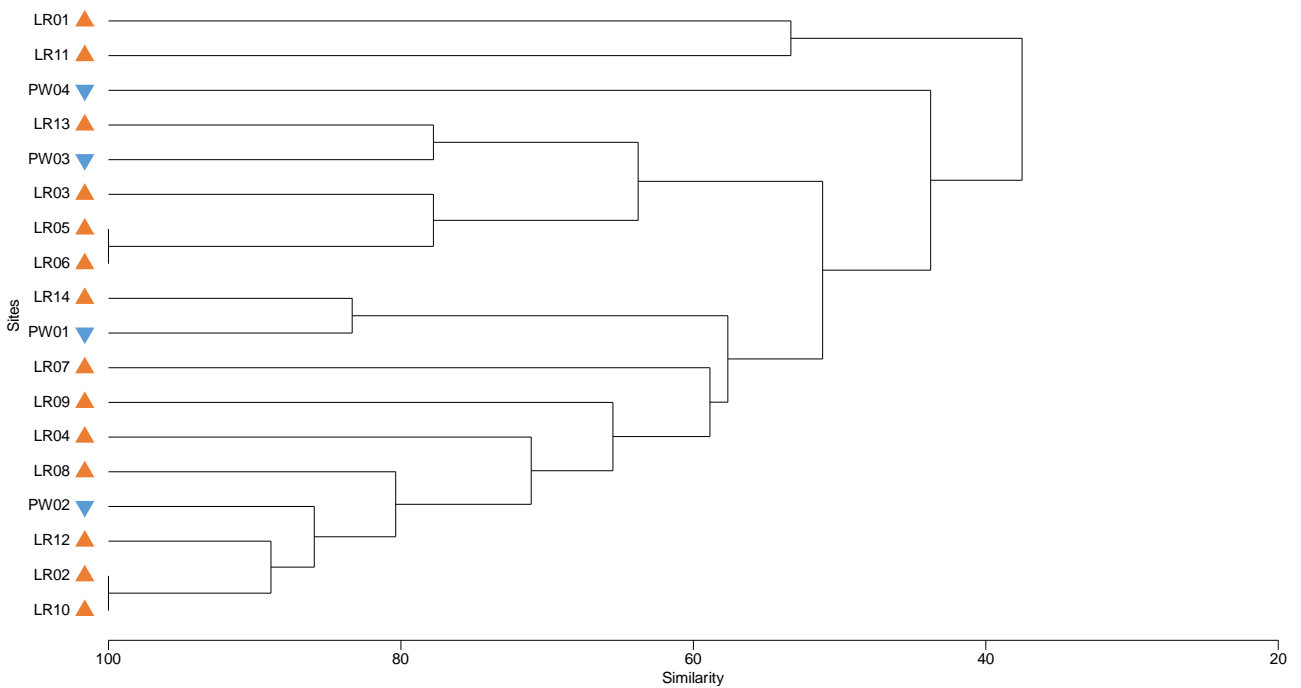


Figure 4-11: Dendrogram of the diatom assemblage recorded during the rewetting trials of the Study (▲=Lake Roe, ▼=salinas).

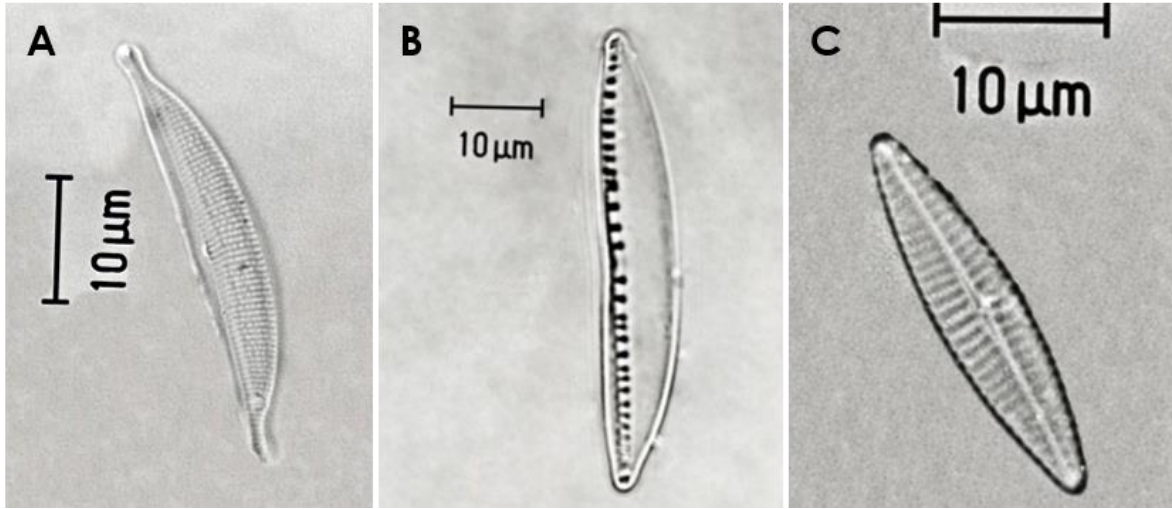


Plate 4-5: Diatom taxa recorded during the rewetting trials of the Study comprising (A) *Amphora coffeaeformis*, (B) *Hantzschia* sp. aff. *baltica* and (C) *Navicula* sp. aff. *incertata*.

4.3.5 Aquatic Invertebrates

A total of 15 taxa were recorded during the rewetting trials of the Study and the opportunistic sampling of the claypan (Table 4-7, Figure 4-12A). There were 11 taxa that occurred in Lake Roe (Figure 4-12B), seven taxa found in the salinas (Figure 4-12C) and three taxa identified from the claypan (Figure 4-12D). The total number of specimens recorded was 1,148 (Figure 4-13A), with more than 850 specimens in Lake Roe (Figure 4-13B), 245 specimens in the salinas (Figure 4-13C) and 22 specimens in the claypan (Figure 4-13D). It should be noted that the disparity in taxa and specimen numbers may be attributed to the difference in site numbers for the lake, salinas and claypan, as well as field versus laboratory methodology.

Crustaceans were the dominant group recorded during the rewetting trials of the Study and opportunistic sampling of the lake (LR01) and claypan (PC01). This group are considered characteristic of inland waterbodies throughout Australia (Williams 1981; Williams 1983). They were mostly represented by Ostracoda (seed shrimp), with more than 1,000 specimens from 11 taxa (Table 4-7). Larger Branchiopods occurred in low numbers (62 specimens) and included Anostraca, Diplostraca and Notostraca. Crustaceans were also a key component of the resting stages (dormant eggs) within the sediment of the lake and salinas (Section 4.4), with the ability of these taxa to produce desiccation-resistant eggs integral to recovery of a wetland during flooding (Waterkeyn *et al.* 2011).

The site diversity of Lake Roe and the salinas from the rewetting trials was typically two to three taxa (Figure 4-14). The maximum site diversity (six taxa) was recorded from LR01, which was a result of combining the datasets for the rewetting trials and opportunistic field sampling. In comparison, the maximum diversity of the salinas was five taxa at PW01, while the claypan diversity was three taxa (Figure 4-14). The most abundant sites (>100 specimens) comprised sites on Lake Roe (LR09, LR04, LR02 and LR12) and the salina (LR04).

The dominant crustaceans recorded during the rewetting trials of the Study were the ostracods *Diacypriis phoxe* or *Patcypris outback* (Plate 4-6A). These taxa were widespread and occurred in at least half of the sites, across the lake and salinas (Figure 4-15). *Diacypriis phoxe* was originally recorded from salt lakes from within a narrow distribution in South Australia (De Deckker 1981), with the collection of this taxon representing a range extension. *Patcypris outback* is also known to have a broad distribution throughout the Goldfields (Halse and Martens 2019) and can persist in salinities over 120,000 mg/L (Stantec unpublished data).

During the rewetting trials of the Study, the Anostracan fauna was dominated by two *Parartemia* (brine shrimp) taxa; *Parartemia serventyi* and *Parartemia veronicae*. Both species were recorded from Lake Roe, whereas the salinas only recorded *Parartemia serventyi*. *Parartemia veronicae* has been previously identified from Lake Yindarlgooda (Campagna 2007), and has a reported salinity tolerance of 225,000 mg/L (Timms 2014). *Parartemia serventyi* is commonly associated with waterbodies in the southern Goldfields and wheatbelt and has been found in salinities over 200,000 mg/L (Timms 2012).

Limited opportunistic sampling at the peripheral claypan (PC01) suggests a contrasting aquatic invertebrate assemblage to Lake Roe and the salinas (Table 4-7). At this site the Notostracan (shield shrimp) *Triops nr australiensis* (Plate 4-6B) and Diplostracan (clam shrimps) *Caenestheia* sp. were dominant opportunistically collected. These taxa are more typically associated with freshwater and low salinity waterbodies in the Goldfields (Quinlan *et al.* 2016; Timms 2002;2015; Timms *et al.* 2006), usually associated with the margins of salt lakes.

Hierarchical classification (Figure 4-16) demonstrated that the majority of Lake Roe and salina sites shared over 40% similarity in their invertebrate community structure, likely reflecting connectivity and dispersal during major floods. Aquatic invertebrates are also strongly influenced by factors such as habitat availability and the presence of macrophytes, water flow, substrate and water quality (Gooderham and Tsyrlin 2002). More broadly the species diversity and assemblage recorded from Lake Roe, the salinas and the claypan during the Study was comparable to other salt lakes located within the Roe Palaeodrainage system, particularly Lake Yindarlgooda (Campagna 2007).

Most of the aquatic invertebrate taxa recorded from the rewetting trials during the Study are known to be distributed more broadly throughout the Goldfields. However, three ostracod taxa were identified that are new to science (Table 4-7):

- *Australocypris* `BOS1364`, abundant in the north of Breaker mining lease (LR02), found in limited numbers further north on the playa (LR04 and LR05), and adjacent to the proposed pit on the lake (LR12);
- *Reticypriis* `BOS1088`, widespread, albeit in limited abundance throughout the lake and salinas (LR01, LR02, LR03, LR05 and LR08, LR13, PW01, PW02 and PW03), inside and outside the proposed development envelope; and
- *Reticypriis* `BOS1363`, abundant at the salina along eastern margin of Lake Roe (PW04), found in low numbers along southern margin of the playa (PW01) and east of development envelope (LR14).

Of these new taxa, *Australocypris* 'BOS1364' and *Reticypris* 'BOS1088' are currently known only from Lake Roe (S. Halse, pers. comm. 2019, although both are widespread throughout the playa and salinas. It is also likely that additional sampling of lakes and salinas within the Roe Palaeodrainage would extend the distribution of these species. As well as Lake Roe, *Reticypris* 'BOS1363' has also recently been identified from another salt lake in the Great Sandy Desert (Stantec unpublished data) and would likely occur in other saline environments throughout the arid interior. Both the *Australocypris* and *Reticypris* genera support several halophilic species of ostracods, with documented tolerance limits in excess of 50,000 to 100,000 mg/L (De Deckker 1974; Pinder *et al.* 2002).

Table 4-7: Aquatic invertebrate taxa recorded during the rewetting trials of the Study.

Aquatic Invertebrate Taxa	Lake Roe														Salinas				Claypan
	LR01^	LR02	LR03	LR04	LR05	LR06	LR07	LR08	LR09	LR10	LR11	LR12	LR13	LR14	PW01	PW02	PW03	PW04	PC01*
Arthropoda																			
Crustacea																			
Branchiopoda																			
Anostraca																			
<i>Parartemia serventyi</i>										14		1				3			
<i>Parartemia veronicae</i>	21										2	1	1						
Diplostraca																			
<i>Caenestheria</i> sp.																			11
Notostraca																			
<i>Triops nr australiensis</i>																			4
Ostracoda																			
Podocopida																			
<i>Australocypris</i> `BOS1364`		50		2	1									1					
<i>Australocypris</i> sp.			2									1							
Cyprididae sp.																			3
<i>Diacypris fodiens</i>	7																		
<i>Diacypris phoxe</i>	6	60	3	133	20		72	1		62	10	100		56	2	100	50		
<i>Patocypris outback</i>	2						4	191		23					12	17	1		
<i>Repandocypris aust inensis</i>											1								
<i>Repandocypris</i> sp.	1			5											5				
<i>Reticypris</i> `BOS1088`	2	2	5		10		3						7		2	3	8		
<i>Reticypris</i> `BOS1363`														2	1				37
<i>Trilocypris horwitzi</i>																			4
Abundance	39	112	10	140	31	0	79	192	0	99	11	104	8	60	22	123	59	41	18
Diversity	6	3	3	3	3	0	3	2	0	3	2	4	2	4	5	4	3	2	3
Overall Diversity	3																		

Note: ^ combined results from opportunistic sampling and rewetting trials; * opportunistic sampling only; yellow shading indicates new species.

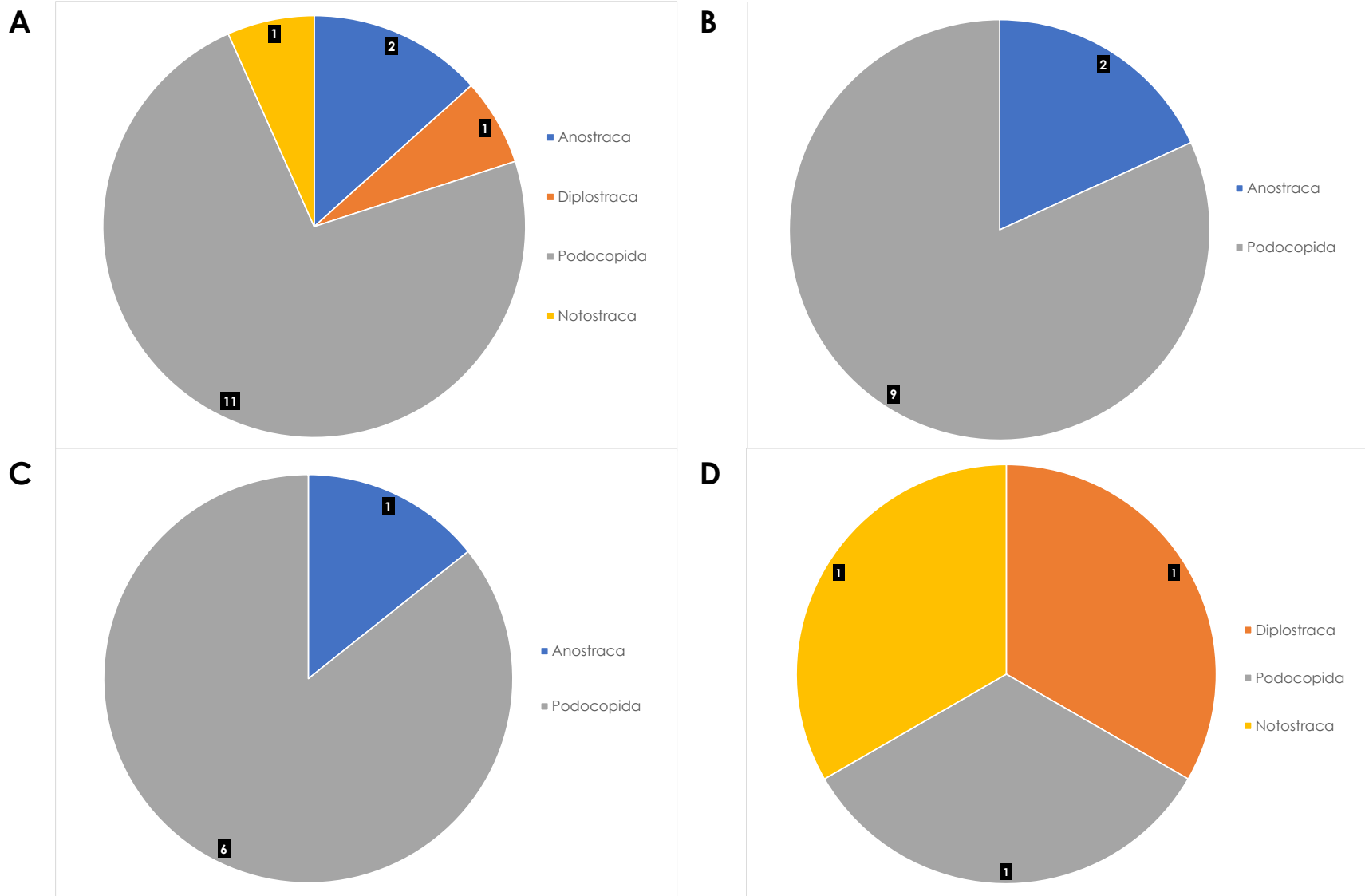


Figure 4-12: Aquatic invertebrate taxa per group recorded (A) in total during the rewetting trials of the Study, (B) from Lake Roe, (C) from the salinas, and (D) from the claypan.

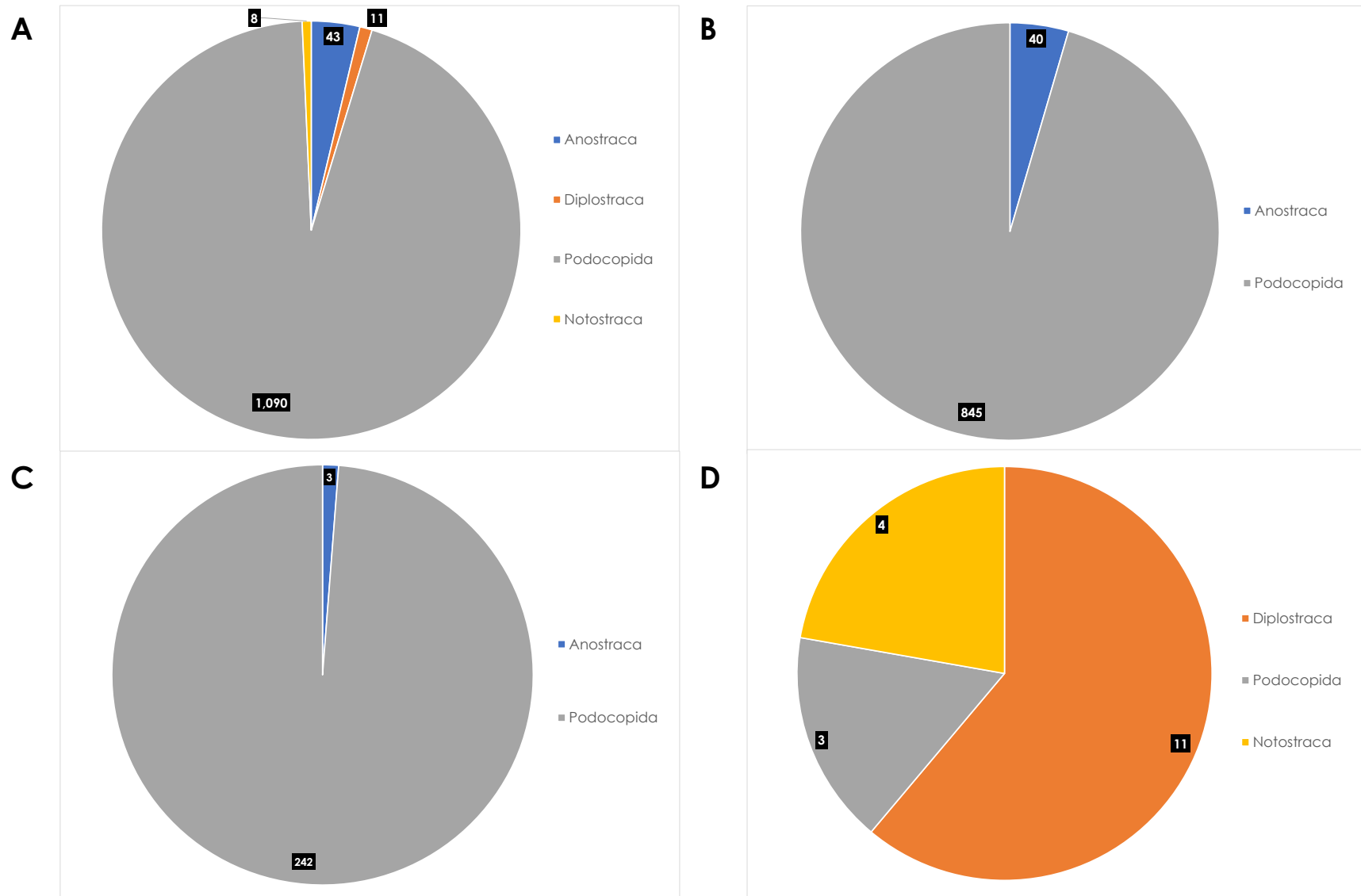


Figure 4-13: Aquatic invertebrate specimens per group recorded (A) in total during the rewetting trials of the Study, (B) from Lake Roe, (C) from the salinas, and (D) from the claypan.

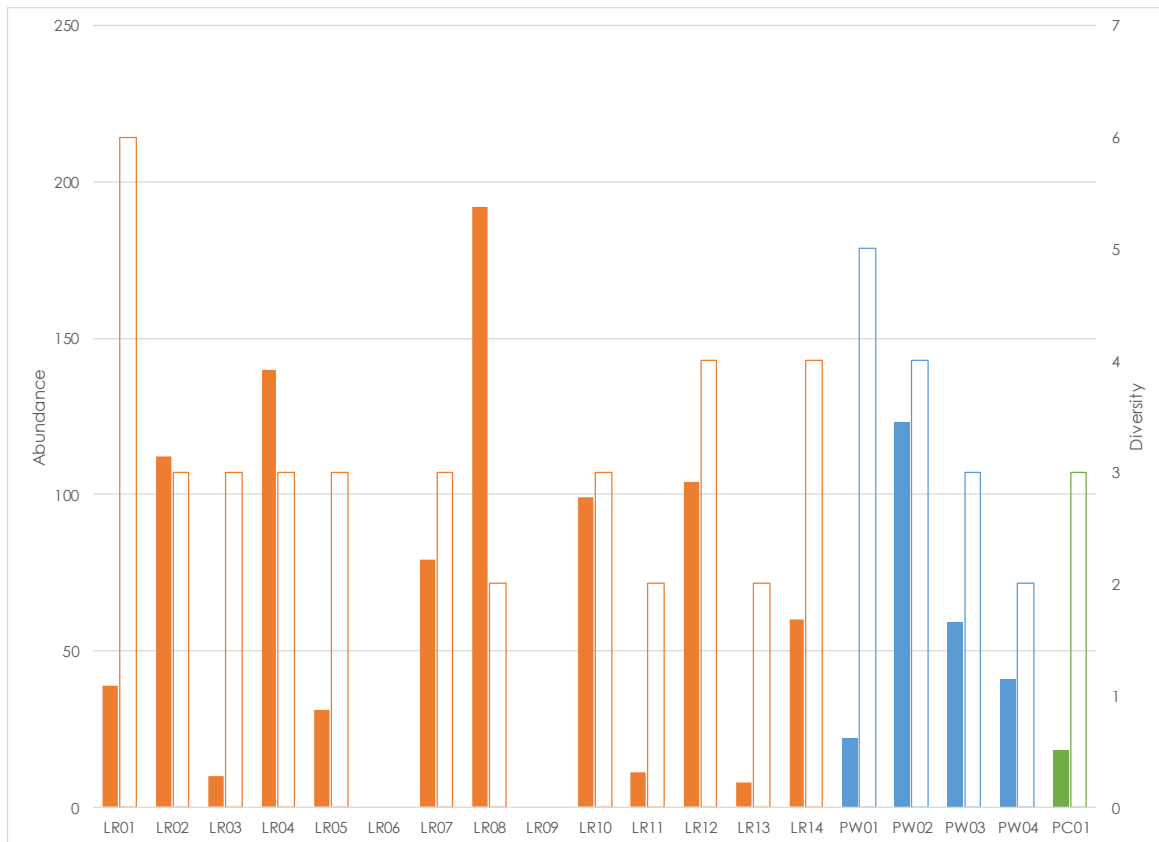


Figure 4-14: Abundance (solid fill) and diversity (no fill) of aquatic invertebrate taxa recorded during the rewetting trials of the Study.

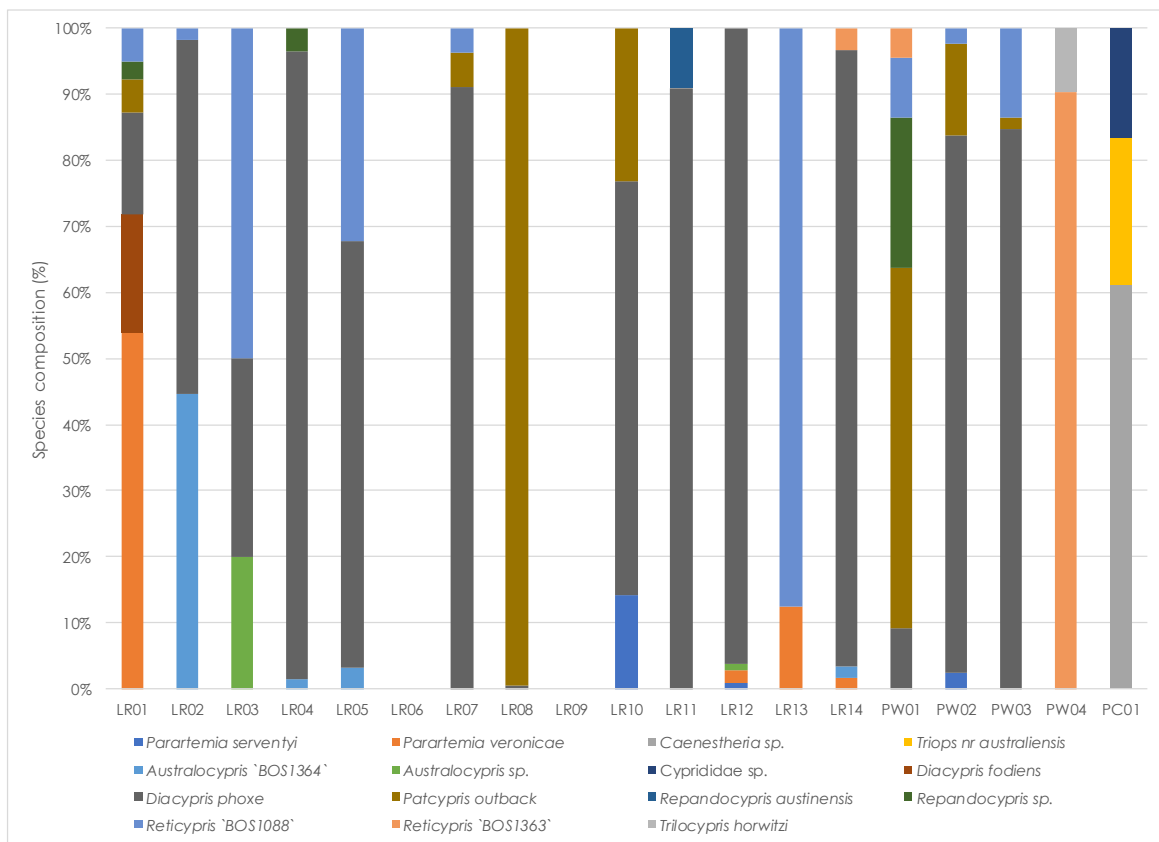


Figure 4-15: Percentage composition of aquatic invertebrate taxa recorded during the rewetting trials of the Study.

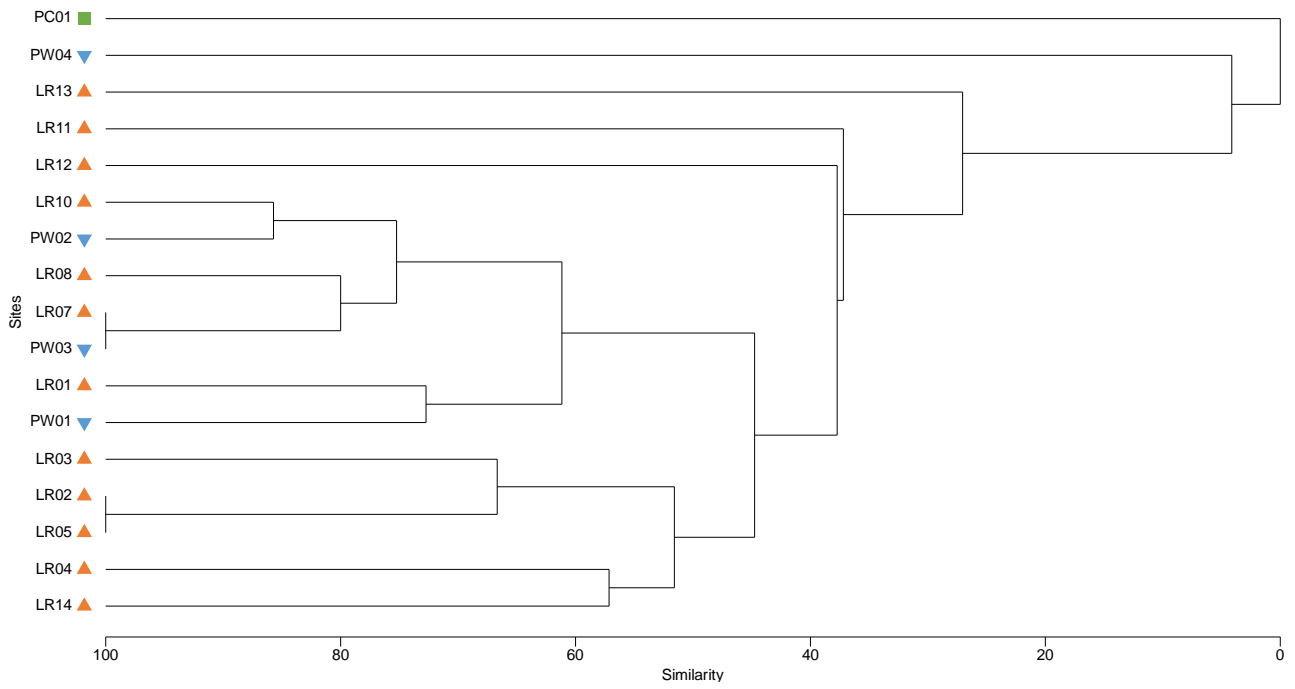


Figure 4-16: Dendrogram of the aquatic invertebrate assemblage recorded during the rewetting trials of the Study (▲=Lake Roe, ▼=salinas and ■=claypan).

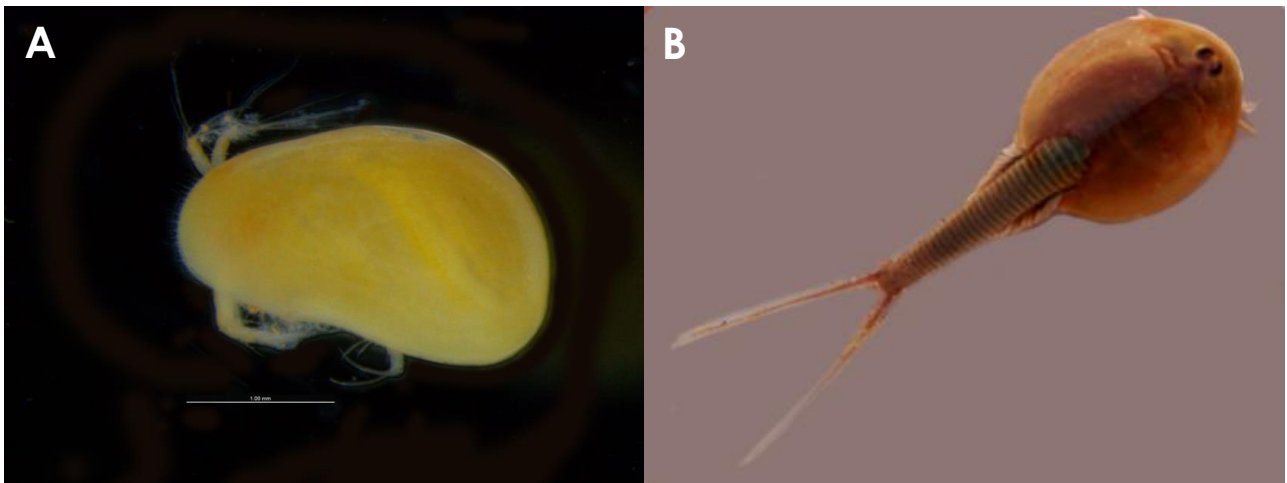


Plate 4-6: Aquatic invertebrate taxa recorded during the rewetting trials of the Study comprising (A) *Patocypris outback*, and (B) *Triops nr australiensis*.

4.4 Resting Stages

During the Study, the resting stages of six taxa were identified from the sediment (**Table 4-8**). These comprised the eggs of two varieties (red and white) of ostracods (seed shrimp), one daphnid (water flea), one anostracan (brine shrimp) and two algae (charophytes). The large green algae (Charophyta) *Lamprothamnium* sp. and *Nitella* sp. contributed to the highest percentage of resting stages (58.2% and 35.9% respectively) (**Figure 4-17**). The representation of aquatic invertebrates was minor in comparison, accounting for less than 10% of total composition in the sediment.

Relatively low numbers of eggs belonging to ostracods (325 eggs per 100 g sieved sediment), *Parartemia* sp. (67 eggs per 100 g sieved sediment) and Daphniidae (39 eggs per 100 g sieved sediment) were recorded (**Figure 4-18**). It is likely that the *Parartemia* eggs belong to *Parartemia serventyi* or *Parartemia veronicae*, both of which were identified during the rewetting trials of the Study (**Section 4.3.5**). The white variety of ostracod eggs were more widespread in their distribution; being recorded from Lake Roe (LR08 and LR14) and the salinas (PW03 and PW04) (**Figure 4-18**). These potentially belong to *Diacypriis phoxe* and/or *Patcypriis outback*, which were commonly identified from the lake and salinas. Eggs belonging to Daphniidae (water fleas) were only recorded from a single salina (PW04), although this group are considered typical of inland waters throughout Australia (Sergeev and Williams 1983).

Comparably higher numbers of charophyte oospores were identified from the sediment during the Study, comprising *Lamprothamnium* sp. and *Nitella* sp. (**Figure 4-18**), despite these taxa not germinating during the rewetting trials. Both are widespread cosmopolitan genera that occur in clear waters in arid wetlands throughout Australia. *Lamprothamnium* is typically more common in saline waters, while *Nitella* sp. favours freshwater or low salinity conditions (Brock *et al.* 2006). The oospores of *Lamprothamnium* may potentially belong to *Lamprothamnium macropogon*, which has an upper salinity tolerance limit of over 200,000 mg/L (Porter 2007), although requires freshwater (<3,000 mg/L) for germination (Porter 2007). Germination is also affected by factors including depth, water clarity, light intensity and temperature (Casanova and Brock 1990;1996; Kalin and Smith 2007).

The highest abundances of these charophyte taxa were recorded from the two salinas PW03 and PW04 (**Table 4-8**), with more than 2,500 oospores per 100 g of sieved sediment (**Table 4-8**). These sites also supported the highest diversity of resting stages, of three and four taxa, respectively. Similar diversity was also found at the Lake Roe sites LR08 and LR14, albeit in lower abundances (<900 eggs per 100 g sediment). The high abundance of charophyte oospores associated with the salinas may indicate these wetlands support a more diverse invertebrate assemblage when flooded. This is likely to comprise a range of insect groups (that cannot be hatched in rewetting trials), due to the complexity of habitat created by charophytes (Davis and Christidis 1999).

Table 4-8: Abundance of resting stages recorded (per 100 g of sieved sediment) during the Study.

Taxa	Lake Roe					Peripheral Wetlands			Taxon Abundance
	LR02	LR05	LR07	LR08	LR14	PW01	PW03	PW04	
Crustacea									
Anostraca									
<i>Parartemia</i> sp.	41	14			12				67
Ostracoda									
red eggs		14	110	93					217
white eggs				47	12		23	26	108
Cladocera									
Daphniidae								39	39
Algae									
Charophyta									
<i>Lamprothamnium</i> sp.					873	64	259	3,027	4,223
<i>Nitella</i> sp.				47			2,330	224	2,601
Abundance	41	28	110	187	898	64	2,611	3,316	7,255
Diversity	1	2	1	3	3	1	3	4	6

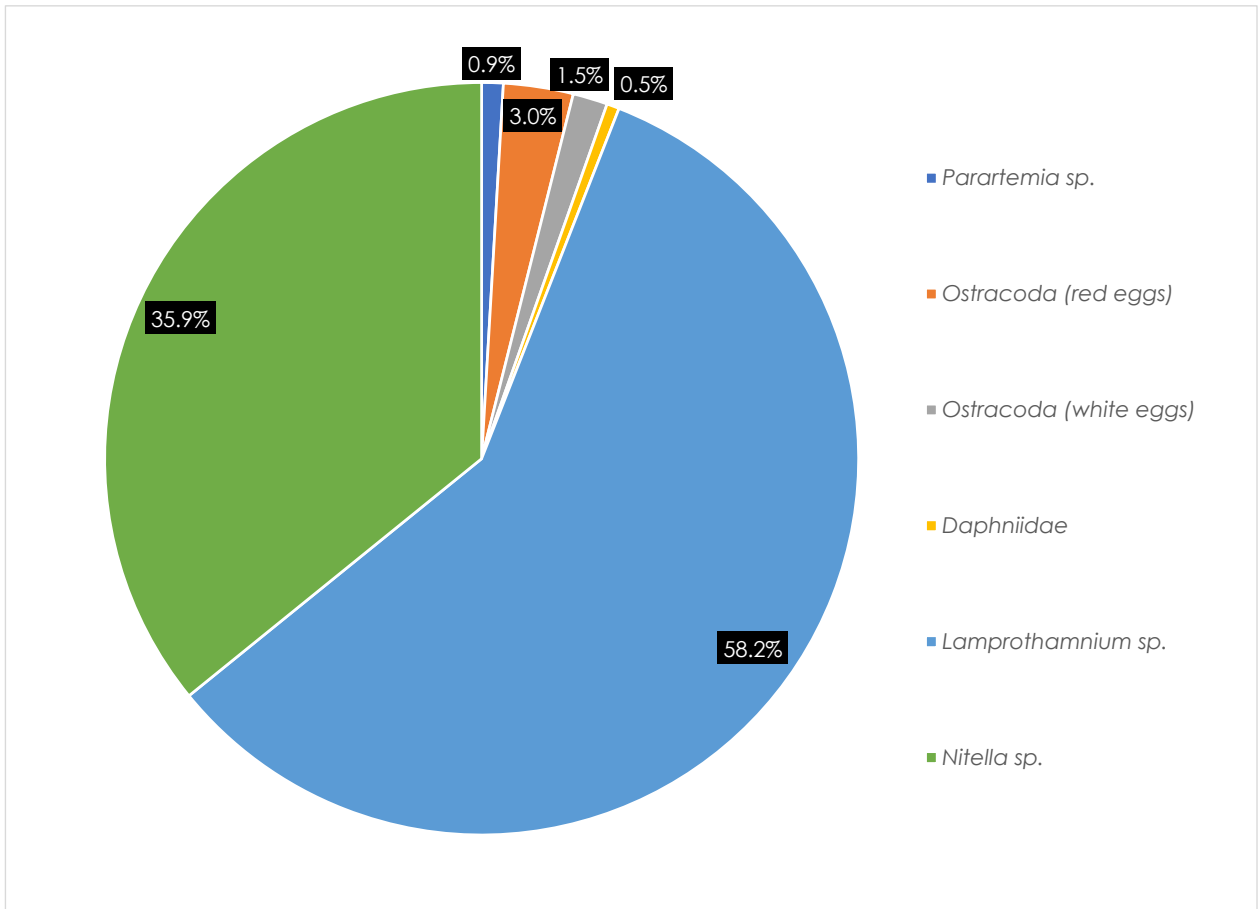


Figure 4-17: Percentage composition of resting stages recorded in the sediment during the Study.

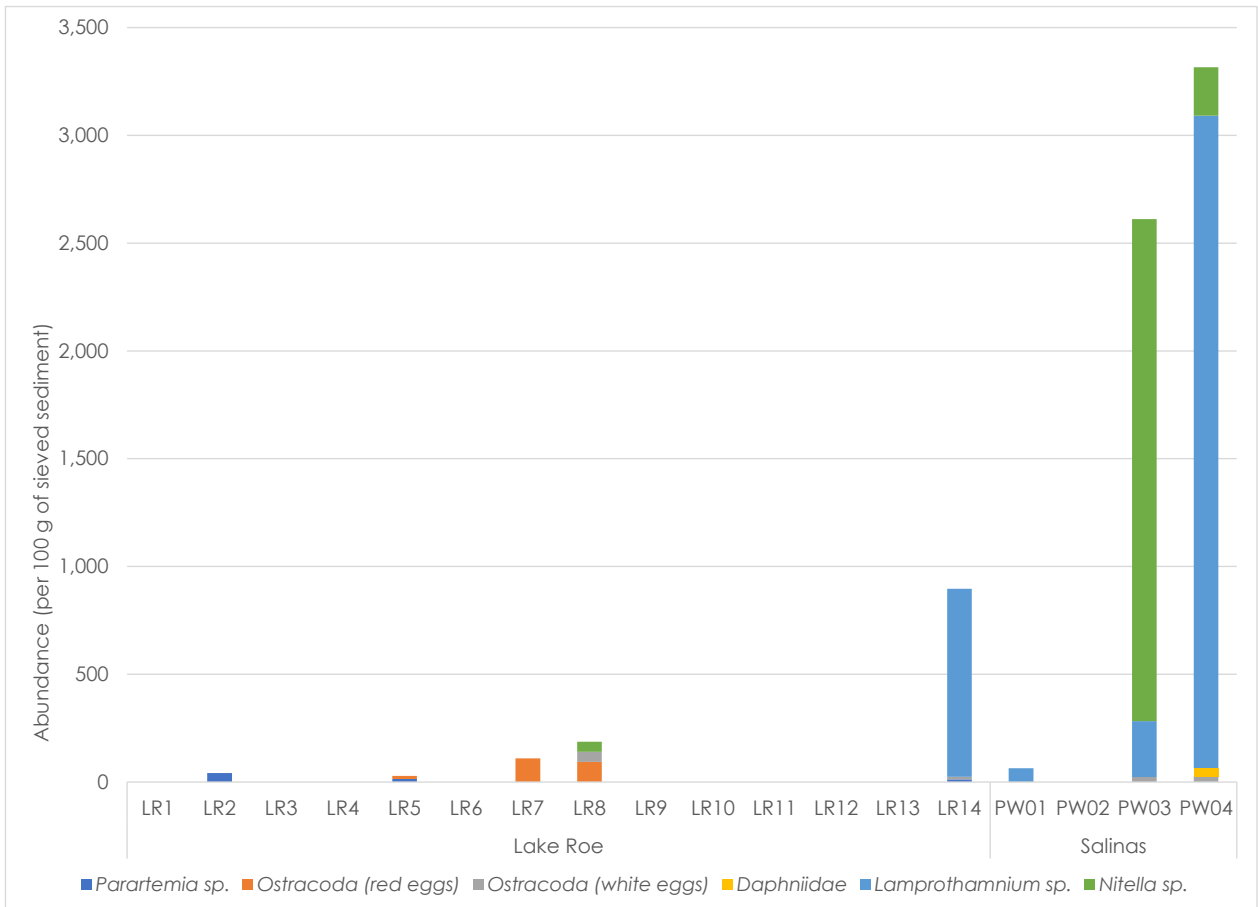


Figure 4-18: Abundance of resting stages taxa recorded from sediment during the Study.

4.5 Riparian Vegetation

4.5.1 Diversity and Abundance

During the Study, a total of 47 plant taxa (including subspecies, varieties and forms), representing 25 genera and 13 families, were identified from the riparian zone of Lake Roe and the salinas (**Table 4-9**). The most well represented families were Chenopodiaceae (Chenopods), with 22 taxa and Asteraceae (daisies), with five taxa (**Figure 4-19**). The most diverse genera were *Tecticornia* (14 taxa) and *Maireana* (three taxa) (**Table 4-9**). The assemblage of plants was considered characteristic of the Coolgardie bioregion, where chenopods and halophytic samphire communities are associated with saline drainage areas (Cowan 2001).

There were 44 and 18 taxa recorded from the riparian zone of Lake Roe and the salinas, respectively during the Study (**Table 4-9**). At Lake Roe, species diversity ranged from two to 19 taxa, with sites LR12, LR11, LR04 supporting the highest number of species (≥ 14) (**Figure 4-20**). In comparison, diversity at the salinas ranged from four (PW04) to 11 (PW01) taxa. An unidentified *Frankenia* sp. (Frankeniaceae) and *Atriplex nana* were the most widespread taxa recorded during the at 14 and 13 sites, respectively (**Table 4-9; Figure 4-21**). *Frankenia* is commonly found in saline areas and grow with a wide range of salt tolerant vegetation in open shrublands (Mitchell and Wilcox 1994). *Atriplex nana* is known from salt lakes and salt flats throughout inland Western Australia (Florabase 2020).

Tecticornia (samphires) were widespread within the riparian zone of the lake during the Study, with at least two taxa collected from the majority of sites (**Table 4-9**). Of these, the most widespread taxa included an unidentified *Tecticornia* sp. 1 (seven sites), *Tecticornia indica* subsp. *bidens* and *Tecticornia pergranulata* subsp. *divaricata* (six sites each). *Tecticornia pergranulata* subsp. *divaricata* is known from the Eastern Goldfields and Eastern Murchison regions (Florabase 2020), whereas *Tecticornia indica* subsp. *bidens* is found throughout Western Australia, growing in well-drained saline soils (Datson 2002).

Other taxa including, *Carpobrotus* sp. (Aizoaceae) and *Surreya diandra* (Amaranthaceae) were also relatively widespread (eight sites each), particularly along the margins of Lake Roe during the Study (**Table 4-9; Figure 4-21**). Along the periphery of the lake, *Tecticornia* dominates, growing in association with *Frankenia* and *Carpobrotus modestus* (inland pigface), transitioning to *Atriplex* (saltbush) and *Frankenia* heath, as distance from the edge of the playa increases (Stantec 2019). This is typical of riparian vegetation zonation of salt lakes, with samphires forming the primary fringing community along the shoreline (Mitchell and Wilcox 1994).

The highest abundance of plants recorded during the Study were corresponded to *Tecticornia pergranulata* subsp. *divaricata* (3,558 plants), *Frankenia* sp. (533 plants), *Tecticornia indica* subsp. *bidens* (289 plants) and *Tecticornia* sp. Dennys Crossing (264 plants) (**Figure 4-21**). A mass germination of juvenile *Tecticornia pergranulata* subsp. *divaricata* plants at the salina PW04 accounted for the substantially high abundance of this taxon. *Tecticornia indica* subsp. *bidens* was most abundant at the salina PW03 (222 plants), with comparatively lower abundances at the playa sites. In contrast the majority of *Tecticornia* sp. Dennys Crossing specimens were recorded from Lake Roe site LR10 (264 plants). *Tecticornia* sp. Dennys Crossing is known from the interior and coastal areas of Western Australia throughout the southwest, Murchison, Goldfields and Pilbara regions (Florabase 2020).

Although several taxa were common to the majority of sites, differences were evident in community structure, with less than 20% similarity in composition according to the hierarchical classification (**Figure 4-23**). Sites located on the northern shoreline of Lake Roe (LR03, LR04, LR05 and LR06) were considered the most similar (>40%) and were also closely grouped with Lake Roe sites LR11 and LR12, located within the proposed development envelope (**Figure 4-23**). These sites also tended to support the most diverse assemblage of species (≥ 10 taxa), with the following taxa common to most sites; *Atriplex nana*, *Carpobrotus* sp., *Frankenia* sp., *Poaceae* sp., *Surreya diandra* and *Tecticornia* sp. 1.

At a local scale, factors such as distance to groundwater, elevation and geology (including soil properties), are known to be strongly influential on the riparian vegetation zone (Barrett 2006; Datson 2002). However, at a regional scale, the riparian zone of Lake Roe and the salinas (**Appendix A**) was considered typical of vegetation associations throughout the Coolgardie bioregion. In addition, there were no declared rare flora, priority species, or weeds recorded during the Study, although several *Tecticornia* representatives were not flowering at the time of collection, and require species level verification.

4.5.2 Cover and Density

Riparian plant cover during the Study was low and typically ranged between 5% and 12% across the sites (**Figure 4-22**). Plant cover was highest at the Lake Roe site LR13 (23%), followed by the salina PW01 (19%) and playa site LR09 (15%). The substantially higher plant cover at LR13 was attributed to large *Eucalyptus* and *Melaluca* shrubs and dense *Triodia* hummocks in quadrats at distance and elevated from the lake shore. In contrast, the dominance of *Tecticornia*; a genus that often displays a wide growth form (Datson 2002) contributed to the comparatively higher plant cover at PW01 and LR13.

The lowest plant cover (<7%) during the Study was recorded at Lake Roe sites LR06, LR07, LR08 and LR11 (**Figure 4-22**). With the exception of LR11, these sites were low-lying and consisted of mobile sands supporting an open shrubland of stunted *Tecticornia* plants (**Appendix A**). Factors affecting vegetation zonation in salt lakes includes soil salinity, depth to saline-ground water table, episodic inundation and aeolian deposition (Barrett 2006).

More broadly, plant density was considered low during the Study, with most sites across Lake Roe and the salinas recording fewer than 10 plants/3m² (**Figure 4-22**), although this is generally typical of salt lake margins throughout the Goldfields. The notable exception was PW04, where over 100 plants/3m² were recorded, attributed to recruitment of *Tecticornia pergranulata* subsp. *divaricata*. This site also had higher moisture content and nutrients in the sediment (**Section 4.2**), which is favourable for the germination of *Tecticornia* seeds (Datson 2002).

Table 4-9: Riparian vegetation taxa recorded during the Study.

Riparian Vegetation Taxa	Lake Roe													Peripheral Salina			
	LR01	LR02	LR03	LR04	LR05	LR06	LR07	LR08	LR09	LR10	LR11	LR12	LR13	PW01	PW02	PW03	PW04
Aizoaceae																	
<i>Carpobrotus</i> sp.^	•		•	•	•	•					•	•					•
<i>Disphyma crassifolium</i>										•	•						
<i>Gunnopsis quadrifida</i>			•	•	•				•			•	•				
Amaranthaceae																	
<i>Surreya diandra</i>			•	•	•	•				•	•	•				•	
Asteraceae																	
<i>Asteraceae</i> sp.^				•							•						
<i>Cratystylis microphylla</i>												•					
<i>Minuria leptophylla</i>						•											
<i>Minuria</i> sp.^		•															
<i>Podolepis capillaris</i>														•			
Chenopodiaceae																	
<i>Atriplex nana</i>	•	•	•	•	•	•	•		•	•	•	•		•	•		
<i>Atriplex</i> sp.^												•					
<i>Maireana amoena</i>											•						
<i>Maireana erioclada</i>												•		•			
<i>Maireana</i> sp.^		•			•	•	•				•	•			•		
<i>Roycea divaricata</i>				•								•					
<i>Sclerolaena fibriolata</i>									•								
<i>Tecticornia dolliformis</i>														•			
<i>Tecticornia indica</i> subsp. <i>bidens</i>			•				•	•				•		•		•	
<i>Tecticornia pergranulata</i> subsp. <i>divaricata</i>	•	•	•	•										•			•
<i>Tecticornia pergranulata</i> subsp. <i>pergranulata</i>						•											
<i>Tecticornia pruinosa</i>					•										•		
<i>Tecticornia pterygosperma</i> subsp. <i>pterygosperma</i>											•						
<i>Tecticornia</i> sp. 1^			•	•			•	•	•		•	•					
<i>Tecticornia</i> sp. 2^						•				•			•	•			
<i>Tecticornia</i> sp. 3^							•										
<i>Tecticornia</i> sp. 4^										•			•				
<i>Tecticornia</i> sp. 5^	•																
<i>Tecticornia</i> sp. 6^														•			
<i>Tecticornia</i> sp. <i>Dennys Crossing</i>		•	•	•						•					•		
<i>Tecticornia undulata</i>	•										•						
Cupressaceae																	
<i>Callitris</i> sp.^				•													
Frankeniaceae																	
<i>Frankenia setosa</i>												•					
<i>Frankenia</i> sp.^	•	•	•	•	•	•	•		•	•	•	•	•		•		•
Malvaceae																	
<i>Lawrenia helm sii</i>							•		•								
Myrtaceae																	
<i>Eucalyptus</i> sp.^													•				
<i>Melaleuca</i> sp.^													•				
<i>Melaleuca subularis</i>														•			•
Poaceae																	
<i>Enneapogon caeruleus</i>												•					
<i>Eragrostis falcata</i>	•	•			•	•	•										
<i>Poaceae</i> sp.^			•	•	•					•	•	•		•	•		
<i>Triodia</i> sp.^		•		•					•		•	•		•			
Santalaceae																	
<i>Exocarpos</i> sp.^			•		•												
Sapindaceae																	
<i>Dodonaea viscosa</i> subsp. <i>angustissima</i>		•				•					•				•		
Scrophulariaceae																	
<i>Eremophila miniata</i>		•		•								•					
<i>Eremophila scoparia</i>												•					
Solanaceae																	
<i>Solanum nummularium</i>												•					
Average Plant Health	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Diversity	7	10	11	14	10	10	8	2	7	8	14	18	7	11	6	3	4
Total Diversity	47																

Note: ^ = insufficient fruits or flowers to undertake identification; *Tecticornia* sp. *Dennys Crossing* is *Tecticornia* sp. *Dennys Crossing* (K.A. Shepherd & J. English KS552).

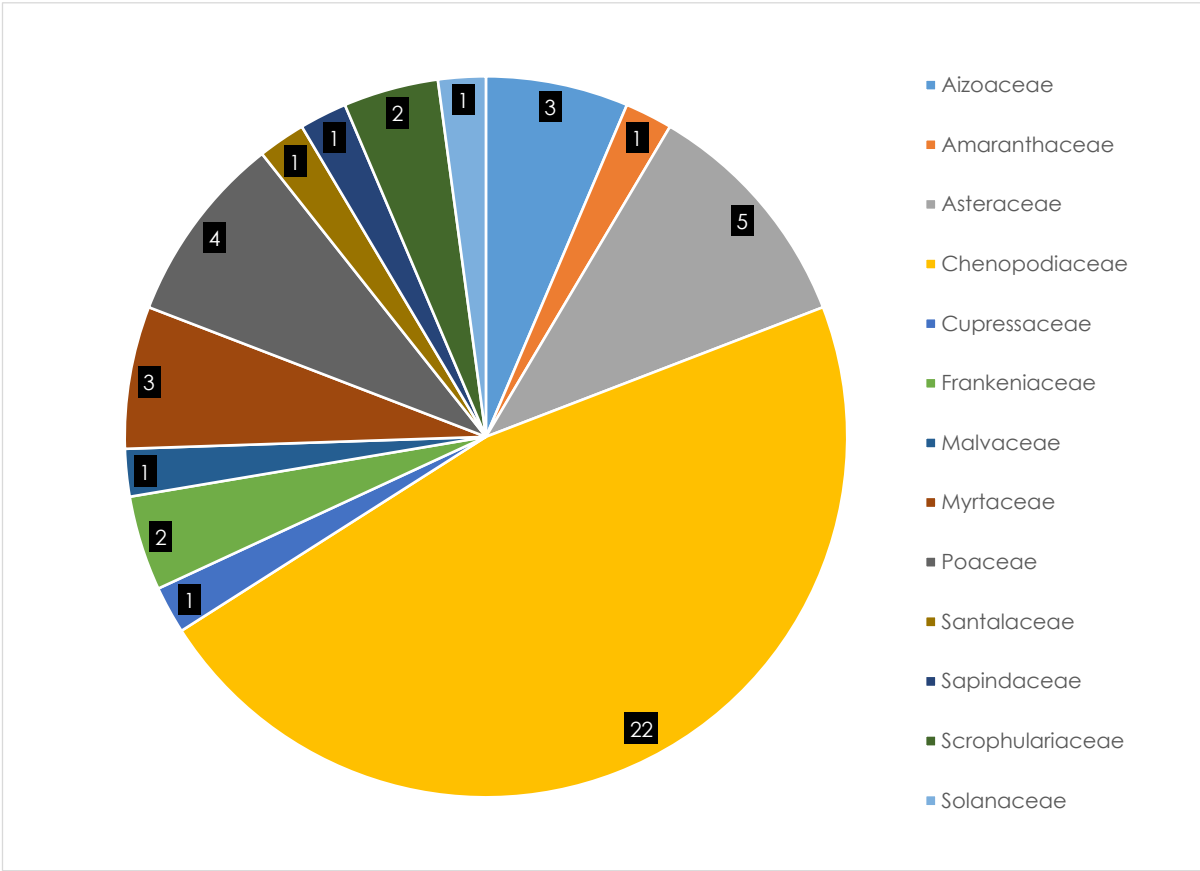


Figure 4-19: Riparian vegetation taxa per family recorded during the Study.

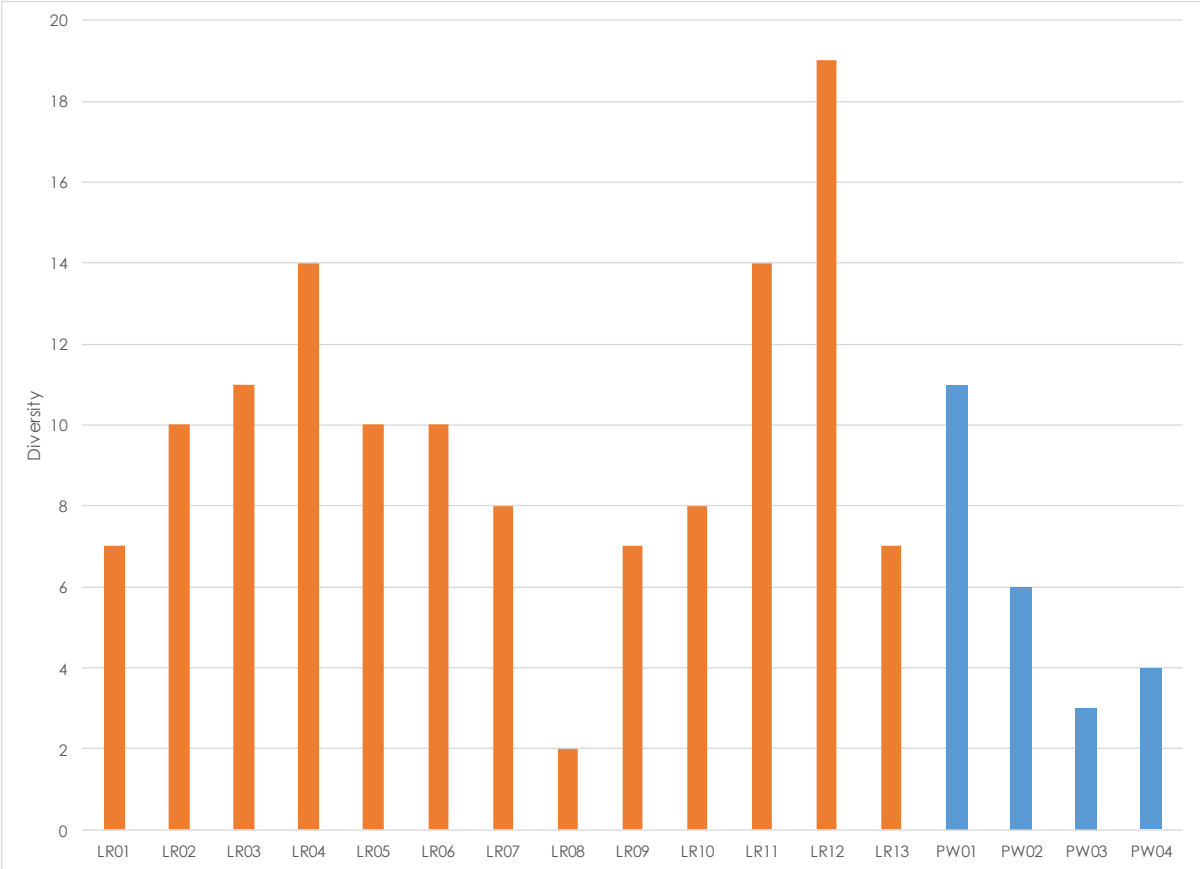


Figure 4-20: Diversity of riparian vegetation taxa recorded during the Study.

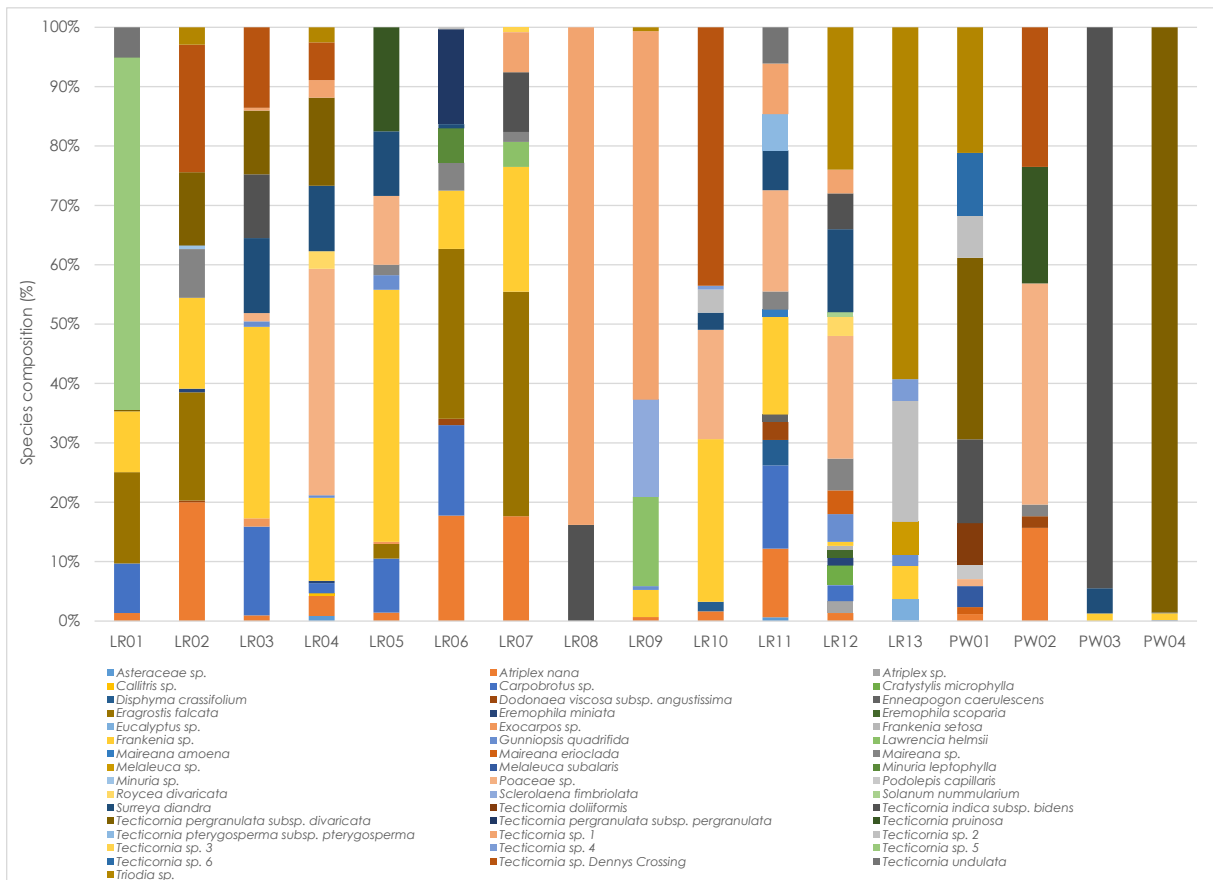


Figure 4-21: Percentage composition of riparian vegetation recorded during the Study.

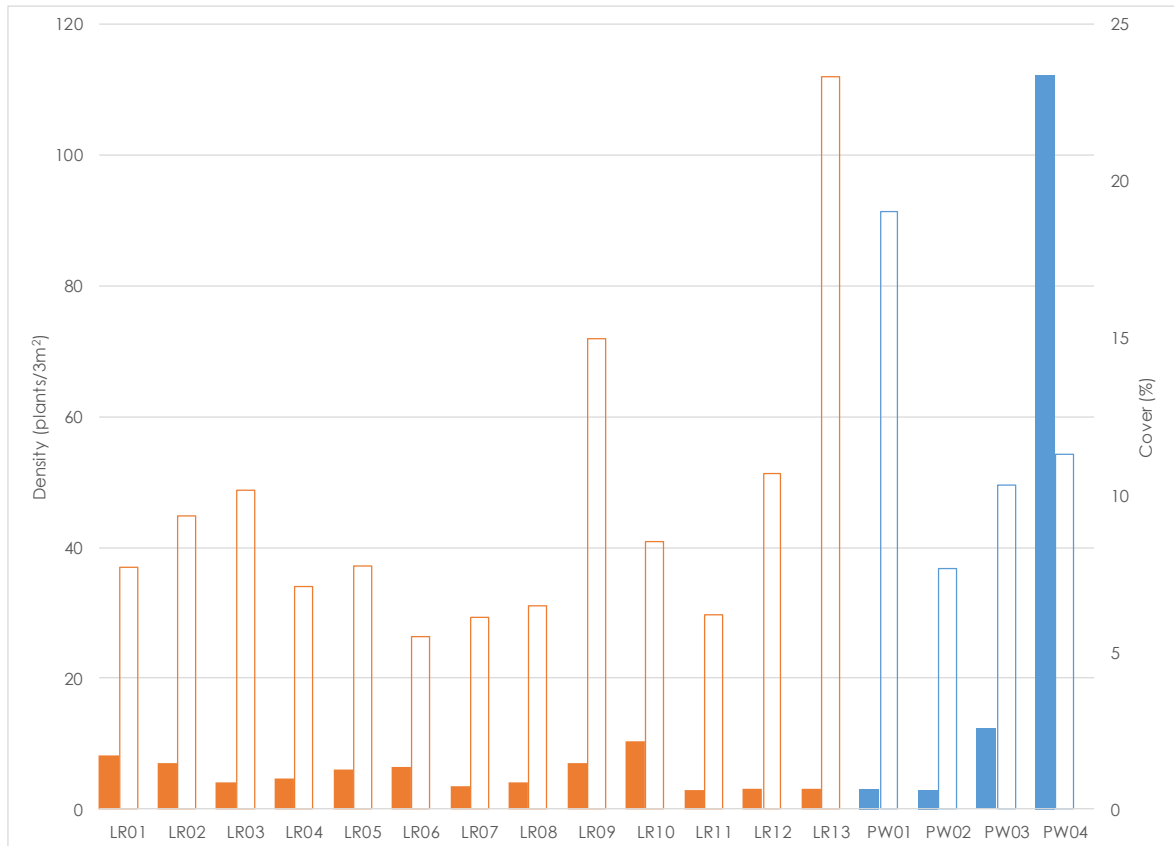


Figure 4-22: Density (solid fill) and cover (no fill) of riparian vegetation taxa recorded during the Study.

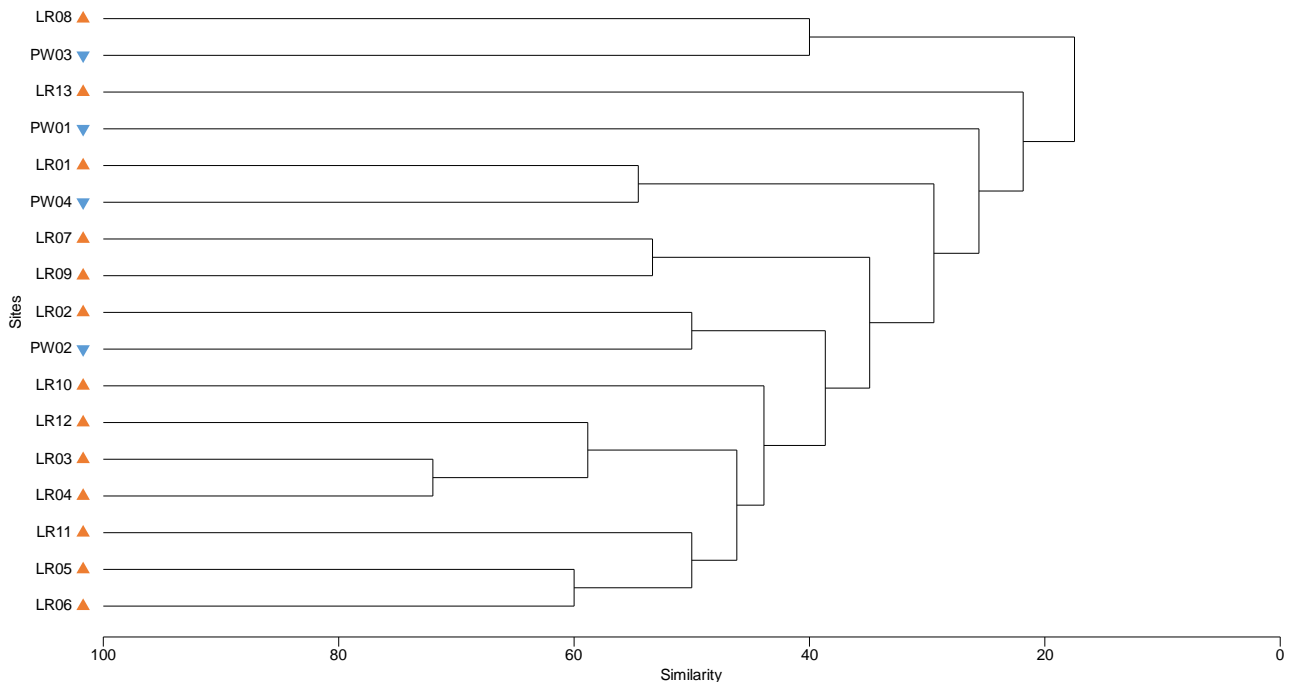


Figure 4-23: Dendrogram of the riparian vegetation assemblage recorded during the Study (▲=Lake Roe and ▼=salinas).

5. Summary & Preliminary Impact Assessment

The Study provided preliminary baseline data on the aquatic and riparian ecology of the naturally saline Lake Roe and surrounding salinas. Water quality from the the rewetting trials indicated that the lake and salinas are likely to be alkaline (pH>7.5) and range in salinity from hyposaline to mesosaline, during the intital stages of flooding. Surface sediment was also typically alkaline (>pH 7.3) and saline, the latter being elevated in the salinas. Nutrient levels were variable, although substantially higher total nitrogen was also recorded in salinas in the north-eastern margin of the lake. For metals, chromium and nickel exceeded the ANZECC & ARM CANZ (2000) ISQG-Low trigger value at most Lake Roe and salina sites, while nickel also exceeded the ISQG-High trigger value within Lake Roe.

The rewetting trials undertaken for the Study were successful, and the results suggested that Lake Roe and the salinas are likely to support a productive and diverse biological assemblage during major flood events. A total of 106 taxa from the various biological groups were identified (**Table 5-1**), characterised by mostly well-documented, salt tolerant species. The taxa recorded collectively from Lake Roe and the salinas comprised 12 algae, two macrophytes, 24 diatoms, 15 aquatic invertebrates, six resting stages and 47 riparian plant taxa. Lake Roe supported the majority of the biodiversity (94 taxa), in comparison to the salinas (57 taxa), however, this disparity can likely be attributed to the unequal sample effort.

Similarities were evident in the biological assemblage observed between Lake Roe and the salinas. Both were characterised by common saline genera of algae such as *Hantzschia*, *Navicula*, *Planktolyngbya* and *Planktothrix* and macrophytes including *Ruppia tuberosa*. Charophyte oospores (*Lamprothamium* and *Nitella*) were also recorded in the sediment, which were particularly abundant at two salinas, located on the north-eastern margin of the playa, despite not germinating in the rewetting trials. Aquatic invertebrates included resident salt tolerant crustacean fauna recorded across the lake and salinas, including the ostracods *Diacypris phoxe* and *Patcypris outback*, while the brine shrimp *Parartemia serventyi* and *Parartemia veronicae* were predominantly associated with the lake. In contrast, *Triops nr australiensis* and *Caenestheia* sp. were characteristic of the peripheral claypan, indicative of freshwater or low salinity conditions. Riparian vegetation was characterised by chenopods, dominated by *Tecticornia*, *Frankenia* and *Atriplex* genera.

The majority of taxa recorded during the Study have been previously documented from the Coolgardie bioregion, and/or are known to occur more broadly throughout inland waters across Australia. There were no significant species of algae, macrophytes, or plants identified. However, three potentially new aquatic invertebrate taxa were recorded; the ostracods *Australocypris* 'BOS1364', *Reticypriis* 'BOS1088' and *Reticypriis* 'BOS1363' (**Table 5-2; Figure 5-1**). Of these, the former two species are currently only known from Lake Roe (although widespread throughout the playa and/or salinas), while the latter species (*Reticypriis* 'BOS1363') has recently been identified from the Great Sandy Desert.

Table 5-1: Summary of the taxa recorded per biota group during the Study.

Biota	Lake Roe Taxa	Salina Taxa	Total Taxa
Algae	12	10	12
Macrophytes	2	2	2
Diatoms	20	16	24
Aquatic Invertebrates	11	7	15
Resting Stages	5	4	6
Riparian Vegetation	44	18	47
Total Taxa	94	57	106

The potential exists for direct and indirect impacts on sensitive biological receptors inhabiting Lake Roe, the salinas, claypans and riparian zone, from development and mining for the Project. Based on the findings of this Study, primary biological receptors were identified, which may be at risk of impacts, comprising:

- algae and macrophytes (including dormant propagules in sediment);
- aquatic invertebrates (including resting stages in sediment); and
- plants inhabiting the riparian zone.

Impacts from the Project may be associated with the location of infrastructure, development and mining of the deposit, and likely dewatering discharge to Lake Roe (**Table 5-2**). Direct impacts include the removal of habitat and release of contaminants, as well as inundation of the playa with hypersaline water, which may impact on aquatic biota and riparian vegetation. Indirect impacts include hydrological changes, drawdown and sedimentation, which may also adversely affect sensitive biological receptors on the playa and surrounds.

The level of risk to the sensitive biological receptors will be dependent on the final layout of infrastructure mining schedule, and associated requirements, as well as the location selected for the discharge outfall. There are several new aquatic invertebrate taxa known from Lake Roe and the salinas, although all species have also been recorded well-outside of the development envelope from numerous locations. It is also likely that these taxa occur in other lakes and salinas throughout the Roe Palaeodrainage system, due to the potential for connectivity and dispersal throughout the area during major flood events. This indicates that minimising impacts on the playa will ensure the persistence of these species. There were no other new, listed or restricted taxa identified during the Study, including within the riparian zone (although several *Tecticornia* taxa remain unverified), reducing the potential risk from the Project. However, limiting the extent and duration of impacts still requires consideration, and appropriate risk assessment utilising a formal framework, as the Project progresses.

Table 5-2: Summary of key findings and preliminary impact assessment for the Study.

Ecological Aspects	Ecological Values				Preliminary Impact Assessment	
	Key Findings	Dominant Taxa	Total Taxa	Significant Taxa	Direct Impacts	Indirect Impacts
Water Quality	<ul style="list-style-type: none"> alkaline (pH>7.5) hyposaline to mesosaline, becoming hypersaline as the hydroperiod progresses 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<p>Infrastructure Layout:</p> <ul style="list-style-type: none"> removal of aquatic and riparian habitat due to clearing for development; surface water runoff, containing potential contaminants (elevated concentrations of salts and metals); and seepage of potential contaminants into groundwater and subsequent discharge to lake and/or riparian zone. <p>Dewatering Discharge:</p> <ul style="list-style-type: none"> change in hydroperiod from temporary to permanent for the duration of the discharge; erosion of lakebed and surrounds; increased salts and formation of a salt crust; and inundation of riparian zone with hypersaline discharge water causing adverse effects 	<p>Infrastructure Layout:</p> <ul style="list-style-type: none"> changes to surface hydrology, influencing water flow and pooling, adversely effecting persistence of aquatic biota and riparian vegetation; and sedimentation from runoff, smothering aquatic biota, riparian vegetation and propagules. <p>Dewatering Discharge:</p> <ul style="list-style-type: none"> reduced emergence and colonisation of aquatic biota due to: <ul style="list-style-type: none"> the presence of a thick salt crust (physical barrier); elevated salinities above potential tolerance limits; elevated concentrations of metals, causing toxicity; reduced recruitment of plants in the riparian zone due to increased salinity; smothering of aquatic biota, vegetation and propagules, due to drawdown and sediment mobilisation; and inundation of surrounding salinas, claypans, tributaries and/or riparian zone with hypersaline discharge water, causing adverse effects.
Sediment Quality	<ul style="list-style-type: none"> acidic to alkaline moderate to high salt loads variable nutrients variable metals, elevated chromium & nickel 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> N/A 		
Benthic Algae	<ul style="list-style-type: none"> Composition comprising diatoms, cyanobacteria and chlorophytes Species typical of saline waters 	<ul style="list-style-type: none"> <i>Hantzschia</i> <i>Navicula</i> <i>Planktolyngbya</i> <i>Planktothrix</i> 	<ul style="list-style-type: none"> 12 	<ul style="list-style-type: none"> None 		
Macrophytes	<ul style="list-style-type: none"> Patchy distribution of species typical of saline waters 	<ul style="list-style-type: none"> <i>Chara</i> sp. <i>Ruppia tuberosa</i> 	<ul style="list-style-type: none"> 2 	<ul style="list-style-type: none"> None 		
Diatoms	<ul style="list-style-type: none"> Composition typical of saline waters, including <i>Amphora</i>, <i>Hantzschia</i> and <i>Navicula</i> 	<ul style="list-style-type: none"> <i>Amphora coffeaeformis</i> <i>Hantzschia</i> sp. aff. <i>baltica</i> <i>Navicula</i> sp. aff. <i>incertata</i> 	<ul style="list-style-type: none"> 24 	<ul style="list-style-type: none"> None 		
Aquatic Invertebrates	<ul style="list-style-type: none"> Composition dominated by crustaceans including ostracods & anostracans Assemblage typical of saline waters 	<ul style="list-style-type: none"> <i>Diacypris phoxe</i> <i>Patcypris outback</i> 	<ul style="list-style-type: none"> 15 	<ul style="list-style-type: none"> <i>Australocypris</i> 'BOS1364' <i>Reticypris</i> 'BOS1088' <i>Reticypris</i> 'BOS1363' 		
Resting Stages	<ul style="list-style-type: none"> Patchy distribution of species typical of saline waters (crustaceans and charophytes) 	<ul style="list-style-type: none"> Ostracoda <i>Nitella</i> sp. <i>Lamprothamnium</i> sp. 	<ul style="list-style-type: none"> 6 	<ul style="list-style-type: none"> None 		
Riparian Vegetation	<ul style="list-style-type: none"> Composition dominated by salt tolerant chenopods Taxa recorded typical of salt lake riparian zone No declared rare or priority flora species recorded No introduced (weeds) species recorded 	<ul style="list-style-type: none"> <i>Tecticornia</i> spp. <i>Frankenia</i> sp. <i>Atriplex nana</i> 	<ul style="list-style-type: none"> 47 	<ul style="list-style-type: none"> None 		

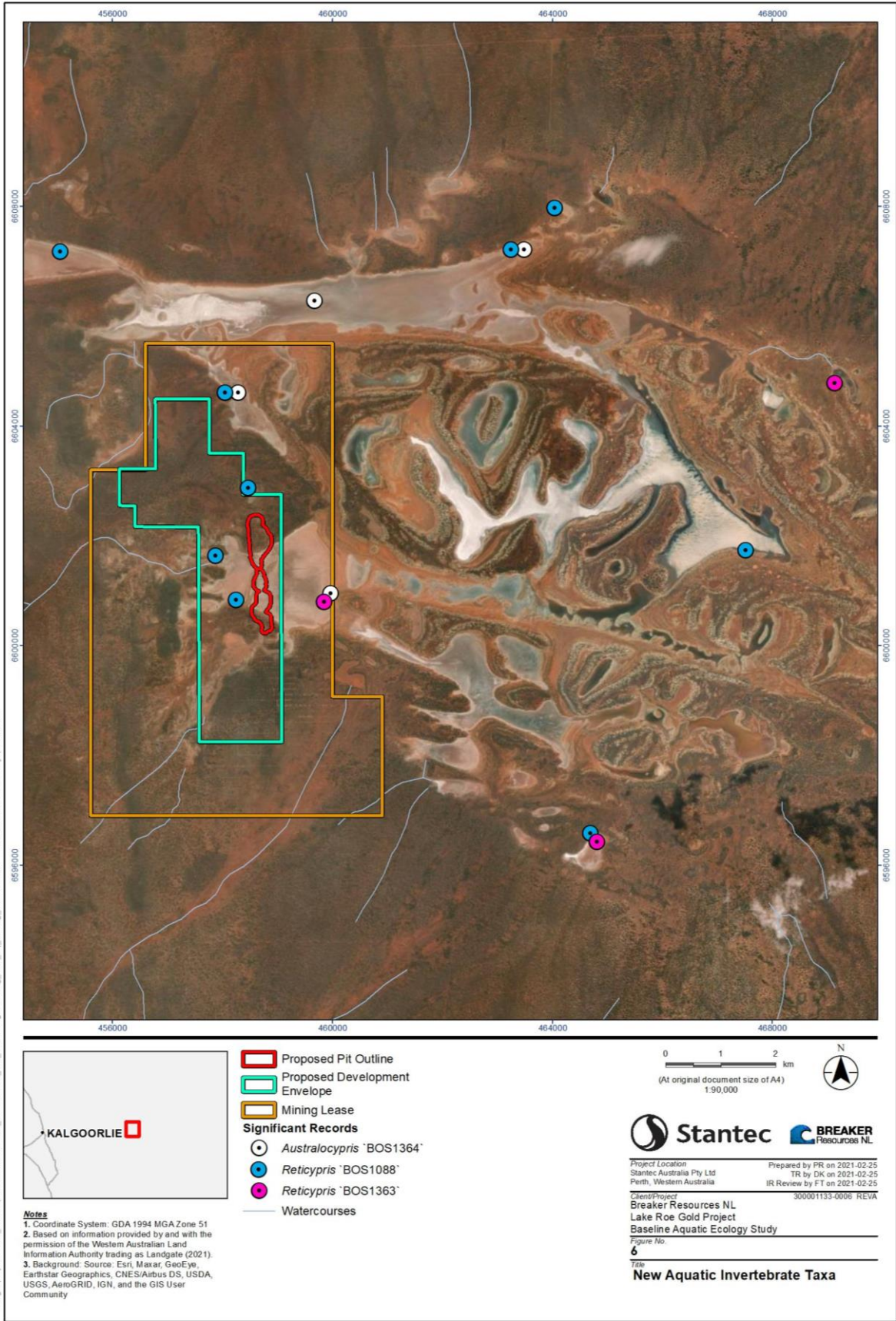


Figure 5-1: Location of new aquatic invertebrates recorded during the Study.

6. Considerations and Recommendations

The Study has outlined key baseline conditions at Lake Roe and surrounds, providing a likely indication of the diversity and productivity that can be expected during flooded conditions. However, these results are considered preliminary, with the following recommendations provided to Breaker for consideration, to reduce potential impacts and maintain ecological integrity.

Project Infrastructure and Layout

- Locate infrastructure in areas that minimise and/or avoid key aquatic and riparian vegetation habitat.
- Ensure the processing plant, tailings facility and waste rock land form are suitably designed to reduce and/or prevent potential contaminant runoff into the lake via surface water and/or groundwater seepage.
- Ensure appropriate hydrological, hydrogeological and engineering studies are undertaken to optimise design and layout of Project infrastructure, minimising hydrological changes to the lake and surrounds.

Dewatering Discharge

- Undertake digital elevation modelling of the playa to determine the most suitable discharge outfall location, which should be on a large, open area of playa and within a deeper part of the basin, following natural drainage patterns, to minimise the backflow of water along tributaries and/or the riparian vegetation zone.
- Undertake a dewatering discharge assessment to understand local holding capacity on the playa, discharge characteristics (water quality, volume and duration), likely discharge extent (in dry/flooded scenarios), water/salt balance estimates (compared to background) and to complete an environmental risk assessment in relation to proposed dewatering discharge.
- Investigate pre-treatment options for the discharge water, including settling ponds, if required, to reduce sedimentation and release of potential contaminants (metals and hydrocarbons) that may cause toxicity to aquatic biota and riparian vegetation.
- Ensure the discharge infrastructure and outfall is appropriately designed, which may include securing the pipeline to the playa, to prevent movement during flooding, with energy dissipation at the outfall, to reduce flow and erosion.
- Consider ceasing discharge to the lake during major flood events, to allow aquatic biota to emerge, persist and reproduce without the influence of hypersaline discharge water during the initial low salinity flooding phase, ensuring replenishment of the egg and seed bank in the sediment.

Monitoring and Management

Following the refinement and establishment of the infrastructure layout and the discharge outfall location for the Project, additional monitoring may be required to inform environmental approvals, as well as to manage and monitor potential impacts as follows:

- Additional, targeted baseline studies of aquatic invertebrates inhabiting the lake during flooding, and surrounding lakes, to provide regional context for the distribution of new taxa, while concurrently collecting flowering *Tecticornia* specimens, to verify unidentified species.
- Update the environmental risk assessment, based on the findings of additional flood studies, and determine additional mitigation measures that may be required to maintain ecological integrity.
- Develop an ecological monitoring program for the lake and surrounds, utilising the results of the baseline studies, assessing abiotic and biotic components annually or biannually, to determine potential Project-related changes over time.

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Appendices



Appendix A Riparian Vegetation Site Photographs

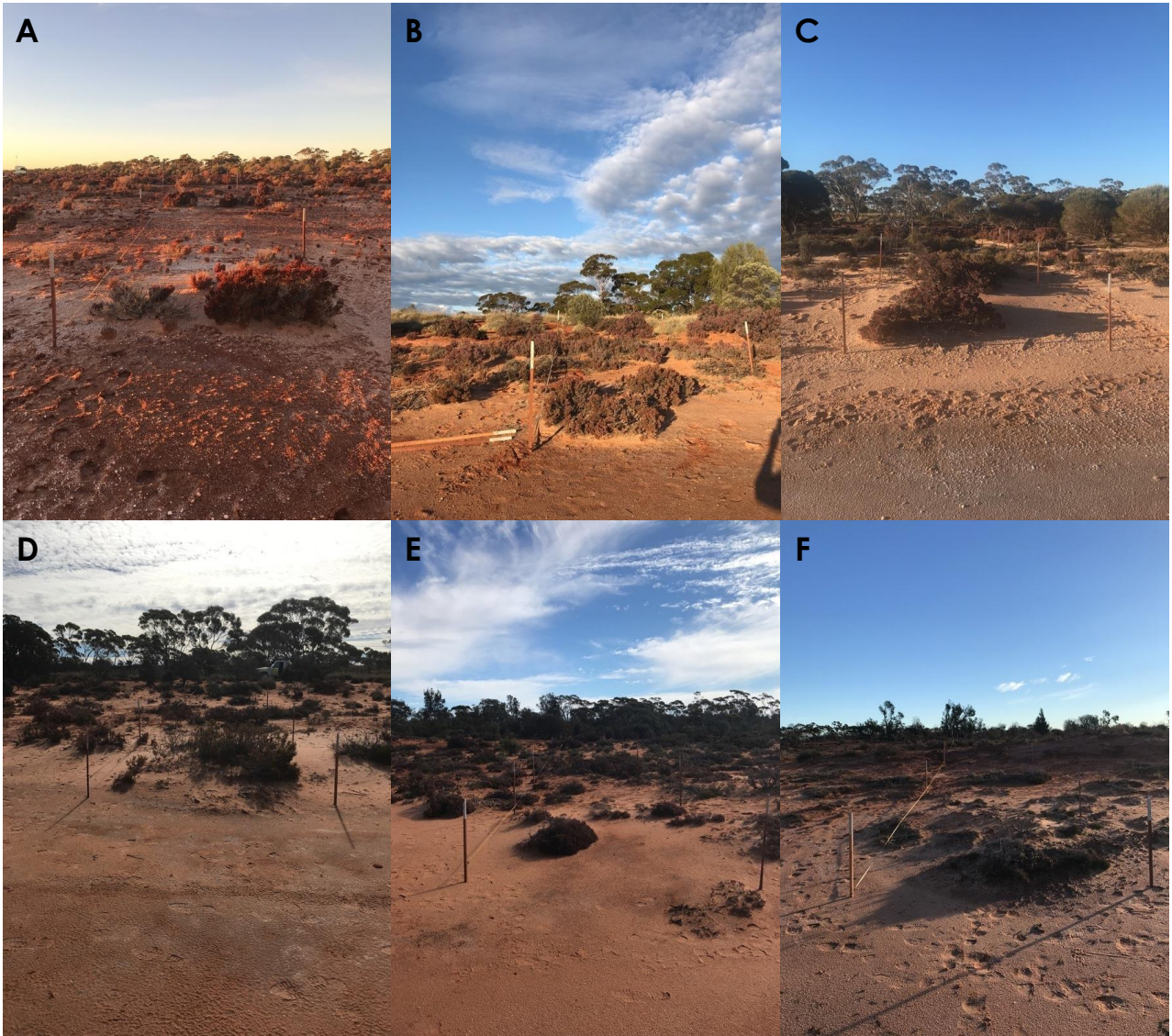


Plate A-1: Riparian vegetation sites assessed during the Study, May 2019. (A) LR01, (B) LR02, (C) LR03, (D) LR04, (E) LR05, and (F) LR06.

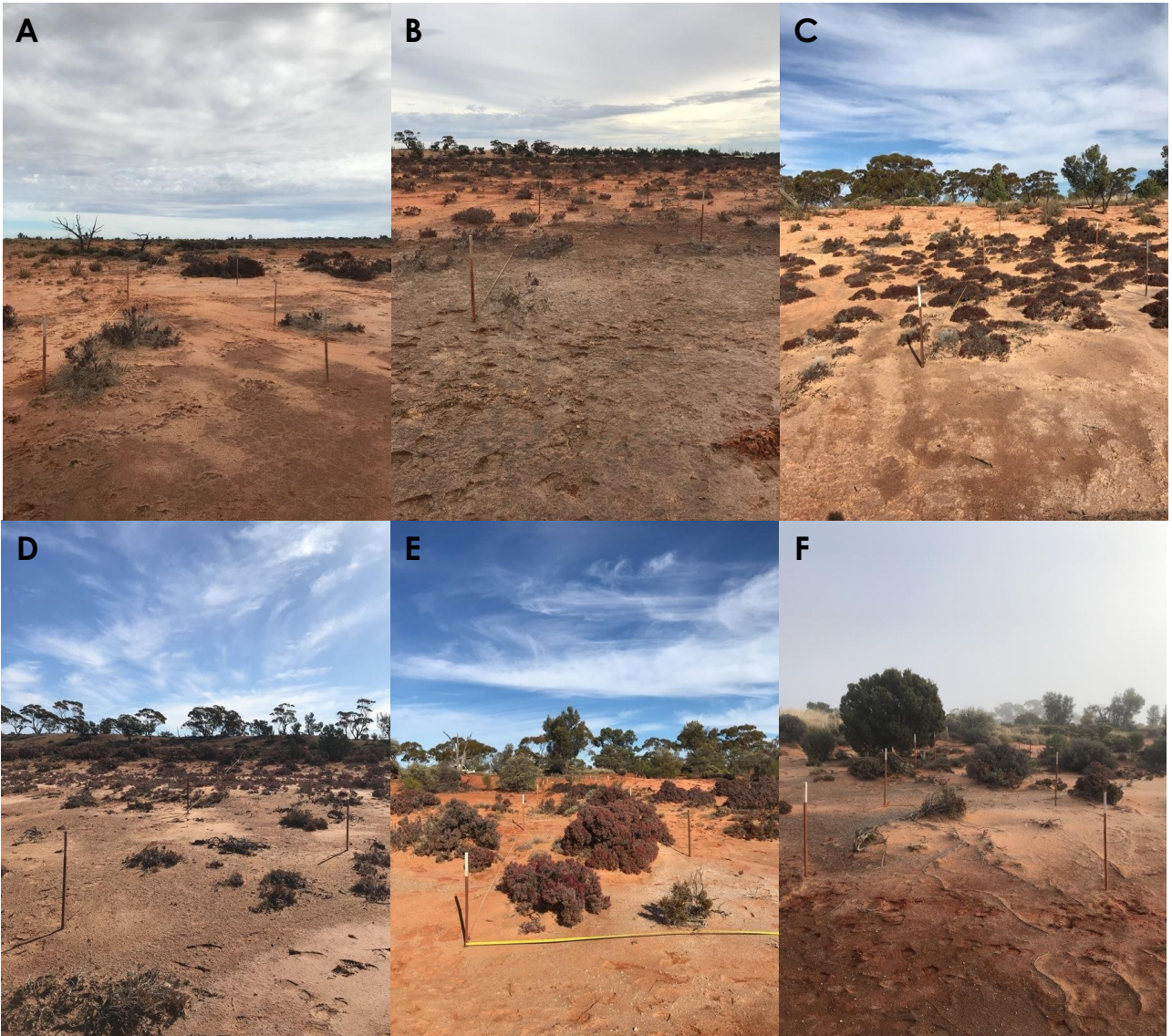


Plate A-2: Riparian vegetation sites assessed during the Study, May 2019. (A) LR07, (B) LR08, (C) LR09, (D) LR10, (E) LR11, (F) LR12.

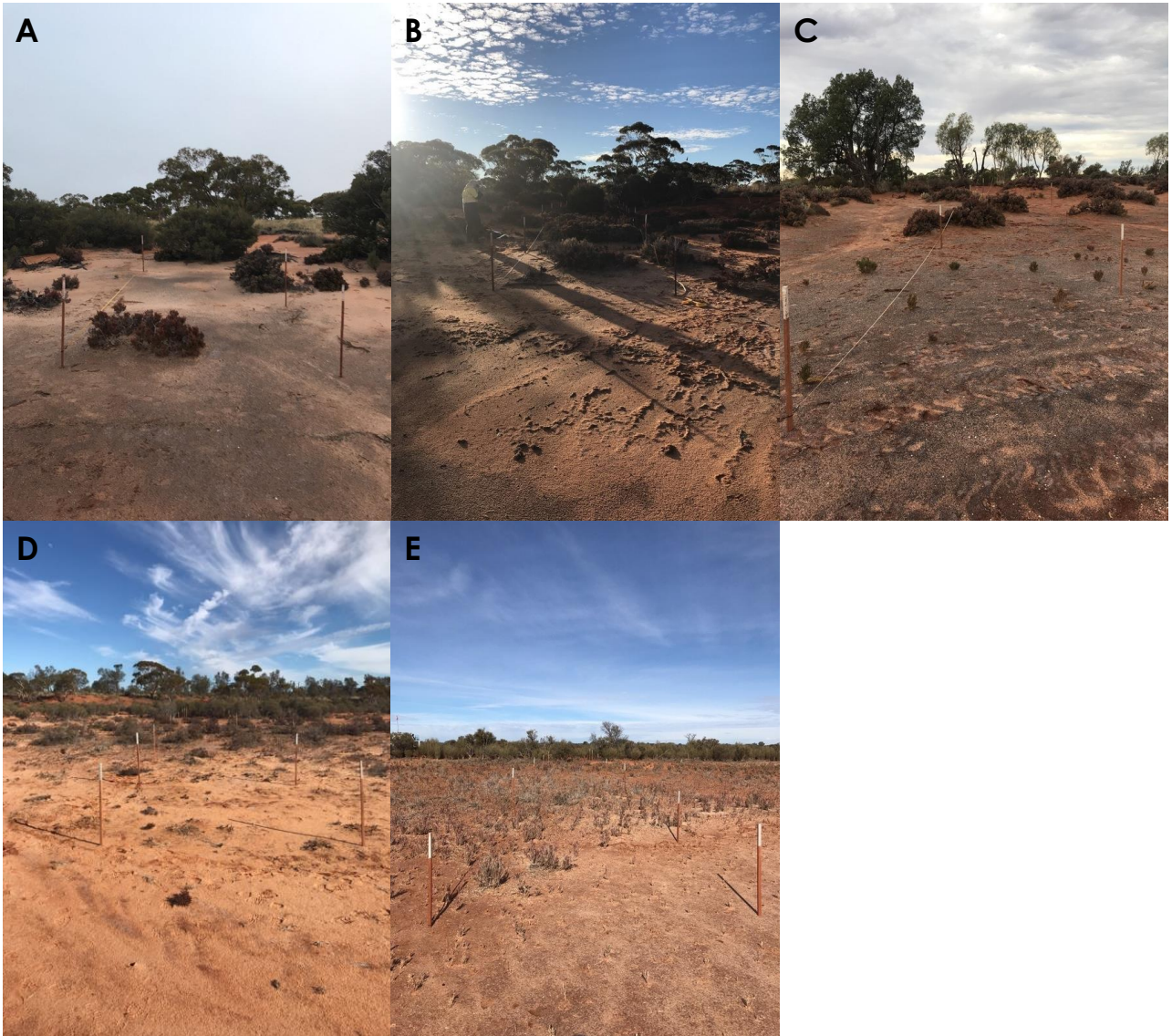


Plate A-3: Riparian vegetation sites assessed during the Study, May 2019. (A) LR13, (B) PW01, (C) PW02, (D) PW03, (E) PW04.

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