Waterbird and aquatic invertebrate survey for the Beyondie Potash Project

Prepared for Kalium Lakes Ltd

March 2017

Final Report

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Final Report

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Date: 31 March 2017

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EXECUTIVE SUMMARY

Kalium Lakes Potash Pty Ltd (Kalium) proposes to develop the Beyondie Potash Project (the Project), located approximately 150 km south-southeast of Newman on the border of the Little Sandy Desert and Gascoyne bioregions. In February 2015, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned to conduct a waterbird and aquatic invertebrate fauna survey for the Project.

The objective of the survey was to define the fauna values of the study area, in particular with respect to conservation significant waterbird species and endemic aquatic invertebrates to inform planning and an environmental impact assessment of the Project.

The study area for the survey covered 27,091 ha and includes large parts of the Beyondie Lakes and Ten Mile Lake. Beyondie Lakes consists of a western freshwater marsh connected to two circular salt playas in line in the east. Ten Mile Lake is a large salt playa located about six kilometres to the south with several claypans located around the lakes that are not hydrologically connected to it. The current project layout also includes Lake Sunshine, situated approximately 20 km north-east of the study area; however, Lake Sunshine was dry during the survey in is therefore not considered here.

A desktop review was conducted prior to field work to identify potential waterbird and aquatic invertebrate fauna of the study area. The field survey was undertaken on 9 February 2015 (Phase 1), 16 April 2015 (Phase 2) and 25 July 2015 (Phase 3). Heavy rainfall flooded the system 10 days prior to Phase 1. Site selection was dependent on the presence of sufficient surface water and therefore only the Beyondie Lakes and an associated claypan were surveyed; Ten Mile Lake did not have sufficient surface water. Five sites were surveyed in Phase 1. Physico-chemical water properties (depth, salinity, conductivity, pH, dissolved oxygen and oxygen reduction potential) were measured in situ. Aquatic invertebrates (zooplankton and benthic macro-invertebrates) were collected using 50 µm and 250 µm nets along a single 50 m transect. Water birds were surveyed by visual sightings and call recognition at the same sites. The same five sites were surveyed with similar methodology in in Phase 2, but only limited water quality parameters were measured (depth, salinity, conductivity) and an additional waterbird site was established. Surveys during Phase 3 did not include waterbirds, but most water quality parameters were measured.

The survey was conducted in accordance with relevant survey guidance that was current at the time of the surveys, including *Guidance Statement no. 56: Terrestrial fauna surveys for environmental impact assessment in Western Australia*, *Technical Guide: Terrestrial vertebrate fauna surveys for environmental impact* assessment and *Guidance Statement no. 20: Sampling of short range endemic invertebrate fauna for environmental impact assessment in Western Australia.* Where appropriate, this report was updated to reflect the new EPA guidance for the environmental factor terrestrial fauna, in particular *Environmental Factor Guideline: Terrestrial fauna*.

Salinity ranged from hypersaline to fresh over the five sites during the three phases (total range 0–156.9 ppt). Salinity increased west to east of the Beyondie Lakes during all surveys, with the marsh sites being freshest and the eastern-most playa site being the most saline. Salinity dramatically dropped from Phase 1 to Phase 2 at all sites, but most notably at the eastern sites which went from hypersaline (up to 156.9 ppt) to hyposaline (up to 9.4 ppt). Salinity increased again in Phase 3 at all sites with mesosalinity (17.8 ppt) representing the highest concentration of salts. The Beyondie Lake marsh and a claypan between Beyondie Lakes and Ten Mile Lake were fresh during the first two phases, but subsaline (0.92 ppt) or hyposaline (7.68 ppt) in Phase 3.

Five waterbird species were identified in the desktop review as potentially occurring in the study area. Of these, four species were of conservation significance, both listed as Migratory under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and/or the *Wildlife Conservation Act 1950* (WC Act): the Garganey (*Anas querquedula*), the Cattle Egret (*Ardea ibis*), the

Great Egret (*Ardea modesta*) and Oriental Plover (*Charadrius veredus*). The Garganey and the Cattle Egret are unlikely to frequent the study area due to the lack of suitable habitat. The desktop review did not identify any invertebrate species with relevance to the aquatic invertebrate survey.

A total of 15 waterbird species were recorded during the field survey including ducks and duck-like birds, swans, small shorebirds, large wading birds, and a gull. Two of these are EPBC Act and WC Act listed Migratory shorebirds, the Oriental Plover and the Common Greenshank (*Tringa nebularia*). Both were recorded in very low numbers during the survey, therefore in accordance with federal guidelines, the study area is not considered to contain nationally or internationally important habitat for Migratory bird species listed under the EPBC Act.

A total of 102 taxa of aquatic invertebrates were collected during the survey, including 68 definite species and 34 unidentified higher taxa ('sp. indet.'). These included two species of water mite, 30 species of crustacean, 36 species of aquatic insects, two species of aquatic snail. The most commonly collected species was the snail *Gabbia* 'beyondie', the copepod *Boeckella triarticulata*, the ostracod *Cyprinotus cingalensis* and the water bug *Anisops nasutus*. None of the species are formally recognised as conservation significant, but several represent new or undescribed species currently only known from the study area, including two snail species in the genera *Gabbia* and *Isidorella*, ostracods in the genera *Limnocythere*, *Mytilocypris* and *Bennelongia*, and a conchostracan in the genus *Ozestheria*. The described species are generally common and/or widespread.

Species richness was greater at the freshwater sites and increased from Phase 1 to Phase 2 and decreased again to Phase 3. The Beyondie Lakes marsh had the highest species richness with at least 61 taxa collected, followed by the single claypan surveyed (44 species). Aquatic macroinvertebrate communities differed distinctly between the three phases. For example, some insect larvae, such as those of mayflies (Ephemeroptera), caddisflies (Trichoptera) and aquatic moths (Lepidoptera) were only collected during Phase 3. Invertebrate community composition was best explained by salinity followed by conductivity (but these water quality parameters are correlated) and least by water depth.

A higher number of waterbirds observed in Phase 2 indicated productivity of the lakes after several months of inundation which has allowed for the growth and development of aquatic macrophytes and invertebrates, both a food source for the birds. All observed waterbirds are common.

In summary, the waterbird fauna of the study area is typical for an arid lake system and included three common Migratory species (two recorded, one identified through the desktop review). Opportunistic nesting was reported by the Black Swan. The diversity of the aquatic invertebrate fauna is comparable to other lake systems that include freshwater to saline habitats. Highest diversity is maintained by the freshwater marsh of the Beyondie Lakes system. There is a clear temporal pattern in the aquatic macroinvertebrate community indicating a complex transition during the filling cycle of the lakes. Poor taxonomic knowledge of some invertebrate groups and lack of regional surveys hindered an interpretation of the endemicity of the local fauna; most significant are the presence of two potentially new and short-range endemic species of snails which have a low capacity for dispersal.

1 INTRODUCTION

In February 2015, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Preston Consulting Pty Ltd (Preston) on behalf of Kalium Lakes Potash Pty Ltd (Kalium) to conduct a waterbird and aquatic invertebrate fauna survey for the Beyondie Potash Project (the Project).

1.1 BACKGROUND

Kalium is seeking to develop the Project as a sub-surface brine deposit to produce 150–250 ktpa Sulphate of Potash (SOP) product via an evaporation and processing operation. A concept study completed in April 2015 assessed the mine life as being 20 years with considerable upside to extend for many decades.

The Project is located approximately 150 km south-southeast of Newman, with access to the Great Northern Highway at Kumarina approximately 65 km to the east (Figure 1-1). The project area spans the border between the Great Sandy Desert and Gascoyne bioregions.

The study area for the survey covered 27,091 ha and features the Beyondie Lakes and Ten Mile Lake (Figure 1-1). Project planning also includes Lake Sunshine approximately 20 km to the north-east of the study area, but this lake is not considered here as it was dry during the field work in the study area.

The Beyondie Lakes consist of a western freshwater marsh connected to two circular salt playas in line in the east. Ten Mile Lake is a large salt playa located about six kilometres to the south. Several claypans are located around the lakes but are not hydrologically connected. The Beyondie Lakes salt playas connect with Ten Mile Lake during extreme inundation events.

Figure 1–1
Location of the Beyondie Potash Project and study area for the waterbird and aquatic invertebrate survey

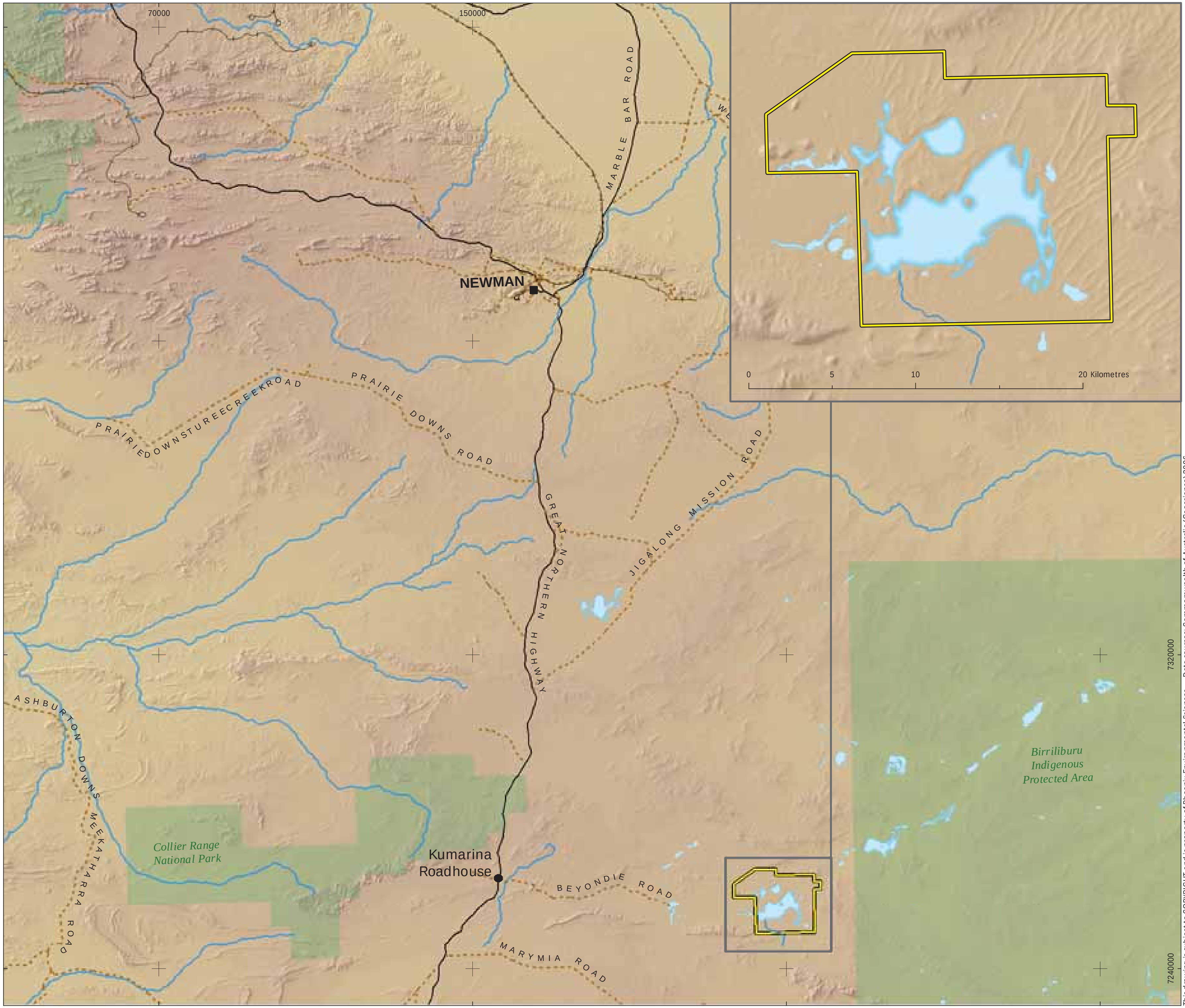
- Study area
- Town
- Railways
- Principal road
- Secondary road
- Minor road
- Major creeks and rivers
- Lakes
- National Parks, Nature Reserves

0 10 20 40 Kilometres
1:1,278,000

Client: Kalium Lakes Potash Pty Ltd
Project: Beyondie Potash Project

Author: G. Bouteloup
Date: 6/07/2015

Coordinate System: GDA 1994 MGA Zone 51
Projection: Transverse Mercator
Datum: GDA 1994



PHOENIX ENVIRONMENTAL SCIENCES

1.2 SURVEY OBJECTIVES AND SCOPE OF WORKS

The objective of the waterbird and aquatic invertebrate survey was to define the fauna values of the study area which will be used to inform planning and an environmental impact assessment of the Project. The scope of work was as follows:

- conduct a desktop review of available technical reports, relevant databases and spatial data to assess the potential for presence of conservation significant aquatic invertebrate and waterbird species and habitats in the study area
- conduct a baseline aquatic invertebrate fauna survey and waterbird census
- undertake data analyses, sample processing and species identifications for samples collected during the field surveys
- undertake water quality analyses
- prepare maps showing significant species records and habitats in the study area
- prepare a comprehensive technical report and supporting digital data.

The survey was conducted in accordance with relevant Environmental Protection Authority (EPA) and other survey guidance that was current at the time of the surveys, including:

- *Position Statement no. 3: Terrestrial biological surveys as an element of biodiversity protection* (EPA 2002)
- *Guidance Statement no. 56: Terrestrial fauna surveys for environmental impact assessment in Western Australia*, *Technical Guide* (EPA 2004) which is now *Technical Guidance: Terrestrial fauna surveys* (EPA 2016h)
- *Guidance Statement no. 20: Sampling of short range endemic invertebrate fauna for environmental impact assessment in Western Australia* (EPA 2009), which is now *Technical Guidance: Sampling of short-range endemic invertebrate fauna* (EPA 2016g)
- *Technical Guide: Terrestrial vertebrate fauna surveys for environmental impact assessment* (EPA & DEC 2010), which is now *Technical Guidance: Sampling methods for terrestrial vertebrate fauna* (EPA 2016f)
- Western Australia AUSRIVAS sampling and processing manual (Department of Water 2009).

Where appropriate, this report also takes into account new EPA guidance released subsequent to the surveys, including:

- *Statement of environmental principles, factors and objectives* (EPA 2016e)
- *Environmental Factor Guideline: Terrestrial environmental quality* (EPA 2016a)
- *Environmental Factor Guideline: Terrestrial fauna* (EPA 2016b)
- *Environmental Factor Guideline: Hydrological processes* (EPA 2016c).
- *Environmental Factor Guideline: Inland waters environmental quality* (EPA 2016d).

2 LEGISLATIVE CONTEXT

The protection of fauna in Western Australia is principally governed by three acts:

- Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- *Wildlife Conservation Act 1950* (WC Act)
- *Environmental Protection Act 1986* (EP Act).

2.1 COMMONWEALTH

Under the EPBC Act, actions that have, or are likely to have, a significant impact on a matter of national environmental significance (NES), require approval from the Australian Government Minister for the Environment. The EPBC Act provides for the listing of Threatened native fauna as matters of NES.

Conservation categories applicable to Threatened Fauna under the EPBC Act are as follows:

- Extinct (EX)[1] – there is no reasonable doubt that the last individual has died
- Extinct in the Wild (EW) – taxa known to survive only in captivity
- Critically Endangered (CR) – taxa facing an extremely high risk of extinction in the wild in the immediate future
- Endangered (EN) – taxa facing a very high risk of extinction in the wild in the near future
- Vulnerable (VU) – taxa facing a high risk of extinction in the wild in the medium-term
- Conservation Dependent[1] – taxa whose survival depends upon ongoing conservation measures; without these measures, a conservation dependent taxon would be classified as Vulnerable or more severely threatened.

The EPBC Act is also the enabling legislation for protection of Migratory species under a number of international agreements:

- Japan-Australia Migratory Bird Agreement (JAMBA)
- China-Australia Migratory Bird Agreement (CAMBA)
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn)
- Agreement between the Government of Australia and the Government of the Republic of Korea on the Protection of Migratory Birds (ROKAMBA).

Under the EPBC Act, and in accordance with EPBC Act Policy Statement 1.1 *Significant impact guidelines – matters of national environmental significance* (Department of the Environment 2013), ‘important habitat’ is a key concept for Migratory species. Important habitats in Australia for Migratory shorebirds are defined by the following criteria (Commonwealth of Australia 2015):

- wetland habitat is considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird, or a total abundance of at least 20,000 waterbirds

[1] Species listed as Extinct and Conservation Dependent are not matters of NES and therefore do not trigger the EPBC Act.

- habitat is considered nationally important if it regularly supports 0.1% of the flyway population of a single species of Migratory shorebird, 2,000 Migratory shorebirds, or 15 Migratory shorebird species.

2.2 STATE

In WA, the WC Act provides for the listing of Specially Protected Fauna species which are under identifiable threat of extinction. Under current classifications, protected fauna are assigned to one of seven categories under the WC Act (Western Australian Government 2017):

- Schedule 1 – fauna that is rare or is likely to become extinct as Critically Endangered (CR) fauna
- Schedule 2 – fauna that is rare or is likely to become extinct as Endangered (EN) fauna
- Schedule 3 – fauna that is rare or is likely to become extinct as Vulnerable (VU) fauna
- Schedule 4 – fauna presumed to be extinct (EX)
- Schedule 5 – Migratory birds protected under an international agreement (Mig.)
- Schedule 6 – fauna that is of special conservation need as conservation dependent (CD) fauna
- Schedule 7 – other specially protected (SP) fauna.

Assessments for listing are based on the International Union for Conservation of Nature (IUCN) threat categories.

The Department of Parks and Wildlife (DPaW) administers the WC Act and maintains a non-statutory list of Priority Fauna species (updated annually). Priority species are still considered to be of conservation significance – that is they may be rare or threatened – but cannot be considered for listing under the WC Act until there is adequate understanding of their threat levels. Species on the Priority Fauna lists are assigned to one of four Priority (P) categories, P1 (highest) – P4 (lowest), based on level of knowledge/concern.

Any activities that are deemed to have a significant impact on listed fauna species can trigger referral to the Environmental Protection Authority (EPA) for assessment under the EP Act.

Fauna species may be significant for a range of reasons other than those listed as Threatened or Priority Fauna. Significant fauna may include short-range endemic species, species that have declining populations or declining distributions, species at the extremes of their range, or isolated outlying populations, or species which may be undescribed (EPA 2016b).

3 EXISTING ENVIRONMENT

3.1 INTERIM BIOGEOGRAPHIC REGIONALISATION OF AUSTRALIA

The Interim Biogeographic Regionalisation of Australia (IBRA) defines 'bioregions' as large land areas characterised by broad, landscape-scale natural features and environmental processes that influence the functions of entire ecosystems (Department of the Environment and Energy 2016; Thackway & Cresswell 1995). They categorise the large-scale geophysical patterns that occur across the Australian continent that are linked to fauna and flora assemblages and processes at the ecosystem scale (Thackway & Cresswell 1995).

Western Australia contains 26 IBRA bioregions and 53 subregions. The study area is situated on the border to two bioregions; the Gascoyne bioregion and Little Sandy Desert bioregion (Figure 3-1). The study area is situated at the junction of the Augustus subregion (GAS3) of the Gascoyne bioregion and Trainor subregion (LSD2) of the Little Sandy Desert bioregion (Figure 3-1).

The Augustus subregion (GAS3) is characterised by (Desmond *et al.* 2001):

- low Proterozoic sedimentary and granite ranges divided by flat broad valleys
- mulga woodland with *Triodia* on shallow stony loams on rises with mulga parkland on shallow earthy loams over hardpan on the plains
- extensive areas of alluvial deposits
- calcrete aquifers of the Carnegie drainage system
- desert climate with bimodal rainfall.

The Trainor subregion (LSD2) is characterised by (Cowan & Kendrick 2001):

- red centre desert on Neoproterozoic sedimentary basement (Officer Basin)
- red Quaternary dune fields with abrupt Proterozoic sandstone ranges of Bangemall Basin
- shrub steppe of acacias, *Aluta maisonneuvei* and grevilleas over *Triodia schinzii* on sandy surfaces
- sparse shrub-steppe over *Triodia basedowii* on stony hills
- eucalypt and coolabah communities and bunch grasses on alluvial deposits and drainage lines associated with ranges
- arid climate with episodic summer rainfall.

Figure 3–1
Location of the Beyondie Potash Project in relation to IBRA regions and subregions

Study area
Town
Railways
Principal road
Secondary road
Minor road
Lakes
Major creeks and rivers

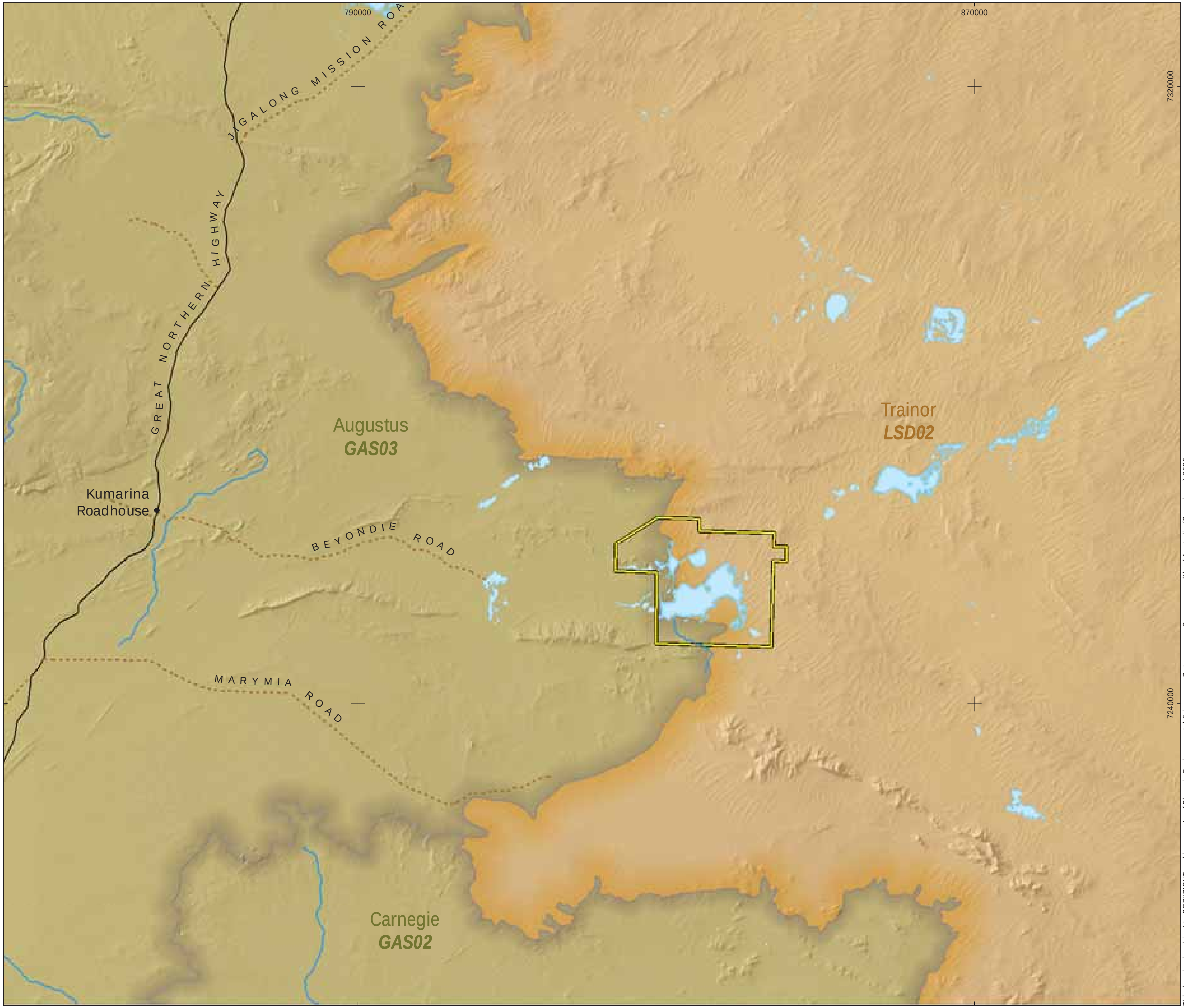
IBRA regions

Gascoyne
Little Sandy Desert

0 5 10 20 Kilometres
1:650,000

Client: Kalium Lakes Potash Pty Ltd
Project: Beyondie Potash Project
Author: G. Bouteloup
Date: 6/07/2015
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

PHOENIX ENVIRONMENTAL SCIENCES



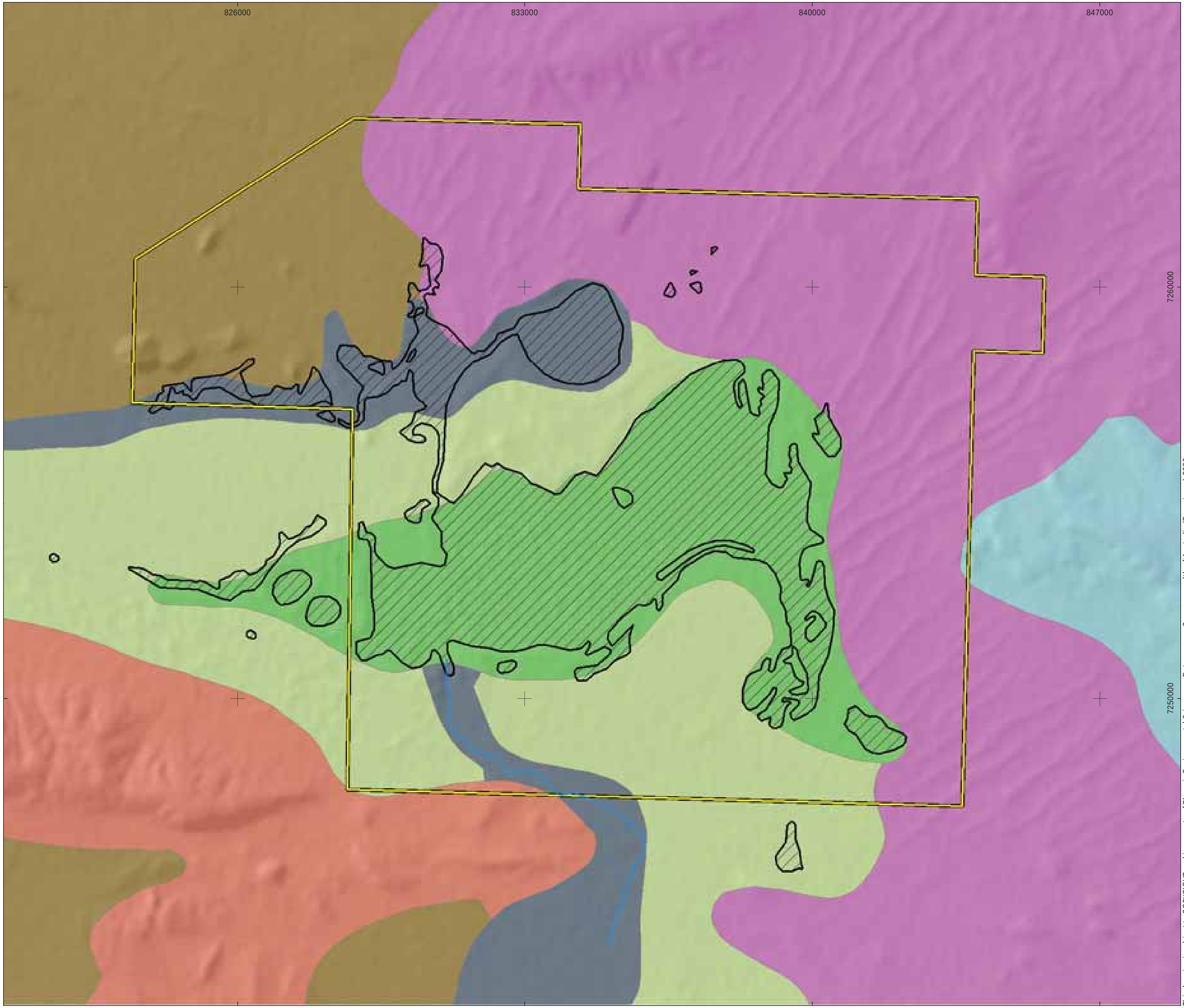
3.2 Land systems

The Department of Agriculture and Food (DAFWA) has mapped the land systems in the Little Sandy Desert and Gascoyne bioregions (DAFWA 2014). The study area covers seven land systems (Table 3-1; Figure 3-2). Beyondie Lakes are primarily part of the land system BB9 which is associated with river systems allied with calcrete outcrops. Ten Mile Lake approximately 6 km to the south is contained within a different land system, SV5 which is associated with saline systems (Figure 3-2). The surrounding land systems comprise of sand plains/dunes, claypans, low stony hills, sandstone hills, and rangelands.

Table 3-1 Land systems of the study area

Land system	Description	Total area (ha)	% of study area
AB14	Upland sand plains with occasional dunes and minor inclusions of associated plains units	5,169.28	19.7%
AB44	Plains with a variable, but usually high, proportion of longitudinal sand dunes, and with some clay pans; scattered sandstone hills and laterite residuals are fairly common	9,209.96	35.1%
BB9	Narrow plain associated with the major river systems, usually occurring upstream of unit Oc47 and characterized by frequent outcrops of calcrete (kunkar)	2,260.32	8.6%
Fa8	Steep ranges comprising fine-grained sedimentary rocks along with basic dykes; extensive portions of this unit are without soil cover	66.85	0.3%
Fa9	Stony hills with some steeply dissected pediments on fine-grained sedimentary rocks and basic dykes; some small valley plains may occur	16.34	0.1%
Oc49	Partially dissected pediments with some low stony hills on fine-grained sedimentary rocks and basic dykes, frequently flanking areas of unit Fa8	2,989.79	11.4%
SV5	Saline soils associated with salt lakes; sand and kopi gypsum dunes, and intervening plains	6508.57	24.8%
Total		**26,221.11**	**100.0%**

Figure 3–2 Land systems of the study area



Study area

Major creeks and rivers

Lakes

Land systems

- AB14
- AB44
- BB9
- Fa8
- Fa9
- Oc49
- SV5

0 1 2 4 Kilometres

1:122,000

Client: Kalium Lakes Potash Pty Ltd
Project: Beyondie Potash Project

Author: G. Bouteloup
Date: 6/07/2015

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

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3.3 Hydrology and geomorphology

Ten Mile Lake is a large salt playa and forms the western end of a chain of ephemeral salt lakes which extend eastwards and include Lake Sunshine, Yanneri Lake and Terminal Lake. This suite of lakes do not connect above ground but they form part of the Ilgari palaeoriver which is a remnant of an extensive river system from the tertiary period (Gentilli 1979). The Ilgari palaeoriver is a tributary of the Disappointment palaeoriver, that includes Lake Disappointment (Beard 2005). The catchment for Lake Disappointment is largely the Little Sandy Desert bioregion (Beard 2005). These salt lakes are dry most of the year but become seasonally inundated during the wet season if there is sufficient rainfall.

The geology of the Beyondie Lakes system approximately 6 km to the north of Ten Mile Lake is different to the other salt lakes in the Ilgari palaeoriver, as it is generally associated with calcrete sediments, whereas the salt lakes to the east are associated with saline soils and sand and kopi gypsum dunes (Figure 3-2). The Beyondie Lakes are a suite of wetlands consisting of a freshwater marsh area to the west, two circular salt playas and interconnecting channels.

3.4 Climate and weather

The Gascoyne bioregion has an arid climate with and summer rainfall in the east. Spatially averaged median (1890–2005) rainfall is 202 mm (DEWHA 2008a). The climate of the Little Sandy Desert bioregion is also arid with summer-dominant rainfall. Spatially averaged median (1890–2005) rainfall is 178 mm (DEWHA 2008b). The climate of south-western Little Sandy Desert has also been described as desert tropical with predominant summer rainfall (van Leeuwen 2002).

The nearest Bureau of Meteorology (BoM) weather station with long-term data averages is Three Rivers (No. 7080, Latitude: 25.13°S Longitude: 119.15°E), approximately 120 km to the south-west of the study area. Three Rivers records the highest maximum mean monthly temperature (39.3°C) in January and the lowest maximum mean annual temperature (22.9°C) in June. The lowest mean minimum temperature is recorded in July (6.2°C) and the highest in January (24.9°C). Average annual rainfall is 238.4 mm with January, February and March recording the highest monthly averages (34.9, 43.5, and 36.1 mm respectively) (Figure 3-3).

The nearest BoM weather station with current daily observations is Newman Airport (No. 7176, Latitude: 24.42°S Longitude: 119.80°E), approximately 150 km to the north-northwest of the study area. Newman records the highest maximum mean monthly temperature (39.2°C) in January and the lowest maximum mean annual temperature (21.0°C) in July. The lowest mean minimum temperature is recorded in July (4.8°C) and the highest in January (24.1°C). Average annual rainfall is 317.1 mm with January, February and March recording the highest monthly averages (65.3, 73.7, and 39.2 mm respectively) (Figure 3-4).

Pan evaporation for the south-western Little Sandy Desert bioregion ranges from 16.1 mm/day in January to 4.5 mm/day in June at an annual daily average of 10.2 mm (van Leeuwen 2002).

During the aquatic fauna surveys (February to July 2015) minimum and maximum mean temperatures recorded at Newman Airport were below averages recorded for previous years (Figure 3-4). Rainfall considerably higher than average at Newman were recorded in March and May facilitating multiple phases of surveys (Figure 3-4). Beyondie Lakes catchment also received a large volume of rainfall throughout March and into early April 2015, evidenced by high water levels into August 2015. Overall, rainfall in the region in the first half of 2015 was very high. For example, Newman received a total of 427 mm of rain between January and July 2015, which is more than the mean annual rainfall (323.6 mm) between 1971 and 2015 (BoM 2016).

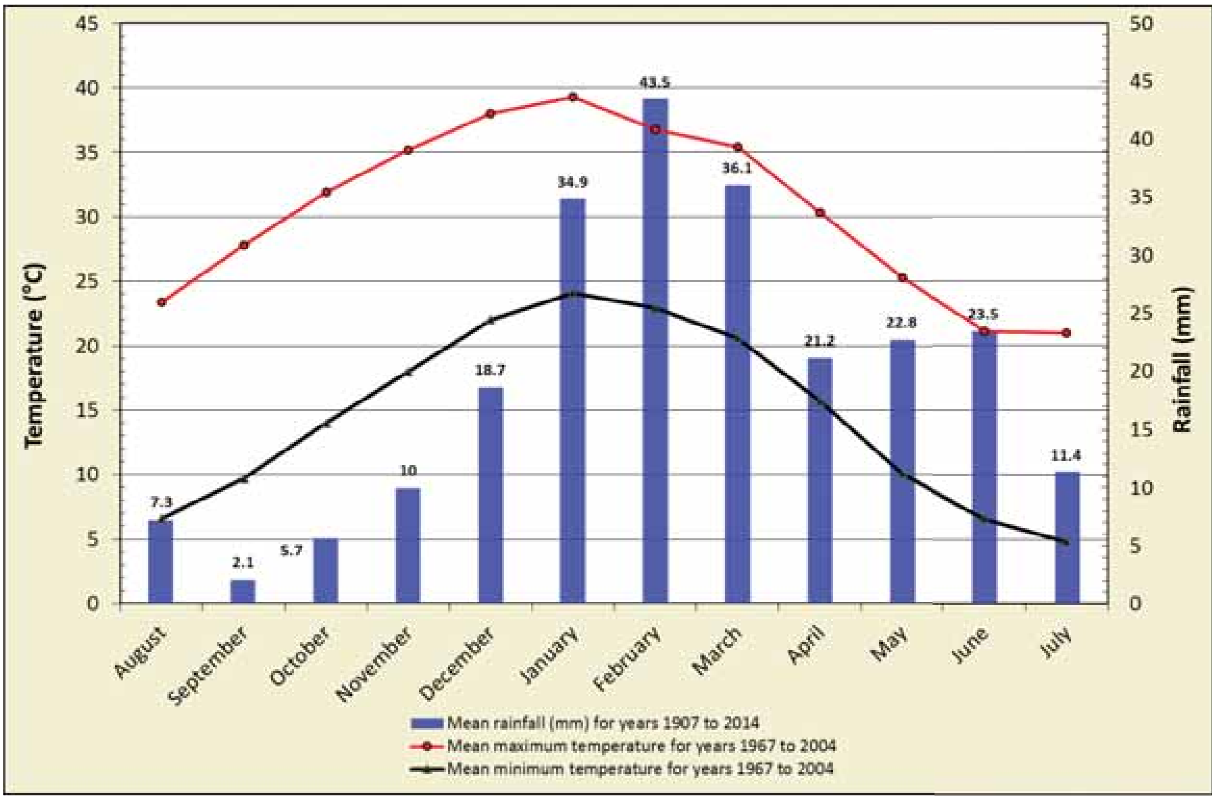

Figure 3-3 Average monthly temperatures and rainfall for Three Rivers (BoM 2016)

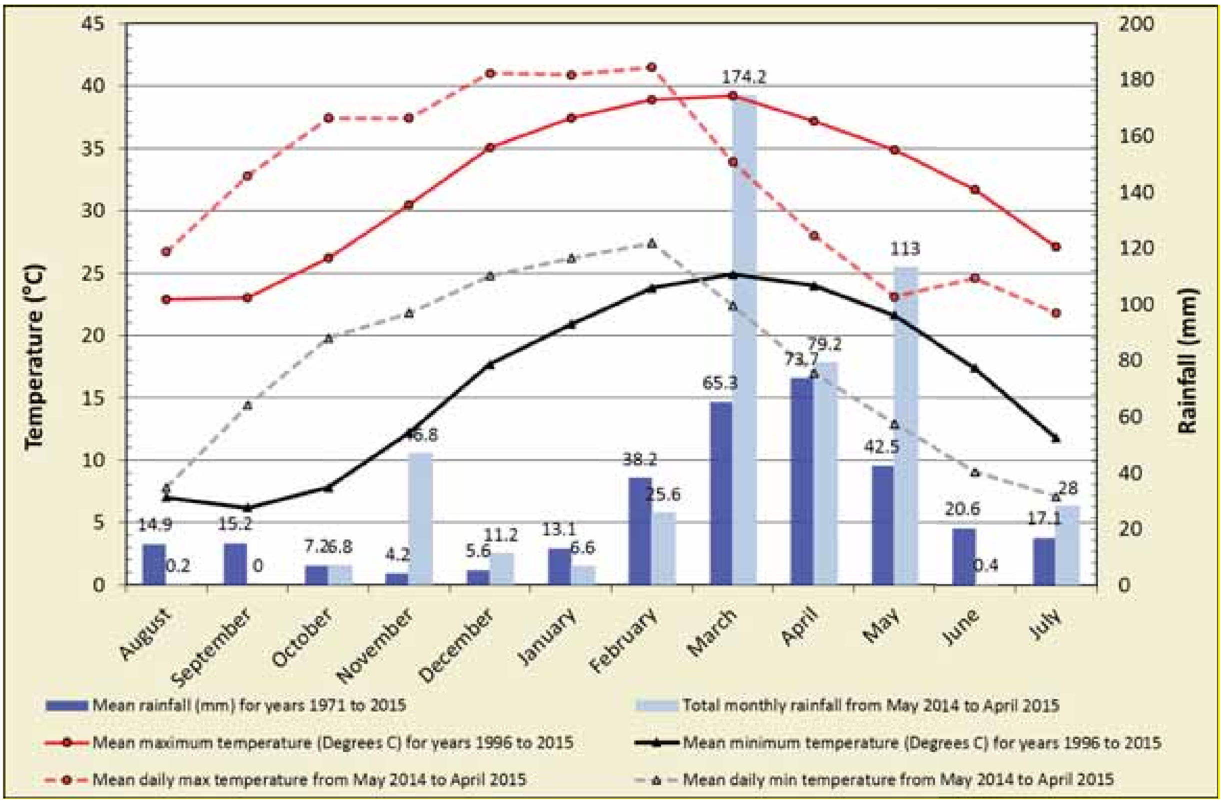

Figure 3-4 Average monthly temperatures and rainfall for Newman Airport (BoM 2016)

3.5 LAND USE

Overall, only 2% of the Little Sandy Desert bioregion is grazed (DEWHA 2008b). In contrast, approximately 80% of the Gascoyne bioregion was grazed between 1992 and 2001 (DEWHA 2008a); however, the study area only partly falls into the western-most part of the latter bioregion and which is therefore much less representative for the Beyondie and Ten Mile Lakes.

At a more local scale, little information is available in relation to land use near the study area. It was covered by a biological study of the south-western Little Sandy Desert (van Leeuwen 2002). This area was principally Unallocated Crown Land with one unvested Crown Reserve (No. 1 Vermin Proof Fence). Three pastoral leases abut the south-western Little Sandy Desert, of which the north-eastern part of Marymia intersects the study area (van Leeuwen 2002). Apart from camel harvesting operations and little four-wheel-drive tourism, the area has been described as 'economically inconsequential' (van Leeuwen 2002).

3.5.1 Threatening processes

Due to the limited land use in the study area, threatening processes that usually apply to Western Australian inland lakes, in particular salt lakes, appear currently of little consequence for the Beyondie and Ten Mile Lakes.

At other WA salt lakes, threatening processes include feral animals, livestock grazing, introduced weed species, recreation, groundwater drawdown, and dewatering are the main threats (Cowan 2001). Mining activities including pit excavation, exploration, construction of infrastructure, and mine dewatering discharge are impacts to some salt lakes in WA. Several WA salt lakes are currently receiving or have previously received mine dewatering discharge (Outback Ecology 2009). Salt lakes are seen as a suitable place to store mine dewater as they are expansive and low lying, enabling relatively quick evaporation to take place (Gregory 2007). Salt lakes are often perceived as ecosystems with little ecological value as they are known to support a low diversity and richness of native flora and fauna than other habitats (Cale *et al.* 2004; Geddes *et al.* 1981; Jones *et al.* 2009a); however, the communities they support are distinct (Jones *et al.* 2009b) and the species are often endemic (De Deckker 1983; Phoenix 2014c).

3.5.2 Reserves

Collier Range National Park 60 km to the west was established in 1978. The park is currently little managed with annual wild dog baiting, but otherwise only occasional visits by Karratha staff (Desmond *et al.* 2001). Giles Nature Reserve covering the south-western parts of the Little Sandy Desert was proposed in 2002 (van Leeuwen 2002). This proposed A-class reserve does not cover the Beyondie and Ten Mile Lakes; however, is likely to provide refugial habitats for local and regional fauna and flora. The Birriliburu Indigenous Protected Area approximately 10 km to the east of the study area covers 6.6 mio ha, including the sandstone Carnarvon Ranges (Anonymous 2013).

3.6 BIOLOGICAL CONTEXT

The interior of mid and south-western Australia contains a vast network of ephemeral salt lakes. These were formed by the fragmentation of palaeodrainage basins that existed prior to the aridification of the continent starting in the Miocene (van de Graaff *et al.* 1977). Proposed ancient basins remained well preserved because of tectonic stability and slow erosion and sedimentation (van de Graaff *et al.* 1977).

Salt lakes host a diverse array of fauna and flora, despite representing one of the most hostile ecosystems on earth due to high incident daily temperatures and high salt concentrations in their soils and their ephemeral water bodies. Colonial waterbird concentrations on freshly filled playas can number hundreds of thousands (Johnstone & Storr 1998) based on significant short-term lake productivity. Primary production of salt lakes is generally based on microbial mats of cyanobacteria and diatoms (Bauld 1981). A productive lake may have a limited range of halobiontic crustaceans, typically one species of brine shrimp (*Parartemia*), ostracods and copepods (Curtin University of Technology 1999). Shield shrimps (*Triops australiensis*) and molluscs, e.g. in the genus *Coxiella* (Pomatiopsidae) (MacPherson 1957), may also contribute to the aquatic food chain.

Due to the sporadic nature of rainfall in arid Western Australia, salt lakes generally support biota which have adapted to ephemeral conditions by producing drought-resistant dormant life stages. Invertebrates may produce cysts (eggs) and aquatic macrophytes will produce zygospores which may persist in dry conditions for many years (Jones *et al.* 2009a). These biota are "programmed" to react to inundation by fast maturation and reproduction. Some invertebrate species can reach maturity in as little as four days and complete their life cycle in a few weeks (Timms 2012). Claypans are particularly unique as the turbidity (produced by wind suspending clay sediments) protects fauna from predation (Jones *et al.* 2009b).

Fauna surveys of salt lakes in Western Australia have traditionally focused on the aquatic biota and these studies showed some degree of endemicity and demonstrated clear links between water quality and the composition of benthic communities. (Pinder *et al.* 2002). Halotolerant species are those which are able to survive high salinities (Pinder *et al.* 2002). These species may either have wide environmental tolerances, such as the dipteran larvae *Tanytarsus barbitarsus*, which is known to tolerate fresh to hypersaline conditions (Pinder *et al.* 2002), or species which are saline specialists such as brine shrimp (*Parartemia* and *Artemia*) which only live in saline conditions (Pinder *et al.* 2002; Timms *et al.* 2009). Fauna which only live in saline water are known as halophiles.

3.6.1 Waterbirds

Ephemeral wetlands of the Australian arid centre can temporarily host a large number of waterbirds, including shorebirds (Johnstone & Storr 1998; Kingsford 1995). The largest of Australia's inland salt lakes, Lake Eyre in South Australia (843,000 ha) has been found to support more than 300,000 waterbirds (Kingsford 1995). As flood events are unpredictable, many waterbirds in Australia move nomadically in response to rainfall event around the country. They may accumulate on large wetlands that may retain water for a few years, but some species may also breed on thousands of smaller, more temporary wetlands (Lawler & Briggs 1991).

Six wetland characteristics—salinity, emergent vegetation, water depth, pH, phosphorus level and wetland size—determined the species composition of a total of 61 waterbird species on 95 wetlands in south-western Australia; however, more species were associated with salinity and vegetation than with other wetland characteristics (Halse *et al.* 1993). Overall, there were more positive associations with brackish than with fresh or saline wetlands, and few species occurred in hypersaline wetlands (Halse *et al.* 1993). In relation to vegetation, most species were associated with trees or shrubs and sedges and few species were recorded on completely open wetlands or those with only samphire.

In the south-eastern arid interior of Western Australia, 35 species of waterfowl were recorded from 23 wetlands following particularly wet first half of 1992; 17 of these species were found breeding (Chapman & Lane 1997). The majority of these wetlands were saline with individual wetlands varying from brackish to hypersaline over relatively short periods that markedly affected use by waterfowl. (Chapman & Lane 1997). The study also showed that some freshwater wetlands supported more avifauna species (but not individuals) than saline wetlands, but the saline wetlands supported greater numbers of certain species (Kingsford & Porter 1994).

In addition, it appears that breeding activity on arid, intermittent wetlands is primarily governed by nutrient availability, in particular aquatic invertebrates including zooplankton, rather than photoperiod or water level; the number of breeding species per wetland is also influenced by depth and wetland bathymetry (Chapman & Lane 1997; Kingford *et al.* 1999; Storey *et al.* 1993).

3.6.2 Aquatic macro-invertebrates and zooplankton

Aquatic macro-invertebrates, in contrast to zooplankton, can be seen with the naked eye. Insects (water beetles, bugs, fly and mosquito larvae, and dragonfly larvae), annelids (oligochaetes and leeches), Acarina (including water mites), Gastropoda (snails) and Crustacea (shield shrimp, fairy shrimp and slaters) are common macro-invertebrate taxa that inhabit aquatic environments. Some aquatic macro-invertebrates such as dragonflies, damselflies, midges and mosquitos only have an aquatic-dependent larval life stage, while others must spend their whole life in water or in wet sediments (Williams 1981), but may have adaptations to survive in ephemeral wetlands such as drought resistant cysts or burrowing behaviours (De Deckker 1983). Aquatic macro-invertebrates are often associated with sheltered habitats and most are collected from the sediment, and around aquatic vegetation and organic debris (Jones *et al.* 2009b).

Zooplankton is composed of aquatic invertebrates which require microscopic aids to be seen. Most types of zooplankton are crustaceans from the orders Copepoda (copepods), Ostracoda (seed shrimps) and Cladocera (water fleas) (Williams 1981). Zooplankton are an important food source for larger invertebrates, fish, amphibians and waterbirds (Geering *et al.* 2007; Jones *et al.* 2009b; Moss 1998).

4 METHODS

4.1 DESKTOP REVIEW

The aquatic ecology of many wetlands in the Gascoyne and Little Sandy Desert bioregions is poorly studied as their ephemeral nature provides limited opportunities for survey. They require large amounts of precipitation in a short amount of time (days) to become inundated. Unpredictable rainfall events large enough to cause inundation of a suitable duration to allow for forward planning for an aquatic biota survey are uncommon and have resulted in most surveys using alternative methods, for example hatching experiments of resting stages.

4.1.1 Database searches and literature review

Database searches and literature reviews of relevant publications were undertaken to compile a list of conservation significant aquatic invertebrates and waterbirds that may occur within the study area based on the proximity of previous records.

The following database searches were undertaken for a quadrat of approximate 100 km length with the diagonal coordinates of -24.31222°S, 119.78444°E (NW point) and -25.23472°S, 120.7808°E (SE point):

- EPBC Act Protected Matters Search Tool (Department of the Environment 2015)
- DPaW/WA Museum NatureMap (DPaW 2015)
- DPaW Threatened Fauna database (DPaW 2014)
- Birdlife Australia Birdata database (Birdlife Australia 2005–2007).

In addition, the WA Museum Crustacea and Mollusca databases were undertaken for a quadrat of approximate 200 km length, consistent with the nominal range of short-range endemic invertebrates (EPA 2016g), with the diagonal coordinates of -23.86°S, 119.30°E (NW point) and -25.67°S, 121.27°E (SE point).

A number of aquatic biota surveys of salt lakes were consulted to provide context of biodiversity for large inland salt lakes in Western Australia, including Lake Disappointment, Lake Way, Lake Maitland, Lake Carey, Lake Cowan and Lake Yindarlgooda (Table 4-1). It is recognised that many of these lakes are in considerable distance from the study area; however, any salt lake in the state can provide background data to interpret the results from the survey in the study area. All of these salt lakes are also under some impact from mining activities.

Table 4-1 Aquatic invertebrate surveys of salt lakes in Western Australia

Project	Author	Remarks
Lake Lefroy, Lake Zot and Lake Cowan	Curtin University of Technology (1999); Dalcon (2010); Phoenix (2014a, 2015)	
Lake Disappointment	Phoenix (2014b)	As part of terrestrial short-range endemic survey
Lake Carey	Timms *et al.* (2006)	Invertebrates only
Lake Maitland	Outback Ecology (2007)	
Lake Way	Outback Ecology (2008)	
Lake Yindarlgooda	Campagna (2007)	
Selected lakes from Lake Carey, White Flag Lake, Lake Way, Lake Miranda, Kopai Lake, Black Flag Lake	Gregory (2007); Gregory *et al.* (2006)	Development of a classification of inland salt lakes in WA

4.2 FIELD SURVEY

4.2.1 Timing and survey effort

Three phases of aquatic survey were undertaken. The initial survey (Phase 1) was undertaken on 9 February 2015, to occur within ten days of the first significant amount of rainfall experienced in the region for the season and coinciding with the migratory shorebird season. This survey included a full suite of physico-chemical water analyses, zooplankton and benthic macroinvertebrate surveys and a waterbird census.

A second survey (Phase 2) was conducted on 16 April 2015 as the area had received significant rainfall since Phase 1 resulting in a higher water level. The Phase 2 survey was limited to determining water conductivity, salinity and depth, surveying benthic macroinvertebrates and censusing waterbirds.

A third survey (Phase 3) on 23 July 2015 completed the field assessment with a further round of sampling benthic macroinvertebrates and measuring most water quality parameters.

4.2.2 Sites selection and habitat characterisation

A total of six sites were surveyed, although only five of these sites were selected for aquatic invertebrate assessment based on water levels (Table 4-2; Figure 4-1). Five sites were situated in the Beyondie Lakes system which included the two salt playas, the channel connecting the salt playas, the channel connecting the playa to the marsh, and the marsh area. One site was a claypan located approximately 1.5 km from the edge of Beyondie Lakes (Figure 4-1). Ten Mile Lake was almost dry during Phase 1 and no suitable sites for aquatic samples could be selected during that or subsequent phases. Detailed site descriptions are provided in Appendix 1.

Figure 4–1
Location of waterbird and aquatic invertebrate survey sites by habitat type

Study area

Survey site

- Channel
- Claypan
- Marsh
- Playa
- Major creeks and rivers
- Lakes

0 0.75 1.5 3 Kilometres
1:100,000

Client: Kalium Lakes Potash Pty Ltd
Project: Beyondie Potash Project

Author: G. Bouteloup
Date: 6/07/2015

Coordinate System: GDA 1994 MGA Zone 51
Projection: Transverse Mercator
Datum: GDA 1994

PHOENIX ENVIRONMENTAL SCIENCES

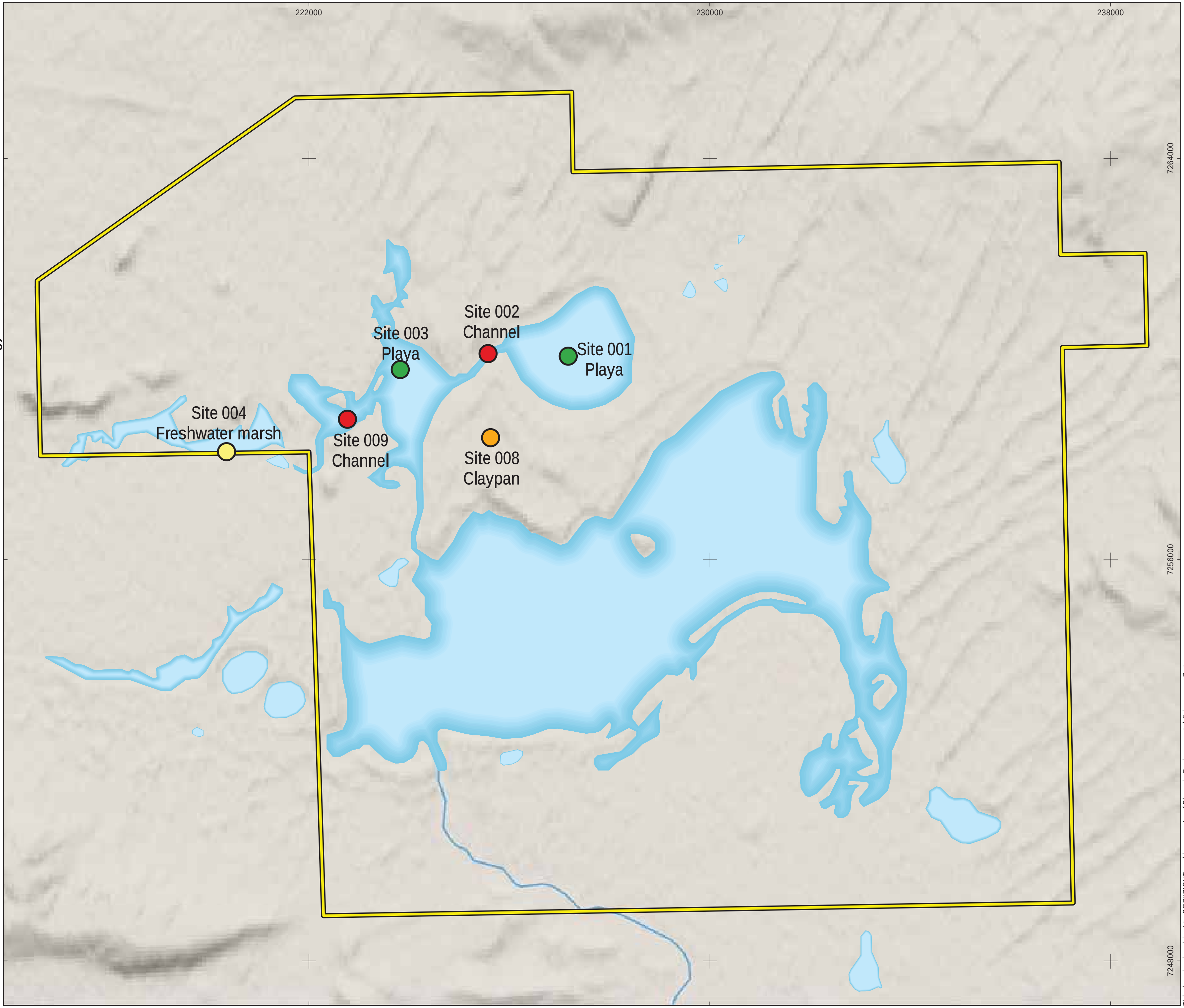

Table 4-2 Site location of aquatic invertebrate and waterbird survey in the study area

Site	Habitat	Easting	Northing	Zone	Latitude (GDA94)	Longitude (GDA94)	Comment
01	Playa	227269	7260135	51J	-24.749194	120.303378	
02	Channel	225583	7260107	51J	-24.749145	120.286717	
03	Playa	223836	7259786	51J	-24.751727	120.269395	
04	Marsh	220364	7258152	51J	-24.765838	120.234770	
08	Claypan	225637	7258422	51J	-24.764356	120.286920	
09	Channel	222774	7258801	51J	-24.760421	120.258709	Single bird census only (Phase 2)

4.2.3 Water quality

In situ measures of water quality including water depth, temperature, dissolved oxygen, conductivity, salinity, total dissolved solids (TDS), pH and Oxidation Reduction Potential (ORP) were taken at each site in Phase 1 using a hand-held water quality meter. Depth, conductivity and salinity only were measured in situ in Phase 2. All water quality parameters were measured in Phase 3 with the exception of dissolved oxygen and TDS.

4.2.4 Waterbirds

Waterbirds were only censused during Phase 1 and Phase 2. They were recorded by visual sightings and call recognition. A spotting scope and binoculars were used to spot, identify and count birds from a stationary position on the ground. The spotter stands at the edge of the wetlands and pans the wetland (i.e. from left to right) to identify and counts the number of different species within range. The census at each site was terminated once no further water bird species were detected. A helicopter was used to spot and identify birds and to count large numbers of birds at the sites by flying over the lake. This method flushes birds that are stationary or hiding around the edge and enables provides a more count of each species.

4.2.5 Aquatic invertebrates

Aquatic invertebrates were collected with 50 µm net targeting zooplankton and a 250 µm net targeting benthic macro-invertebrates. A single 50 m transect was surveyed which aimed to include all habitats present. The samples were sorted in the laboratory and identifications were undertaken using Leica M205C and M80 stereo and a Leica DM2500 phase-contrast compound microscopes.

4.3 TAXONOMY AND NOMENCLATURE

4.3.1 Morphological species identification

Identification of aquatic invertebrates was undertaken by Phoenix staff with relevant taxonomic expertise. Senior staff involved in the identification are also Research Associates with a longstanding taxonomic research history at the WA Museum. External expertise was sought for Gastropoda and some Crustacea (see section 4.5).

4.3.2 Molecular species identification

The identification of species based on comparisons between DNA sequences is referred to as DNA barcoding. Any gene can be used for barcoding purposes; however, the primary gene targeted by researchers is Cytochrome Oxidase Subunit I (COI) (Hebert *et al.* 2003). A molecular framework for COI exists at the WA Museum for most SRE taxa and was therefore sequenced here. Species identification based on COI barcoding is not without problems as sequence divergence within species can be high and may exceed that between species in some taxa, including SRE target groups (e. g. Bond 2004; Boyer *et al.* 2007; Köhler & Johnson 2012). Sequence divergence must therefore be interpreted cautiously.

Two snail species in the general *Gabbia* and *Isidorella* represented taxa potentially new to science and taking the poor reliability of morphological identification based on shell morphology into account, DNA sequencing for these species was conducted (Table 4-3). DNA was amplified by Phoenix staff utilising the molecular laboratory of the School of Animal Biology, University of Western Australia, but did not provide suitable PCR product for sequencing.

Table 4-3 Invertebrate specimens from the survey sequenced for molecular identification

Family	Genus and species	Site	Phoenix database	Remarks
Eupulmonata (snails)				
Planorbidae	*Isidorella* sp. indet.	08	19607	Did not provide suitable PCR product for sequencing.
Bithyniidae	*Gabbia* sp. indet.	01	19609	Did not provide suitable PCR product for sequencing.

4.3.3 Nomenclature

The nomenclature of described invertebrates and higher taxa follows a number of taxon-specific references, most of which are available online (Table 4-4). However, many species are undescribed and morphospecies designations are generally adopted from the consulted scientists.

Table 4-4 Taxonomic references, morphospecies designations and reference collections for the identification of aquatic biota of the Beyondie Lakes system

Taxonomic group	Taxonomic references for described species and higher taxa; morphospecies designation and reference collection
Crustacea - crustaceans	
Ostracoda (seed shrimps)	De Deckker (2002); Karanovic (2008)
Copepoda (copepods)	Boxshall & Halsey (2004a, b)
Notostraca (shield shrimp)	Williams (1981)
Anostraca (fairy shrimp)	Timms (2012)
Insecta - insects	
Trichoptera (caddisflies)	Trichoptera Checklist Coordinating Committee (2017)
Ephemeroptera (mayflies)	Suter and Campbell (2014)
Lepidoptera (butterflies and moths)	Nielsen *et al.* (1996)
Coleoptera (beetles)	Watts (2002)
Hemiptera (bugs and allies)	Anderson & Weir (2004)
Chironomidae (non-biting midges)	Cranston (2000); Leung (2011)
Ceratopogonidae (biting midges)	Elson-Harris (1990)
Gastropoda - snails	
Bithyniidae	Smith (1992); Ponder (2003)
Planorbidae	Smith (1992)
Aves - birds	
Waterbirds	Simpson and Day (2010); Morcombe (2004); Pizzey and Knight (2012)

4.4 Statistical analyses

4.4.1 Water quality

Differences in water quality between the survey sites were explored by Principal Coordinates Analysis (PCO) using Euclidean distance as similarity measure using the software package Primer 7.0.12 (Clarke & Gorley 2015). Environmental data were normalised prior to analysis to remove the influence of different measurement scales and units (Anderson *et al.* 2008).

4.4.2 Species richness

Species accumulation curves were compiled to obtain an estimate of survey completeness, i.e. whether the collection adequately represents the fauna of the study area. Individual-based taxon accumulation curves were plotted in favour of sample-based curves, as they assess species richness rather than density (Gotelli & Colwell 2001).

Taxon richness was calculated using the software package EstimateS v9.1 (Colwell 2009) with 10,000 randomizations. In addition, the abundance-based, non-parametric species estimators ACE, Chao1 and Jack Knife1 were used to estimate the total number of taxa combined for all sites. These above estimators were chosen as they are insensitive to pooling collection data ('grain size') and perform well when tested against real data (Hortal *et al.* 2006; Walther & Moore 2005).

For aquatic invertebrates, species richness estimates were conducted with estimated specimen numbers for species with high numbers of individuals (i.e. in the 100s and 1,000s). All identified taxa ('sp. indet.') were included in the analysis.

A number of important limitations must be considered when interpreting the species accumulation results. The above analyses do not extrapolate the total species numbers within the study area, but provide estimates for the circumstances under which the data were collected. They reflect potential results for more comprehensive surveys (i.e. more samples), but with the same methods at the same sites at the same time of the year. Total species numbers present in the study area may be higher, when seasonal variations are considered.

4.4.3 Water quality and invertebrate communities

Community data of the sampled sites were compared after transformation to presence-absence and based on Sørensen similarity as implemented in PRIMER 7.0.12. Results were explored graphically in the two-dimensional space based on non-metric Multi-Dimensional Scaling (nMDS).

The BEST-routine as implemented in PRIMER 7.0.12 examines all possible combinations of water quality parameters variables, from each parameter separately through to all at the same time, and how these contribute to site differences based on their aquatic community data. BIOENV examines all possible combinations of variables, from each environmental variable separately through to all at the same time. The combination of aquatic parameters, that maximises the correlation ρ between the two resemblance matrices of biotic and abiotic factors, best explains the differences in the composition of the aquatic fauna of the samples (Clarke & Gorley 2015). The BEST analysis was performed for all samples of Phase 1 Phase 2 and Phase 3, but limited to the three aquatic parameters salinity, conductivity and water depth as only these were measured during all surveys.

4.5 SURVEY PERSONNEL

The personnel involved in the survey are presented (Table 4-5).

Table 4-5 Project team

Name	Qualifications	Role/s
Dr Volker W. Framenau[1]	M.Sc. (Cons. Biol.), Ph.D. (Zool.)	Project Manager, report writing
Ms Anna Leung[1]	B.Sc. (Env. Sci.) (Hons)	Field survey, taxonomy (Anostraca, Notostraca, Insecta, Eupulmonata), report writing
Mr Mike Brown[1]	B.Sc. (App Sci.)	Field survey
Mr Jarrad Clark[1]	B.Sc. (Env. Mgmt)	Field survey
Ms Karen Crews[1]	B.Sc. (Env. Biol.) (Hons)	Report review
Mr Corey Whisson[2]	B.Sc. (Env. Sci.)	Eupulmonata
Ms Jane McRae[3]		Taxonomy (Copepoda)
Dr Stuart Halse[3]	Ph.D. (Zool.)	Taxonomy (Ostracoda)
Dr Russel Shiel[4]	Ph.D. (Zool.)	Taxonomy (Cladocera)
Dr Brian Timms[5]	Ph.D. (Zool.)	Taxonomy (Anostraca)

[1]Phoenix Environmental Sciences; [2]WA Museum; [3]Bennelongia Environmental Consultants (Bennelongia), [4]University of Adelaide, [5]University of New South Wales.

5 RESULTS

5.1 DESKTOP REVIEW

5.1.1 Waterbirds

The database searches identified five species of waterbirds that may occur in the area, two of which being listed as Migratory under the EPBC Act (Table 5-1).

Table 5-1 Waterbirds identified through the desktop review and their conservation significance

Scientific name	Common name	Conservation listing[1]	
		EPBC Act	WC Act
Anas querquedula	Garganey	Mig.	Mig.
Ardea ibis	Cattle Egret		Mig.
Ardea modesta	Eastern Great Egret, Great Egret, White Egret		Mig.
Charadrius ruficapillus	Red-capped Plover		
Charadrius veredus	Oriental Plover	Mig.	Mig.

[1] Mig. — Migratory.

5.1.2 Aquatic invertebrates

Review of aquatic fauna surveys of inland WA salt lakes revealed a wide range of species richness and diversity (Appendix 2). Invertebrate richness at saline lakes ranged between 4 and 14 taxa, with crustaceans being most diverse. Diptera was the most common insect order at saline lakes. Wetlands in the Lake Carey catchment, which include a variety of wetland types from fresh to saline conditions, recorded 118 taxa of invertebrates (Appendix 2).

The WA Museum Crustacea database only returned subterranean stygofauna and the Mollusca database only returned two records of terrestrial snails in the family Camaenidae; none of these are relevant for assessing the aquatic invertebrate fauna of the Beyondie and Ten Mile Lakes system.

5.2 FIELD SURVEY

5.2.1 Hydrology

Heavy rainfall that occurred in February inundated the Beyondie and Ten Mile Lake system; however, much of the water evaporated within about ten days and at commencement of survey Phase 1, the water level at the playa sites of the Beyondie Lakes (sites 01 and 03) had evaporated to less than 10 cm depth (Table 5-2). Most of the playa surface was exposed or inundated with only 1 cm of water and salt crusting was visible. The marsh (site 04) contained deeper water (more than 1 m) and the water level claypan (site 08) was deeper than 50 cm.

Between Phase 1 and Phase 2, 205.1 mm and 184.8 mm of rainfall were recorded at Weelarrana and Newman weather station respectively. Subsequent increases in water levels prior to Phase 2 were most noticeable at the playa sites at Beyondie Lakes where the water completely inundated the playa surface and encroached into the *Tecticornia* riparian zone. Water depth at all survey sites was at least 50 cm (Table 5-2).

During Phase 3, water levels were generally lower than during Phase 2, but all previous sample sites had sufficient water for aquatic invertebrate sampling (Table 5-2).

Ten Mile Lake was completely dry in all three phases, with the exception of a very small low lying area to the west of the lake, which was hypersaline and to shallow to sample.

Table 5-2 Water quality parameters at the survey sites

	Phase 1					Phase 2					Phase 3				
	01	02	03	04	08	01	02	03	04	08	01	02	03	04	09
Depth (cm)	<1	<10	<8	>100	>50	>50	>100	>100	>100	>50	25	50	40	100	15
Temperature (°C)	30.2	28.1	32.6	32.6	32.7	Not taken					15.1	16.1	16.4	17.3	17.7
Dissolved Oxygen (% sat.)	19.1	75.5	70	61	62.9	Not taken					88.3	91	115	138	133
Dissolved Oxygen (mg/L)	0.61	4.03	4.68	7.9	4.5	Not taken					Not taken				
Conductivity (ɥS)	203,059	88,290	25,527	1,066	317.1	16,250	15,460	2,730	242	142	23,254	20,123	12,780	1,544	11,448
Total Dissolved Solids (mg/L)	120.05	60.84	14.46	0.30	0.18	Not taken					Not taken				
Salinity (ppt)	156.9	67.1	13.23	0.22	0.13	9.4	9	1.3	0	0	17.8	14.77	8.96	0.92	7.68
pH	7.63	8.59	8.17	8.54	8.26	Not taken					8.13	8.63	8.49	8.16	8.3
Oxidation Reduction Potential	22.7	-2.2	-7.7	-33.9	-54.4	Not taken					170	134.9	149	155	171

5.2.2 Water quality

The salinity and conductivity of the Beyondie Lakes was highly variable between sites with a trend of increasing salinity from the western-most (site 04) to the eastern-most site (site 01) in both phases (Table 5-2). Salinities dramatically decreased between Phase 1 to Phase 2 at all sites, with a noticeable difference at sites 01 and 02, where water quality changed from hypersaline to mesosaline (Table 5-2). Site 03 changed from mesosaline to fresh, and both sites 04 and 08 stayed fresh but still exhibited lower salinities and conductivities in Phase 2. Salinity increased in Phase 3 with similar overall pattern to Phase 1 (i.e. highest salinities at sites 01, 02 and 03), although differences were much less pronounced than in Phase 1.

The PCA analysis based on environmental variables for Phase 1 and Phase 3 (Phase 2 excluded due to lack of parameters measured) clearly separates the sites from Phase 1, situated to the left of the graph) and Phase 3 (situated to the right) (Figure 5-1). The spread of the sites from Phase 1 along the PC1 axis is mainly caused by those environmental factors of which the lines are oriented horizontally, e.g. salinity, conductivity, pH and depth. In contrast, the split of sites between Phase 1 and Phase 3 are mainly caused by an increase in oxygen reduction potential and dissolved oxygen and decrease in temperature. Sites of Phase 3 are much less different to each other in relation to those factors that spread the sites of Phase 1 (Figure 5-1).

Overall, the environmental variables contributed fairly equally to the differences along the first axis of the PCA analysis which explained a total of 55.0% of the differences in sites. The second axis explained a further 27% of the variation in environmental values and here temperature contributed the most followed by pH and DO (%) (Figure 5-1).

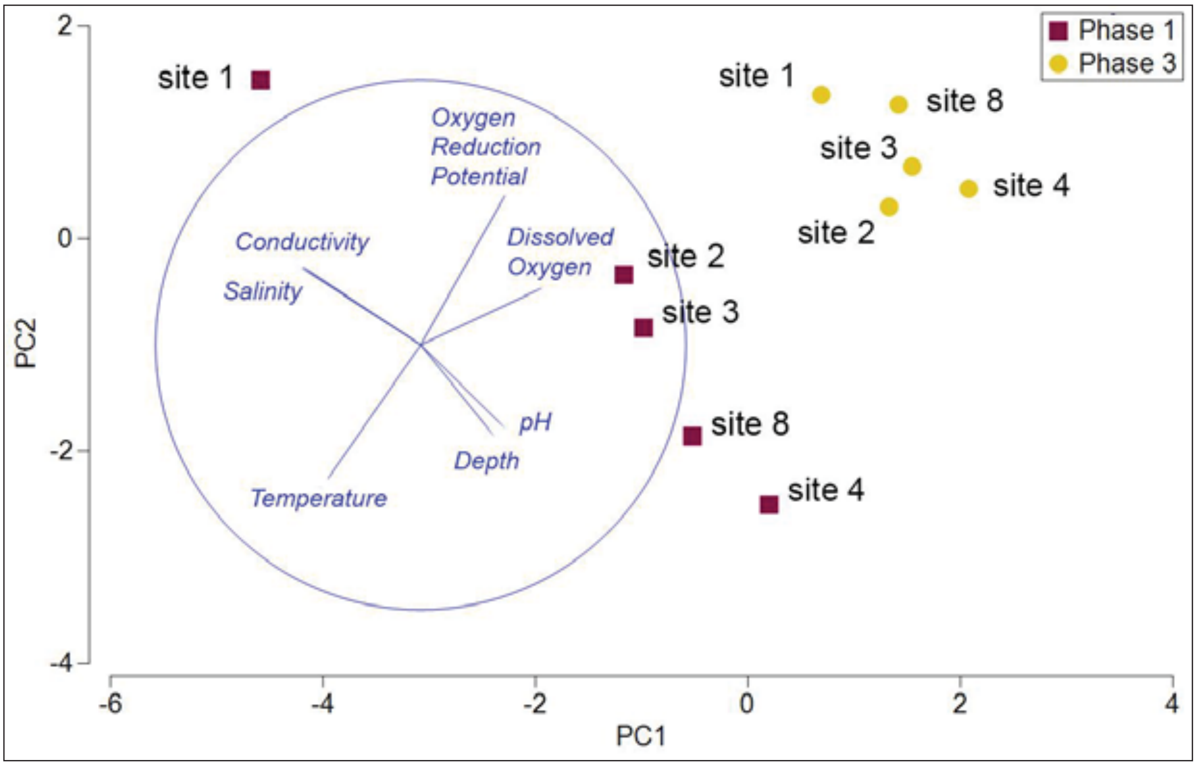

Figure 5-1 Principal Component Analysis (PCA) of water quality parameters in Phase 1

Only three water quality measures were taken in all three phases, salinity, conductivity and depth (Table 5-2). The graphical representation based on a PCA again shows the most similar sites based on environmental variables closest together (Figure 5-2). The high relative differences in salinity and conductivity spread the samples of Phase 1 along both the PC1- and PC2-axis and explain the differences between sites 1, 2 and 3 in Phase 1. Consequently, the first axis (PC1) with 81.3% explains most of the variation within the three water quality parameters.

Salinity and conductivity did not explain any of the differences between sites 3, 4 and 8 of Phase 1 and any of the sites in Phase 2 and Phase 3. The sites of Phase 2 and Phase 3 are oriented along increasing depth with those with of Phase 2 (deeper water) towards the bottom right of the graph mainly along the PC2- axis (Figure 5-2). The second axis (PC2) explained 18.7% of the variation between the sites. Salinity and conductivity differences on this plot are much less pronounced for Phase 2 and Phase 3 sites as their range is more than a magnitude smaller than those of Phase 1.

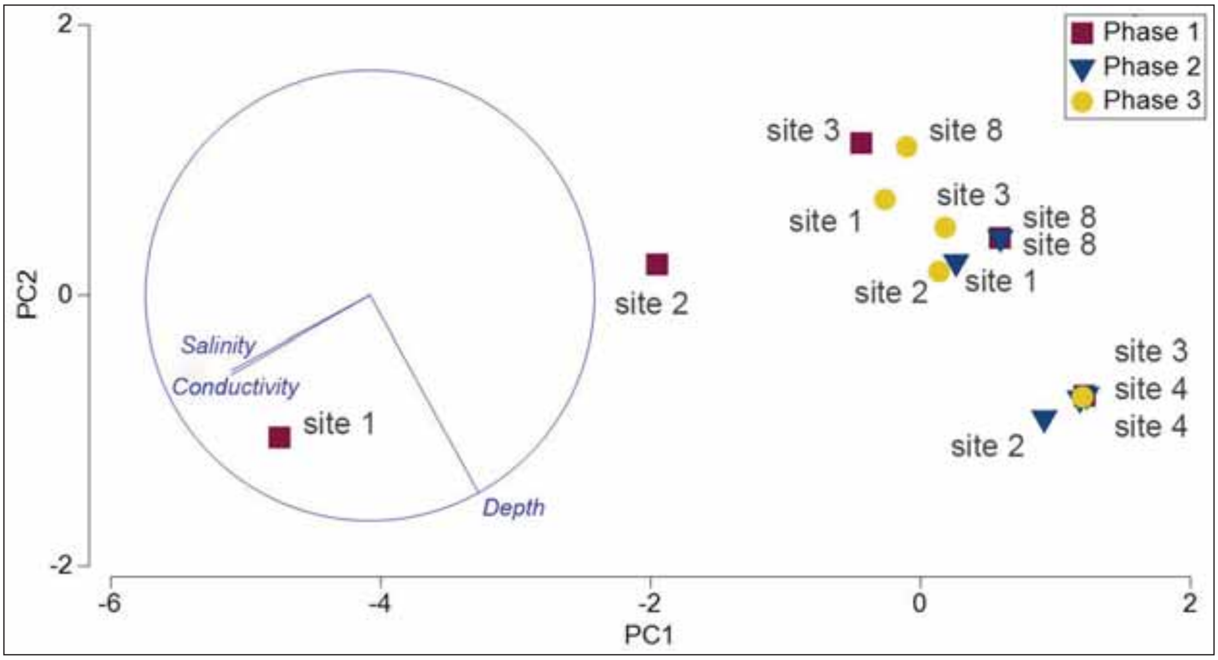

Figure 5-2 Principal Component Analysis (PCA) of water quality parameters measured in Phases 1, 2 and 3

5.2.3 Waterbirds

Fifteen species of waterbirds were sighted during the survey, most of these during Phase 2 (Table 5-3). These include seven species of ducks and duck-like birds (diving/dabbling), one swan, four shorebirds, two herons, and one gull. Overall abundance was also greater in Phase 2; however, larger numbers of the Black-winged Stilt, Grey Teal and Australian Shelduck were also high in Phase 1.

Two species, the Oriental Plover and the Common Greenshank (both shorebirds), are listed as Migratory under the EPBC Act and, correspondingly, Schedule 3 on the WC Act (Table 5-3).

Numbers in Table 5-3 indicate individuals counted or estimated at each site but may or may not be the same individuals seen at other sites as waterbirds are highly mobile and most species are likely to move between sites, particularly those of similar habitat.

Table 5-3 Estimated numbers of waterbirds recorded in the study area by phase and site

Scientific name	Common name	Conservation status[1]	Phase 1		Phase 2				
			03	04	01	03	04	08	09
Anas gracilis	Grey Teal			173	100	10	100	10	100
Anas rhynchotis	Australasian Shoveler						4		100
Ardea pacifica	White-necked Heron							1	
Aythya australis	Hardhead			20		100	20		50
Charadrius veredus	Oriental Plover	Mig. (EPBC, WC Act)	8						
Chroicocephalus novaehollandiae	Silver Gull				3				
Cygnus atratus	Black Swan				21[2]	21			
Egretta novaehollandiae	White-faced Heron					2			
Fulica atra	Eurasian Coot					200			
Himantopus himantopus	Black-winged Stilt			154	200	50			
Malacorhynchus membranaceus	Pink-eared Duck			2		10			
Poliocephalus poliocephalus	Hoary-headed Grebe						12		
Recurvirostra novaehollandiae	Red-necked Avocet				8	10			
Tadorna tadornoides	Australian Shelduck			82	2	14	10		
Tringa nebularia	Common Greenshank	Mig. (EPBC, (WC Act)							5

[1]Mig. – Migratory. [2]Indicates evidence of breeding; nests were seen.

5.2.3.1 Conservation significant species recorded in the study area

Potential habitat was identified in the study area for a further one of the four species of conservation significance from the desktop review. Species records and an assessment of the potential occurrence and distribution of conservation significant species within the study area are discussed here. Species identified in the desktop review that are considered unlikely to occur within the study area due to lack of suitable habitat are not discussed further.

1. **Eastern Great Egret (*Ardea modesta*)**

Status: Migratory (WC Act)

Distribution and ecology: The Eastern Great Egret can be found along inland rivers, lakes and shallow freshwater or saltwater wetlands and inundated samphire flats. This species is highly mobile and can be found throughout most of the western fringes of the State in coastal areas and towards the semi-arid interior (Johnstone & Storr 1998).

Records and likely distribution in the study area: The Eastern Great Egret was not recorded in the survey but has the potential to occur in the study area. The nearest record of the Eastern Great Egret is located approximately 60 km south-west of the western most end of the study area (DPaW 2015).

Suitable creek and drainage lines within the study area are not permanently flowing or abundant within the study area; however, the species may occur after rains when water is present within minor creek and drainage lines and lakes are holding water.

2. **Oriental Plover (*Charadrius veredus*)**

Status: Migratory (EPBC Act, WC Act)

Distribution and ecology: The Oriental Plover is a non-breeding visitor to Australia. It has a widespread distribution but most records are along the north-western coast between Exmouth Gulf and Derby (Department of the Environment and Energy 2017). Inland habitats occupied by the species include sparsely vegetated plains or recently burnt open areas.

Records and likely distribution in the study area: The Oriental Plover was recorded during Phase 1 of the survey. Eight individuals were recorded at site 03. The species is likely to occur within the study area when conditions are favourable, particularly after rainfall when water is present within lakes.

3. **Common Greenshank (*Tringa nebularia*)**

Status: Migratory (EPBC Act, WC Act)

Distribution and ecology: The species is present in summer across all Australian states, mostly along the coast but sometimes inland. The overall population appears stable (Delany & Scott 2006). The species is not gregarious. Small groups can sometimes be seen when roosting at high tide (Geering *et al.* 2007). They prefer coastal open mudflats.

Records and likely distribution in the study area: The Common Greenshank was recorded during Phase 2 with a total of five individuals at site 09. The species is likely to occasionally occur within the study area, particularly following rainfall when water is present within lakes. The Greenshank was previously recorded approximately 50 km north of the study area (DPaW 2015).

5.2.4 Aquatic invertebrates

A total of 102 taxa were identified from the study area, including 68 definite species and 34 unidentified higher taxa (‘sp. indet.’). The fauna included two definite species of water mites, 30 species of crustaceans, 36 species of aquatic insects and two species of aquatic snails (Table 5-4). The average number of taxa collected per site was lowest in Phase 1 (8.8 ± 9.0 s.d., n = 5), followed by Phase 3 (16.4 ± 8.1 s.d., n = 5), and highest for Phase 2 (23.6 ± 7.7 s.d., n = 5).

The most commonly collected species was the snail *Gabbia* ‘beyondie’ which were collected in ten of the 15 samples, the copepod *Boeckella triarticulata* (8 samples) and the ostracod *Cyprinotus cingalensis* and hemipteran *Anisops nasutus* (six samples each).None of the species are formally recognised as conservation significant species, but several represent new or undescribed species currently only known from the study area, including the snails in the genera *Gabbia* and *Isidorella*, ostracods in the genera *Limnocythere*, *Mytilocypris* and *Bennelongia*, and a conchostracan in the genus *Ozestheria*.

The Beyondie Lakes marsh (site 04) had the highest taxon richness of all sites with 61 taxa collected. Site 08 (claypan), site 04 (claypan) had the second overall highest richness (44 taxa), followed by site 02 (channel; 39 taxa), site 03 (salt lake; 38 taxa) and site 01 (salt lake; 19 taxa). Sites 01, 02, and 03 were particularly depauperate in Phase 1 with only two, one and four species collected respectively (Table 5-4).

The described species are generally common and/or widespread, with some occurring over large areas of Australia and others being endemic to Western Australia or inland/northern Australia. These include all of the insects and many of the crustaceans.

Table 5-4 Aquatic invertebrates recorded in the study area, by phase and site

Higher taxon	Identification	Phase 1					Phase 2					Phase 3				
		01	02	03	04	08	01	02	03	04	08	01	02	03	04	08
Acari (water mites)	*Arrenurus* sp. indet.									2						
	Hydrachna sp. indet.									2						
Crustacea – Anostraca (fairy shrimp)	*Branchinella mcraeae*				41	>100										
Crustacea – Cladocera (water fleas)	*Celsinotum* cf. *hypsilophum*													20	2	
	Chydoridae sp. indet.														11	
	cf. *Ceriodaphnia* sp. indet.														9	
	Daphnia carinata					>1000										
	Diaphanosoma excisum									2						
	Latonopsis brehmi										15					
	Macrothrix breviseta									2	2					
	Maraura macracantha								15	15						
	Moina micrura			>100	>1000	>1000				>100	2					
Crustacea – Conchostraca (clam shrimp)	*Eocyzicus* sp. indet.				20											
	Ozestheria 'beyondie'						2		1	3						
	Ozestheria 'nr packardi'				>100	17				13	10				4	
	Boeckella triarticulata				>1000	30		10	17	66	42				50	50

Higher taxon	Identification	Phase 1					Phase 2					Phase 3				
		01	02	03	04	08	01	02	03	04	08	01	02	03	04	08
Crustacea – Copepoda (copepods)	*Calamoecia ampulla* var. P1 (SW)										68					
	Calamoecia sp. indet. [1]					30										
	Meridiecyclops baylyi	20		75	>1000	>100										
	Metacyclops sp. 442 (*salinarum* in Moreton) (CB)										6					
	Microcyclops varicans										5					
Crustacea – Notostraca (shield shrimp)	*Triops australiensis*				41	8					2					
Crustacea – Ostracoda (seed shrimp)	*Bennelongia ?dedeckkeri*				1											
	Bennelongia coondinerensis														50	
	Bennelongia cuensis									2						
	Bennelongia 'beyondie'					7										
	Cypretta sp. indet.					15					>100					
	Cyprinotus cingalensis				>1000	18		>100	>100	>1000	>100					
	Cyprinotus kimberleyensis				1								50	50	50	50
	Cyprinotus sp. indet.				2											

Higher taxon	Identification	Phase 1					Phase 2					Phase 3				
		01	02	03	04	08	01	02	03	04	08	01	02	03	04	08
	Diacypris dictyote											50	50	50		
	Heterocypris '548'			>100			>100	>100	>100							
	Ilyocypris australiensis				7											
	Ilyodromus williamsi s.l.														3	
	Limnocythere 'beyondie'									1						
	Mytilocypris 'beyondie'			>100			>100	>100	>100							
	Mytilocypris 'moojari'											50	50	50		50
	Reticypris kurdimurka											50				
	Sarscypridopsis sp. indet.														50	50
	Ostracoda sp. indet.[1]							2								
Insecta – Coleoptera (beetles)	*Allodessus bistrigatus*								3	4						
	Berosus munitipennis				11											
	Berosus nutans				1	2										
	Berosus sp. indet.[1]				1	1				5						
	Bidessini sp. indet.[1]				6	1		2		1						
	Dineutus australis								1							
	Enochrus elongatus						1						2			
	Eretes australis				76	4										
	Hyphydrus elegans								1	11	1				1	

Higher taxon	Identification	Phase 1					Phase 2					Phase 3				
		01	02	03	04	08	01	02	03	04	08	01	02	03	04	08
	Hyphydrus sp. indet.[1]							3								
	Sternopriscus sp. indet.														1	
Insecta – Diptera (flies & mosquitoes)	*Ablabesmyia notabilis*									3	1					
	Anopheles amictus										7					
	Bezzia sp. indet.													2		
	Cladotanytarsus sp. indet.												5			
	Chironomus tepperi					8										
	Cryptochironomus griseidorsum								2							
	Culicoides sp. indet.						6	12	8	12	8			1		1
	Dicrotendipes sp. indet.									3				12	50	28
	Dolichopodidae sp. indet.						1									
	Nilobezzia sp. indet							1		2			1	1		
	Polypedilum nubifer						3	3								1
	Procladius paludicola							1				6	18	20	5	
	Procladius sp. P1 (DEC)						1	2								7
	Stilobezzia sp. indet.						3									
	Tabanidae sp. indet.							1								
	Tanytarsus 'B1'										25					
	Tanytarsus 'K5'									>100						

Higher taxon	Identification	Phase 1					Phase 2					Phase 3				
		01	02	03	04	08	01	02	03	04	08	01	02	03	04	08
	Tanytarsus sp. indet.[1]											6	2	2		1
	Tanytarsus semibarbitarsus						>100	20	1	1						
	Thienemannimyia sp. indet.														22	1
Insecta – Hemiptera (water bugs)	*Agraptocorixa parvipunctata*									2					50	
	Anisops baylyi													1		
	Anisops gratus							1								
	Anisops nasutus				1			1	8	5	5				4	
	Anisops sp. indet.[1]				7	>100	9	25	20	9	4			20	8	
	Anisops thienemanni							1	2					7	4	
	Corixidae sp. indet.[1]				1											
	Micronecta gracilis								1	5	2					
	Micronecta robusta							6	5					20	13	2
	Micronecta sp. indet.[1]									30						
Insecta – Odonata (dragonflies & damselflies)	*Agriocnemus pygmaea*							4		14	14				2	
	Anax papuensis							7					1			
	Anisoptera sp. indet.[1]							7		3	2					
	Austroagrion cyane												2	3		10
	Austrolestes annulosus														3	1
	Austrolestes aridus										2					
	Hemicordulia tau							2		1				5	11	

Higher taxon	Identification	Phase 1					Phase 2					Phase 3				
		01	02	03	04	08	01	02	03	04	08	01	02	03	04	08
	Orthetrum caledonicum												4			
	Pantala flavescens							1	1							
	Rhodothemis lieftincki							1								
	Xanthagrion erythroneurum									3				1	3	
	Zygoptera sp. indet. [1]							2					20			
Ephemero-ptera (mayflies)	Ephemeroptera sp. indet.														2	
Trichoptera (caddisflies)	*Oecetis* sp. indet.												1	1	4	
	Triplectides australicus														1	
	Triplectides sp. indet.[1]													1		
Lepidoptera (butterflies and moths)	Acentropinae cf. S1 (Hawking)												3			
	Acentropinae sp. indet.[1]												15		1	
Gastropoda (snails)	*Gabbia* ‘beyondie’	50	50		8		24	17	10	2			50	50		1
	Isidorella ‘beyondie’										2					
Oligochaeta (worms)	*Ainudrilus* sp. indet.						1	1	1	1						
Total number of taxa:		**2**	**1**	**4**	**20**	**17**	**13**	**29**	**21**	**33**	**22**	**5**	**16**	**20**	**27**	**14**

1 – unidentified specimens of groups otherwise represented in the sample possibly belonging to those; not included in species richness estimates.

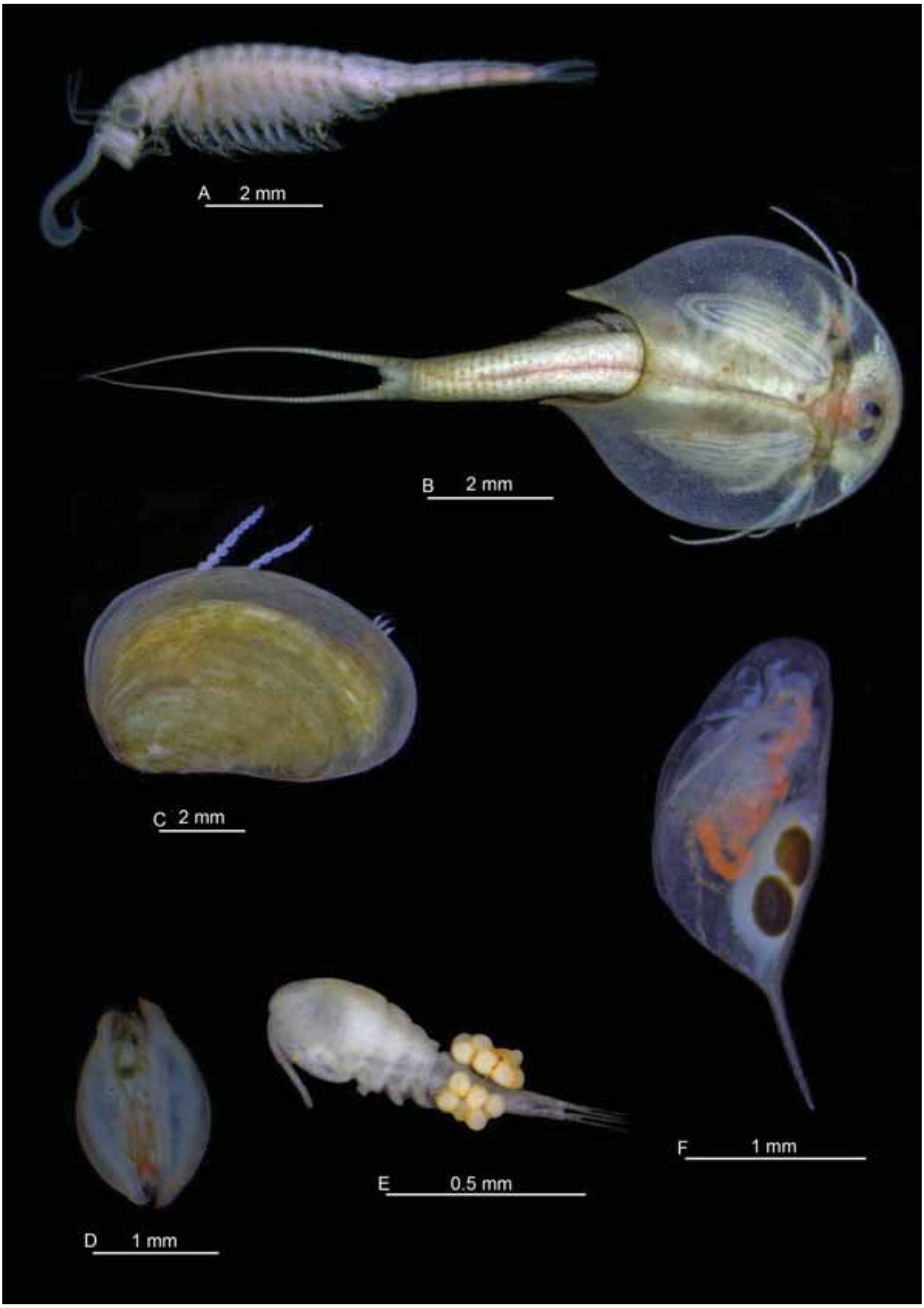

Figure 5-3 **Aquatic invertebrates collected in the study area – crustaceans. A, *Branchinella mcraeae*; B, *Triops australiensis*; C, *Ozestheria* 'beyondie'; D, *Bennelongia* 'beyondie'; E, *Meridiecyclops baylyi*; F, *Daphnia carinata***

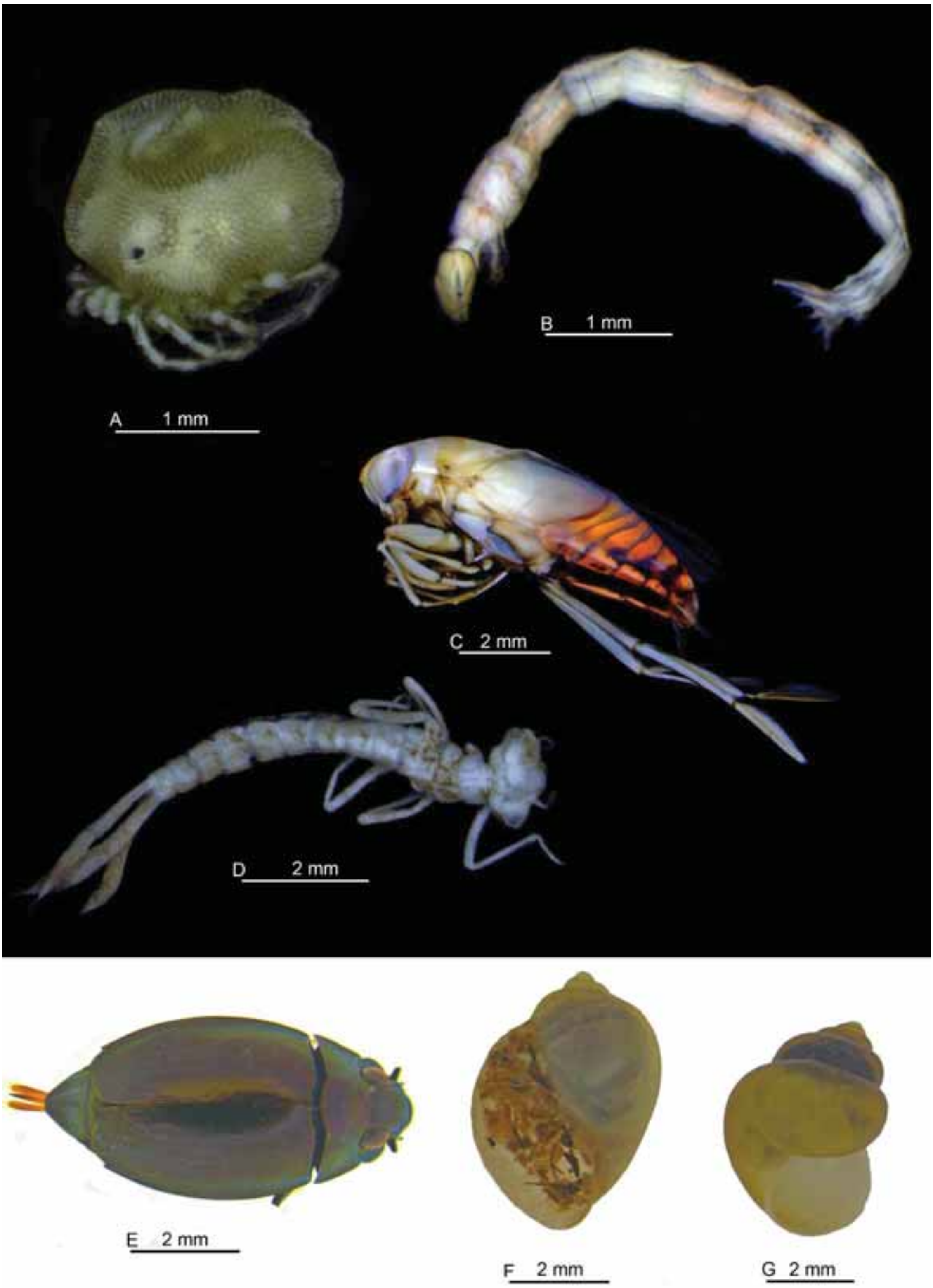

Figure 5-4 **Aquatic invertebrates collected in the study area – insects and molluscs. A, *Hydrachna* sp. indet.; B, *Procladius paludicola*; C, *Anisops nasutus*; D, *Agriocnemus pygmaea*; E, *Dineutus australis*; F, *Isidorella* 'beyondie'; G, *Gabbia* 'beyondie'**

Differences in aquatic invertebrate composition between the two survey phases are clearly evident in their separation mainly along the along the second (y-) axis of the nMDS plot (Figure 5-5). Along the first (x-) axis they appear to separate by salinity, with the freshwater sites located towards the left of the plot (Figure 5-5).

Salinity as main factor driving the differences of the biotic samples was confirmed by the BEST-routine as implemented in PRIMER 7 (see section 4.4.3) (Table 5-5). Salinity by itself or salinity and conductivity combined best explained the differences in survey sites based on the biotic data and as expressed in Figure 5-5, followed by conductivity by itself (Table 5-5). Depth alone showed the poorest correlation of biotic and abiotic resemblance matrices (Table 5-5).

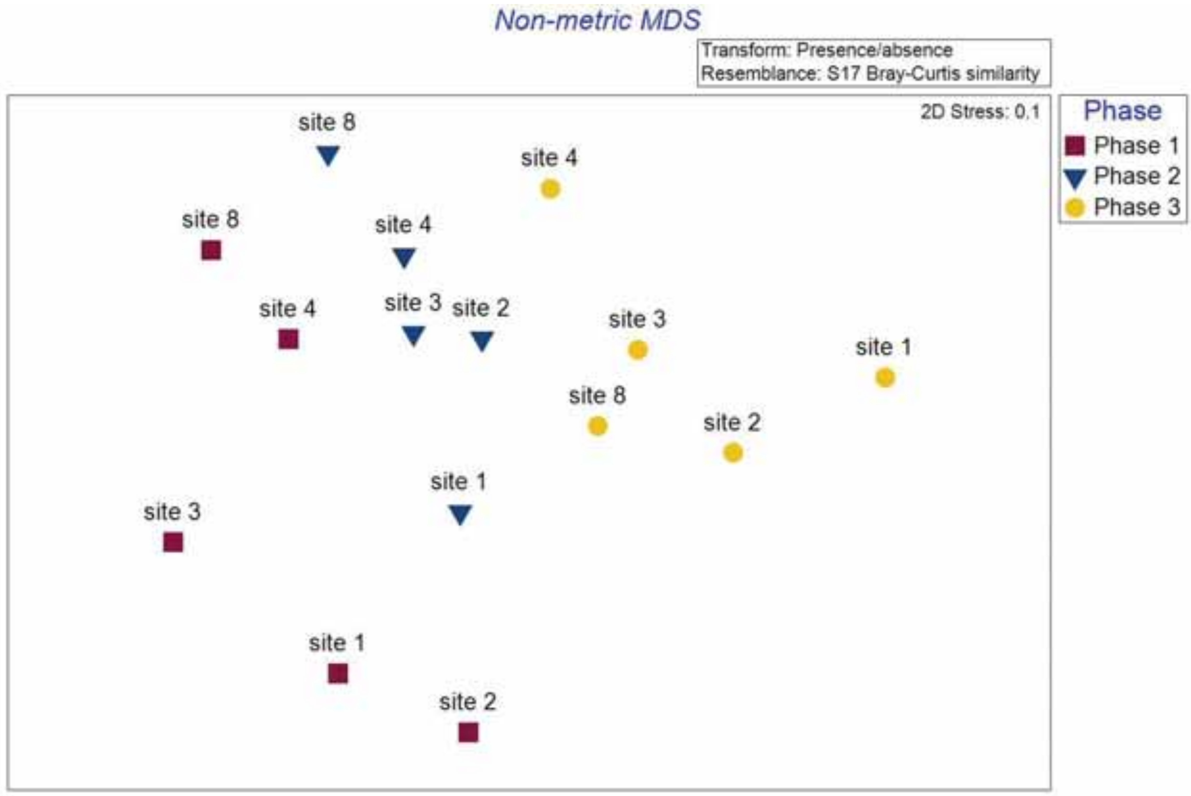

Figure 5-5 **Non-metric Multi-Dimensional Scaling (nMDS) of the species composition of aquatic invertebrates by site and phase**

Table 5-5 Correlation (ρ) of resemblance matrices of biotic data and water quality parameters as implemented in the BEST-routine of PRIMER 7

Combination of water quality parameters	No. of variables	ρ
Salinity	1	0.554
Salinity, conductivity	2	0.554
Conductivity	1	0.546
Salinity, conductivity, depth	3	0.323
Conductivity, depth	2	0.292
Salinity, depth	2	0.288
Depth	1	0.157

5.2.5 Arachnida (spiders and allies)

5.2.5.1 Acari (mites)

Water mites (Hydrachnida, Hydracarina) commonly occur in many freshwater wetlands and there are many described and undescribed species in Australia (e.g. Harvey 1998). *Arrenurus* and *Hydrachna* (Figure 5-4A) are widespread genera and four unidentified specimens of both genera were collected from site 04 in Phase 2 only (Table 5-4).

5.2.6 Crustacea (crabs and allies)

5.2.6.1 Anostraca (fairy shrimp and brine shrimp)

Fairy shrimp and brine shrimp are typically associated with ephemeral wetlands. Brine Shrimps (*Parartemia*) are generally associated with saline wetlands (Geddes 1981; Timms *et al.* 2009) and fairy shrimp (*Branchinella*) are generally associated with freshwater wetlands (Timms 2002; Timms 2008). No brine shrimp was collected from the survey; however, the fairy shrimp *Branchinella mcraeae* (Figure 5-3A) was found at freshwater sites 04 and 08 in Phase 1 (Table 5-4). The species is not uncommon in the Pilbara region (Timms 2008).

5.2.6.2 Cladocera (water fleas)

Cladocerans are microscopic crustaceans mostly found in freshwater habitats (Shiel 1995). Seven species were collected in the survey, five of which were only found in the fresh sites, and one species in fresh to brackish water (Table 5-4). All species are common and widespread in Australia, including *Daphnia carinata* (Figure 5-3F), commonly found at site 08 in Phase 1.

5.2.6.3 Conchostraca (clam shrimp)

Clam shrimp are a small shrimp enclosed in a shell with two valves and are usually about 0.5–1 cm long (Richter & Timms 2005). Some genera within this groups have an “unfathomed and complex” taxonomy (B. Timms, UNSW, email to A. Leung, April 2015), including the genera *Ozestheria* and *Eocyzicus*. Three species of clam shrimp were collected in the study area (Table 5-4):

- *Ozestheria* 'nr *packardi'* (collected at sites 04 and 08) is morphologically identical to the common and widespread species *Ozestheria packardi* but recent DNA analyses indicated that they are genetically distinct (B. Timms, UNSW, email to A. Leung, April 2015).
- *Ozestheria* 'beyondie' (Figure 5-3C) (sites 01, 03, and 04) is a new species only known from the study area.
- *Eocyzicus* sp. indet. (site 04) is also poorly understood and no further information was provided by the consulting taxonomist.

5.2.6.4 Copepoda (copepods)

Copepods are microscopic teardrop-shaped crustaceans that are common in freshwater and saline wetlands (Maly *et al.* 1997; Stoch 2001). At least five unique species of copepod were collected from the study area, all of which widespread and common. *Meridiecyclops baylyi* (Figure 5-3E) was the only copepod found in hypersaline water in Phase 1 and is very common in saline waters throughout WA (Fiers 2001; Pinder *et al.* 2005). Four of the remaining five species were found in fresh water only.

5.2.6.5 Notostraca (shield shrimp)

The Australian shield shrimp, *Triops australiensis*, represents a monotypic genus and is widespread across Australia. They are common in ephemeral wetlands. Several morphologically similar types of *T. australiensis* appear to separate by habitat preference (Department of the Environment 2014; Timms *et al.* 2006) and molecular data shows that a number of unique lineages exist (Korn *et al.* 2013; Vanschoenwinkel *et al.* 2012). A halotolerant type has been recorded in salinities up to 93 g/L (Timms *et al.* 2006). *Triops australiensis* (Figure 5-3A) was recorded at the freshwater sites site 04 and site 08 (Table 5-4).

5.2.6.6 Ostracoda (seed shrimp)

Seed shrimp are a small crustaceans enclosed in a shell with two valves, usually less than 1 mm long (De Deckker 2002). They are a common taxon in any wetland habitat and many species are known to be halotolerant. Ten species of seed shrimp were collected in the study area, of which at least four are undescribed; however, there is no evidence to suggest that any are endemic (S. Halse, email to V.W. Framenau, 10 April 2015). Copepods were collected form brackish and freshwater sites only and two (*Bennelongia* 'beyondie' and *Cypretta* sp. indet.) were collected from the claypan only (Table 5-4):

- *Bennelongia* 'beyondie' (Figure 5-3D) is a new species in the *triangulata*-lineage (Martens *et al.* 2015) and was only collected from site 08.
- *Bennelongia cuensis* is known from a locality near Cue, approximately 380 km south of the study area (Martens *et al.* 2012).
- *Bennelongia coondinerensis* has previously been known from the Pilbara region only (Martens *et al.* 2012).
- *Bennelongia* ?*dedeckkeri* was collected at site 04 only. This specimen was dead on collection, with only valves present in the sample. It is either *B. dedeckkeri*, a widespread species (Shearn *et al.* 2012) or a new species in the *barangaroo*-lineage (S. Halse, email to V.W. Framenau, 10 April 2015).
- *Heterocypris* '548' is an undescribed species but has been found previously in Fortescue Marsh approximately 250 km north of Beyondie Lakes, and Weelarrana salt marsh approximately 85 km north west of the study area (S. Halse, email to V.W. Framenau, 10 April 2015).

- *Limnocythere* 'beyondie' is an undescribed species, but it is likely to be the same as an undescribed *Limnocythere* species from the Pilbara (S. Halse, email to A. Leung, May 2015).
- *Mytilocypris* 'beyondie' is an undescribed species but has also been collected at Fortescue Marsh and Roy Hill claypan both approximately 250 km north of the study area, and Weelarrana salt marsh approximately 85 km north west of the study area (S. Halse, email to A. Leung, May 2015).
- *Ilyocypris australiensis* is a common widespread species, but was only found at site 04.
- *Cypretta* sp. indet. was collected only at site 08 (claypan). At least ten species of *Cypretta* are known from the Pilbara region, and this specimen is possibly one of these (S. Halse, email to A. Leung, May 2015).
- *Cyprinotus cingalensis* and *C. kimberleyensis* are morphologically similar species with some taxonomic uncertainty due to high morphological variability as they age. Some taxonomists consider these two species synonymous; however, independent of their taxonomic status, species are widespread (Karanovic 2008). *Cyprinotus cingalensis* was common in the collection, whilst *C. kimberleyensis* was only collected with a single specimen at site 04.

5.2.7 Insecta (insects)

Insects are common in most inland wetlands; however, species richness is known to decline with increasing salinity (Pinder *et al.* 2005). All insect species collected in the survey are common and/or widespread species. This is generally the case as many aquatic insect groups only spend their larval stage in the water to disperse and seek refugia as winged adults in other wetlands during the drought conditions (Marshall 2012). Others produce drought resistant eggs or burrow to avoid desiccation. Some dipteran species are especially tolerant of saline conditions and are often the only type of insect to be found in hypersaline wetlands along with copepods and ostracods (Pinder *et al.* 2005).

The aquatic insect fauna of the study area included at least seven species of beetles (Coleoptera) (Figure 5-4E), ten species of flies (Diptera) (Figure 5-4B), six species water bugs (Hemiptera) (Figure 5-4C), and at least seven species of dragon- and damselflies (Odonata) (Figure 5-4D) (Table 5-4).

Three order of insects were only collected in Phase 3, caddisflies (Trichoptera), mayflies (Ephemeroptera) and butterflies and moths (Lepidoptera) indicating a longer term inundation is required to trigger ontogenetic development for these groups. Only one of these could be identified to species level, the common caddisfly *Triplectides australicus* (ALA 2017).

5.2.8 Gastropoda (snails)

Molluscs are one of the most diverse groups of invertebrates and the Australian fauna is characterised by a high degree of endemism (Beesley *et al.* 1998). Lunged snails belong to the target groups for SRE surveys due to their limited dispersal capabilities, in combination with often strict dependencies on particular soils (EPA 2016g; Harvey 2002). These characteristics have also resulted in a significant global decline of non-marine molluscs (Lydeard *et al.* 2004). Two aquatic snail species in two families were collected in the study area (Table 5-4); both where subject to molecular analyses but did not yield suitable DNA for sequencing:

- *Gabbia* 'beyondie' (family Bithyniidae) is currently only known from the study area where it was at all sites; however, species of bithyniid snails are difficult to define morphologically (Ponder 2003). The species was also collected at Ten Mile Lake during the terrestrial fauna survey for the Project (Phoenix 2017). In WA, *Gabbia* are mainly known from the coastal northwest (Ponder 2003); two undescribed species of *Gabbia* are known from the Carnarvon Basin (A. Pinder, DPaW, pers. comm. to A. Leung, May 2015).

- *Isidorella* 'beyondie' (Planorbidae), only collected at site 08, is here tentatively referred to a new morphospecies, but this assessment needs to be verified by molecular methods. In WA, *Isidorella newcombi* has been found in the Great Sandy Desert (Walker 1988) and *I. egregia* is known from the Pilbara and Kimberley coastline (Köhler *et al.* 2012). Unidentified specimens have also been collected at Lorna Glen wetlands approximately 200 km south of the study area (A. Pinder, DPaW, pers. comm. to A. Leung) and Lake Carey wetlands (Timms *et al.* 2006).

5.2.9 Oligochaeta (aquatic worms)

Oligochaete taxonomy is not well understood, with detailed microscopic techniques required to assign a species name (Pinder 2010). Oligochaetes are often cryptic species where specimens are morphologically identical, even under a microscope, but genetically distinct.

Ainudrilus is a common genus in the Pilbara and inland areas (e.g. Pinder & Halse 2002). A currently unidentified species of the genus was collected at sites 01, 02, 03 and 04 (Table 5-4). It may represent a new species pending further morphological investigations (A. Pinder, DPaW, pers. comm. to A. Leung).

5.2.10 Species richness

5.2.10.1 Waterbirds

Species richness estimators suggest that between 15 and 21 waterbird species could have been collected at the study sites with the same methods during the survey, of which the observed 15 species represent between 71.4–100% (Table 5-6). However, accumulation curves have not commenced to plateau suggesting that the species richness is higher than estimated here (Figure 5-6).

Table 5-6 Species richness estimates for waterbirds

Taxa group	Survey data				Species estimators		
	Number of individuals	Number of singleton species	Number of doubleton species	Number of species recorded	ACE mean	Chao1 mean	Jack Knife1 mean
Waterbirds	1,602	1	1	15	16	15	21
Percentage of observed species richness					93.8	100	71.4

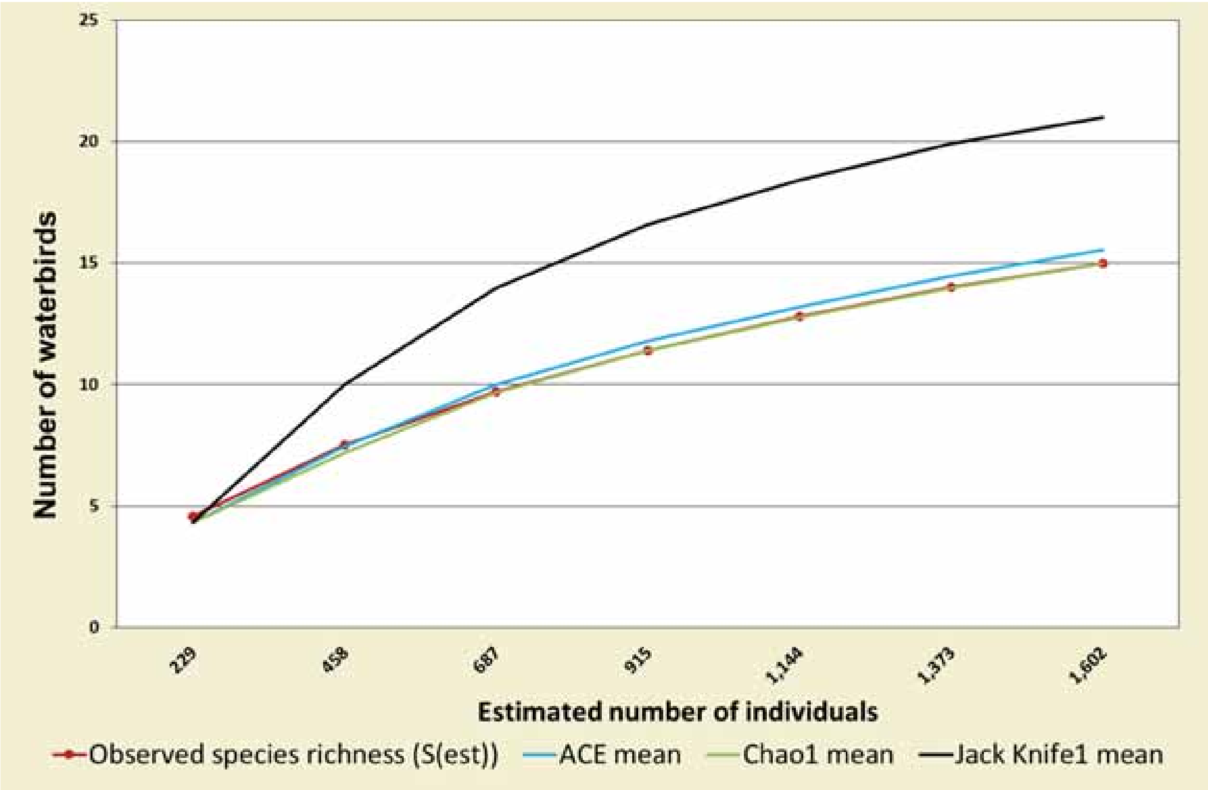

Figure 5-6 Observed and estimated species richness of waterbirds in the study area

5.2.10.2 Aquatic invertebrates

Species richness estimators suggest that between 110 and 17 aquatic invertebrate taxa could have been collected at the study sites with the same methods during the three phases of the survey, of which the observed 102 species represent between 69.4–94.4% (Table 5-7). However, accumulation curves have not commenced to plateau suggesting that the species richness is higher than estimated here (Figure 5-7).

Table 5-7 Species richness estimates for aquatic invertebrates at the survey sites

Taxa group	Survey data				Species estimators		
	Number of individuals	Number of singleton species	Number of doubleton species	Number of taxa recorded	ACE mean	Chao1 mean	Jack Knife1 mean
Aquatic invertebrates	>11,712	12	12	102	110	108	147
Percentage of observed species richness					92.7	94.4	69.4

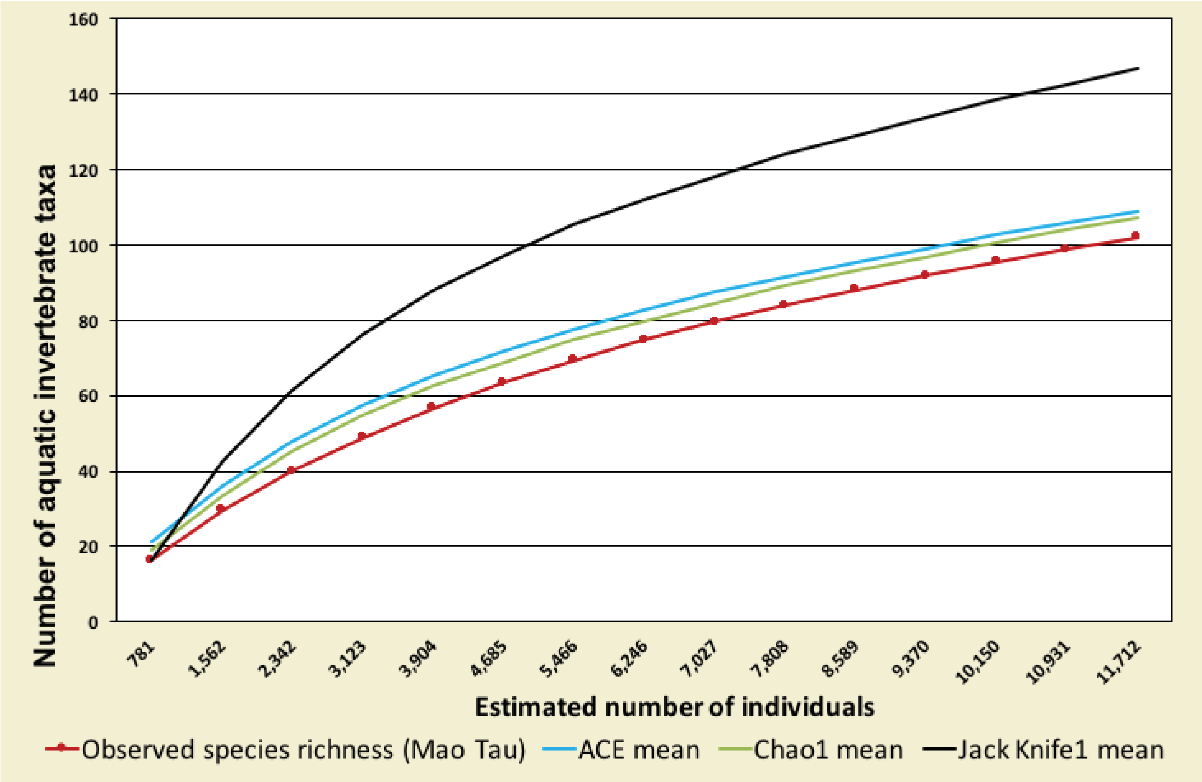

Figure 5-7 Observed and estimated species richness of aquatic invertebrates in the study area

5.3 Survey limitations

The EPA *Technical Guide: Terrestrial fauna surveys* (EPA 2016h; previously Guidance Statement 56) identifies potential limitations that may be encountered during terrestrial fauna surveys. With respect to this guidance statement, minor limitations only exist due to the lack of contextual information in this poorly surveyed region (Table 5-8).

Table 5-8 Survey limitations from EPA Technical Guidance: Terrestrial fauna surveys (EPA 2016h)

Limitations	Limitation for this survey?	Comments
Competency/experience of survey personnel, including taxonomy	No	The field and laboratory teams and report authors have extensive experience in survey of aquatic ecosystems in WA; external taxonomist were consulted for key invertebrate groups.
Scope and completeness - were all planned survey methods implemented successfully, was the study area fully surveyed	No	Suitable collecting methods were used based on comparable surveys in WA and consistent with wetland surveys conducted by DPaW.
Intensity - in retrospect, was the intensity adequate	No	The survey intensity was appropriate for the areas that were surveyed.
Proportion of fauna identified, recorded and/or collected.	Yes	The accumulation curves for neither aquatic invertebrates nor waterbirds plateaued, suggesting that not all taxa present at the time of the survey were recorded. However, survey completeness is comparable to similar surveys. Some invertebrates (i.e. ostracods and cladocerans) remain taxonomically poorly known as evidenced by statements of the consulted experts.
Availability of adequate contextual information	Yes	The region where the study area is located is poorly surveyed and the desktop review only recovered data for waterbirds, but not aquatic invertebrates within ca. 100 km of the study area.
Timing, weather, season, cycle	No	The survey was timed after a significant rainfall that flooded the ephemeral lakes of the study area.
Disturbances which affected the results of the survey	No	No disturbances occurring during the period of the field survey are considered to have impacted the results.
Remoteness and/or access problems	No	The use of a helicopter facilitated access to undertake survey work in areas inaccessible areas by vehicle.

6 DISCUSSION

In assessing development proposals, the EPA's broad objective for terrestrial fauna is protection so that biological diversity and ecological integrity are maintained (EPA 2016e). Considerations for terrestrial fauna in EIA include the significance of the terrestrial fauna, current state of knowledge of the species present, the potential impacts to terrestrial fauna, the scale at which the impacts are considered and application of the mitigation hierarchy to avoid or minimise impacts.

The EPA's objective for invertebrates, i.e. short-range endemics (SREs), is to ensure that proposals do not potentially threaten the viability of, or lead to the extinction of any SRE species (EPA 2016g). This objective focuses on the impacts of the Project on the persistence of species rather than, as in waterbirds, impacts on populations of conservation significant species which are often widespread. Therefore, the aim of aquatic invertebrate survey was mainly to determine whether any species may be restricted solely to the study area and therefore be at risk from the Project.

The study area is situated in a poorly surveyed area where the eastern Gascoyne and southwestern Little Sandy Desert bioregions intercept and where limited contextual information, particularly for conservation significant species, exists (van Leeuwen 2002). This was evident in the poor return from the desktop review, in particular in respect to SREs.

6.1 WATER QUALITY

Water quality is an abiotic factor which is known to influence biotic communities. Many species of aquatic flora and fauna are known to be highly sensitive to factors such as salinity, pH, nutrients, and heavy metal contents of the water (Jones *et al.* 2009a). The Beyondie Lakes and Ten Mile Lake consists of a range of habitats including playas, channels, and a freshwater marsh with varying connectivity. Ephemeral claypans are located between the Beyondie Lakes and Ten Mile Lake.

Salinity (ppt) and electrical conductivity (µS/cm) are measures of total dissolved salts while total dissolved solids (TDS) (g/L) measures total dissolved salts plus organic matter (Boulton & Brock 1999). In regards to wetlands, fresh water is generally defined as <3 g/L, hyposaline (or brackish) water is 3–20 g/L, mesosaline water is 20–50 g/L, and hypersaline water is >50 g/L (Hammer 1986; Williams 1981). Within this context the salinity and conductivity of the Beyondie Lakes was highly variable between sites and phases with a trend of increasing salinity from west to east, most probably reflecting the geomorphology of the sites. The eastern playas are the lowest lying and apparently accumulate salts over time. Hydrology seemed to play a major role in the dramatic salinity changes, with lower than expected precipitation in the months leading up to Phase 1 (December, January and February), and rainfall in the months between the two phases (March and April) far exceeding the long-term average. Salinity increased between Phase 2 and Phase 3 due to evaporation and concomitant accumulation of dissolved solids.

Variability in water quality within a large inland salt lake may also be influenced by other factors such as hydrocycle, geography and geology (Gregory 2007). This was true for the water quality of the Beyondie Lakes system. Hydrocycle influenced salinity as measurements fluctuated between the phases of and their different water levels. Salinity was overall lower during the second Phase, potentially due to larger water bodies and therefore lower salt concentrations.

6.2 Waterbirds

Fifteen species of waterbird were observed at the Beyondie Lakes system during the survey with five species during Phase 1 and 14 species during Phase 2. The waterbird assemblage consisted of ducks and duck-like birds, small shorebirds, large wading birds and a gull.

The assemblage included two Migratory species listed under the EPBC Act, the Oriental Plover and the Common Greenshank. As both were recorded in very low numbers during the survey, the study area is not considered to contain nationally or internationally important habitat for Migratory bird species listed under the EPBC Act in accordance with EPBC Act guidelines for determining important habitat (see section 2.1).

Based on the desktop review (i.e. historic or recent records nearby) and known habitat preferences, one additional Migratory species listed under the WC Act, the Eastern Great Egret, may frequent the study area. All three Migratory birds are common and widespread.

The increase in waterbird diversity and numbers between the two surveys correlated with the increase in invertebrate richness and potentially biomass, although the latter was not evaluated during the survey. Several studies (Roshier *et al.* 2002; Timms 1997) suggested that large numbers of waterbirds are attracted to ephemeral wetlands several months after filling. This is due to the time required for macrophytes and invertebrate abundance increase to levels that are able to support them.

Ducks or duck-like species feed mostly on submerged aquatic macrophytes and aquatic invertebrates, some also feed on small fish (Jones *et al.* 2009a). Small shorebirds are known to feed on small aquatic invertebrates and the large wading birds will feed on invertebrates, frogs and fish, and the natural diet of the silver gull is invertebrates and fish (Jones *et al.* 2009a).

Several nests of Black Swans were observed during Phase 2. Swans are opportunistic breeders when conditions are favourable, in the north usually in February to May (Pizzey & Knight 2012). As this species is highly nomadic and only a few nests were seen, it is not likely to be an important breeding ground for the species.

6.3 Aquatic invertebrates

At least 68 species of aquatic invertebrate species were collected in the study area, including species of crustaceans, aquatic insects, water mites, aquatic snails, and an aquatic worm, of which most were collected in Phase 2. The most commonly collected species was the snail *Gabbia* 'beyondie', the copepod *Boeckella triarticulata*, the ostracod *Cyprinotus cingalensis*, and the hemipteran *Anisops nasutus*. None of the species collected are formally recognised as conservation significant, but several represent new or undescribed species currently only known from the study area, including two snail species in the genera *Gabbia* and *Isidorella*, ostracods in the genera *Limnocythere*, *Mytilocypris* and *Bennelongia*, and a conchostracan in the genus *Ozestheria*. In contrast, the described species are generally common and/or widespread.

Species richness was greater at the freshwater sites and increased from Phase 1 to Phase 2 with increasing water levels, but decreased from Phase 2 to Phase 3 with decreasing water depth and increasing salinity. The Beyondie Lakes marsh supported the highest species richness with 61 taxa collected, followed by the single claypan surveyed (44 taxa).

Hydrology is known to affect invertebrate diversity and richness (Jones *et al.* 2009a). A higher water level is also associated with lower salinities due to the salts being less concentrated in a higher volume of water. While some aquatic invertebrates are halotolerant or halophilic, most are not. Therefore, aquatic invertebrate communities exhibit a strong correlation to salinity (Pinder *et al.* 2005). This effect is enhanced by their dependency on aquatic macrophytes as food source and habitat, many of which do not tolerate saline water (De Szalay & Resh 2000).

The hydroperiod (length of time water is present) is positively correlated with species diversity and richness in ephemeral lakes (Casanova & Brock 2000). A longer hydroperiod means that aquatic plants have more time to establish, thrive, and reproduce, therefore living longer and growing more. The invertebrates collected from this survey are known to produce drought-resistant cysts (crustaceans) or have other adaptations such as burrowing or refuge seeking behaviours (insects) to survive the dry period. Some species were exclusively found during Phase 3, including first records of Trichoptera, Lepidoptera and Ephemeroptera, indicating the importance of long-term submersion of the lake habitats for some species.

The paucity of species collected from the playa sites during Phase 1 is consistent with results other inland salt lakes (Appendix 2); however, the overall species richness and diversity indicates that the system is capable of being very productive following a period of extensive rainfall.

Some limitations of the survey result in uncertainty and incompleteness of data analyses, these include taxonomic resolution and lack of regional information.

The taxonomy of some species could not be resolved to species level due to lack of taxonomic knowledge and paucity of regional information. This is particularly true in some Crustacea groups. Whilst some large inland wetlands have been surveyed to provide some biological context, these are may be many hundreds of kilometres away (Appendix 3). The prime difficulty is timing surveys with rainfall. As rainfall is unpredictable in inland areas and often much localised, personnel and gear must be mobilised to remote sites at short notice. Depending on the amount of rainfall, the wetlands may evaporate quickly, and different results are achieved if samples are taken at different times in the hydro cycle, if the water persists for some time.

6.4 CONCLUSION

In summary, the waterbird fauna of the study area is typical for an arid lake system and included three common Migratory species (two recorded, one identified through the desktop review). Opportunistic nesting was reported by the Black Swan. No Migratory avifauna were recorded in significant numbers that trigger the area to represent nationally or internationally important habitat for migratory shorebirds.

The diversity of the aquatic invertebrate fauna is comparable to other lake systems that include freshwater to saline habitats. Highest diversity is maintained by the freshwater marsh of the Beyondie Lakes system. Poor taxonomic knowledge of some invertebrate groups and lack of regional surveys hindered an interpretation of the endemicity of the local fauna; most significant are the presence of two potentially new and endemic species of snails which have a low capacity for dispersal.

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Appendix 1 Site descriptions

Site name: Site 01, playa

Habitat description: bare sediment only present during Phase 1 with additional inundated peripheral samphire in Phase 2 and 3 due to rise in water level.

Substrate: silt/clay with fine salt crusting on top (<1 cm)

Site name: Site 02, channel between playas

Habitat description: bare sediment and submerged vegetation present during Phase 1 with additional inundated peripheral samphire in Phase 2 and 3 due to rise in water level.

Substrate: silt/clay

Site name: Site 03, playa

Habitat description: bare sediment only present during Phase 1 with additional inundated peripheral samphire in Phase 2 and 3 due to rise in water level.

Substrate: silt/clay with slight salt crusting

Site name: Site 04, marsh

Habitat description: bare sediment with inundated samphire around the periphery

Substrate: silt/clay

Site name: Site 08, claypan

Habitat description: bare sediment, emergent/submerged and floating aquatic macrophytes present and inundated samphire around the periphery

Substrate: silt/clay

Site name: Site 09, claypan

Habitat description: bare sediment, emergent/submerged and floating aquatic macrophytes present, waterbird survey only in Phase 2

Substrate: silt/clay

Appendix 2 Aquatic fauna of Western Australian inland salt lakes identified through the desktop review

(Nomenclature used follows that of authors of the report as references. NA= not surveyed)

	Lake Carey catchment wetlands (Timms *et al.* 2006)	**Lake Maitland (Outback Ecology 2007)**	**Lake Maitland (Gregory 2007)**	**Lake Way (Toro Energy 2011)**	**Lake Cowan (Curtin University of Technology 1999)**	**Lake Carey (Gregory 2007)**	**White Flag (Gregory 2007)**	**Lake Way (Gregory 2007)**	**Lake Miranda (Gregory 2007)**	**Lake Kopai (Gregory 2007)**	**Black Flag Lake (Gregory 2007)**	**Lake Zot (Curtin University of Technology 1999)**	**Lake Yindarlgooda (Campagna 2007)**	**Lake Lefroy (Phoenix 2014a)**
Saline/fresh	(saline & fresh)	Saline	Saline	Saline	Saline	Saline	Saline	Saline	Saline	Saline	Saline	Saline	Saline	Saline
INVERTEBRATES														
CRUSTACEA: ANOSTRACA														
Branchinella affinis	X													
Branchinella australiensis	X													
Branchinella denticulata	X													
Branchinella frondosa	X													
Branchinella halsei	X													
Branchinella nichollsi	X													
Branchinella occidentalis	X													
Branchinella proboscida	X													
Branchinella simplex	X													
Branchinella sp.							X				X			
Branchinella sp. (cyst)		X		X									X	
Parartemia n. sp. d													X	
Parartemia n. sp. g	X							X						

	Lake Carey catchment wetlands (Timms *et al.* 2006)	**Lake Maitland (Outback Ecology 2007)**	**Lake Maitland (Gregory 2007)**	**Lake Way (Toro Energy 2011)**	**Lake Cowan (Curtin University of Technology 1999)**	**Lake Carey (Gregory 2007)**	**White Flag (Gregory 2007)**	**Lake Way (Gregory 2007)**	**Lake Miranda (Gregory 2007)**	**Lake Kopai (Gregory 2007)**	**Black Flag Lake (Gregory 2007)**	**Lake Zot (Curtin University of Technology 1999)**	**Lake Yindarlgooda (Campagna 2007)**	**Lake Lefroy (Phoenix 2014a)**
Parartemia n. sp. x	X													
Parartemia sp. nov.											X	X		
Parartemia sp.1	X						X							
Parartemia sp.2							X							
Parartemia cf. *informis*				X								X		
Parartemia contracta											X			
Parartemia *informis*	X													
Parartemia serventyi					X									
Parartemia sp. (cyst) or hatched		X		X	X							X		
Streptocephalus sp.	X													
CRUSTACEA: NOTOSTRACA														
Notostraca sp.								X						
Triops ‘australiensis	X										X			
Triops ‘‘australiensis’’ form a	X													
Triops ‘‘australiensis’’ form b	X													
Triops sp. 1													X	
CRUSTACEA: CONCHOSTRACA														
Caenestheria dictyon	X													

	Lake Carey catchment wetlands (Timms *et al.* 2006)	Lake Maitland (Outback Ecology 2007)	Lake Maitland (Gregory 2007)	Lake Way (Toro Energy 2011)	Lake Cowan (Curtin University of Technology 1999)	Lake Carey (Gregory 2007)	White Flag (Gregory 2007)	Lake Way (Gregory 2007)	Lake Miranda (Gregory 2007)	Lake Kopai (Gregory 2007)	Black Flag Lake (Gregory 2007)	Lake Zot (Curtin University of Technology 1999)	Lake Yindarlgooda (Campagna 2007)	Lake Lefroy (Phoenix 2014a)
Caenestheriella packardi	X													
Conchostraca													X	
Cyzicus sp.											X			
Eocyzicus sp.	X													
Eulimnadia dahli	X													
Eulimnadia sp.											X			
Limnadia sp.											X			
Limnadopsis birchii	X													
Lynceus sp.	X													
CRUSTACEA: CLADOCERA														
Daphniidae								X						
Diaphanosoma sp.	X													
Daphniopsis sp.	X						X						X	
Latonopsis brehmi	X								X					
Daphnia carinata	X													
Daphnia nr *projecta*	X													
Ceriodaphnia sp.	X													
Moinidae sp.								X						
Moina sp.											X			

	Lake Carey catchment wetlands (Timms *et al.* 2006)	**Lake Maitland (Outback Ecology 2007)**	**Lake Maitland (Gregory 2007)**	**Lake Way (Toro Energy 2011)**	**Lake Cowan (Curtin University of Technology 1999)**	**Lake Carey (Gregory 2007)**	**White Flag (Gregory 2007)**	**Lake Way (Gregory 2007)**	**Lake Miranda (Gregory 2007)**	**Lake Kopai (Gregory 2007)**	**Black Flag Lake (Gregory 2007)**	**Lake Zot (Curtin University of Technology 1999)**	**Lake Yindarlgooda (Campagna 2007)**	**Lake Lefroy (Phoenix 2014a)**
Moina baylyi	X													
Moina micrura	X													
Moina australiensis	X													
Macrothrix carinata	X													
Alona spp.	X													
Chydorus sp.	X													
Bosmina meridionalis											X			
CRUSTACEA: COPEPODA														
Apocyclops dengizicus	X				X						X			
Australocypris similis	X													
Boeckella sp. nr *triarticulata*	X													
Boeckella triarticulata	X													X
Calamoecia nr *ampulla*	X													
Calamoecia sp.											X	X		
Calanoida sp.									X					
Copepoda sp.											X			
Meridiecyclops baylyi														X
Meridiecyclops platypus	X													
Meridiecyclops sp.					X						X	X		

	Lake Carey catchment wetlands (Timms *et al.* 2006)	**Lake Maitland (Outback Ecology 2007)**	**Lake Maitland (Gregory 2007)**	**Lake Way (Toro Energy 2011)**	**Lake Cowan (Curtin University of Technology 1999)**	**Lake Carey (Gregory 2007)**	**White Flag (Gregory 2007)**	**Lake Way (Gregory 2007)**	**Lake Miranda (Gregory 2007)**	**Lake Kopai (Gregory 2007)**	**Black Flag Lake (Gregory 2007)**	**Lake Zot (Curtin University of Technology 1999)**	**Lake Yindarlgooda (Campagna 2007)**	**Lake Lefroy (Phoenix 2014a)**
Mesocyclops brooksi	X													
CRUSTACEA: OSTRACODA														
Australocypris sp.				X	X								X	
Bennelongia spp.	X													
Cyprinotus edwardsi	X													
Diacypris dictyote					X									
Diacypris fodiens					X									
Diacypris spp.	X												X	
Diacypris whitei					X									
Heterocypris '548'														X
Heterocypris sp.					X						X		X	
Mytilocypris sp.													X	
Mytilocypris sp.1								X						
nr *Cypridopsis* sp.	X													
nr *Heterocypris* sp.	X													
Ostracoda sp.	X	X		X				X	X					X
Ostracoda sp. (cyst)		X		X										
Repandocypris austinensis	X													
Reticypris sp.	X						X	X			X		X	

	Lake Carey catchment wetlands (Timms *et al.* 2006)	Lake Maitland (Outback Ecology 2007)	Lake Maitland (Gregory 2007)	Lake Way (Toro Energy 2011)	Lake Cowan (Curtin University of Technology 1999)	Lake Carey (Gregory 2007)	White Flag (Gregory 2007)	Lake Way (Gregory 2007)	Lake Miranda (Gregory 2007)	Lake Kopai (Gregory 2007)	Black Flag Lake (Gregory 2007)	Lake Zot (Curtin University of Technology 1999)	Lake Yindarlgooda (Campagna 2007)	Lake Lefroy (Phoenix 2014a)
Sarcypridopsis sp.					X									
Trigonocypris globulosa	X													
ROTIFERA														
Asplanchna herricki											X			
Asplanchna sp. 2					X									
Brachionus nilsoni					X									
Brachionus plicatilus	X													
Brachionus sp.								X						
Filinia perjleri											X			
Filinia sp.	X													
ARACHNOIDA: HYDRACARINA														
unidentified Hydracarina	X													
INSECTA: COLEOPTERA														
Allodessus bistrigatus	X													
Antiporus gilberti	X													
Antiporus sp.									X					
Bagous sp.	X													
Berosus approximans	X													
Berosus australiae	X													

	Lake Carey catchment wetlands (Timms *et al.* 2006)	Lake Maitland (Outback Ecology 2007)	Lake Maitland (Gregory 2007)	Lake Way (Toro Energy 2011)	Lake Cowan (Curtin University of Technology 1999)	Lake Carey (Gregory 2007)	White Flag (Gregory 2007)	Lake Way (Gregory 2007)	Lake Miranda (Gregory 2007)	Lake Kopai (Gregory 2007)	Black Flag Lake (Gregory 2007)	Lake Zot (Curtin University of Technology 1999)	Lake Yindarlgooda (Campagna 2007)	Lake Lefroy (Phoenix 2014a)
Berosus macumbensis	X													
Berosus munitipennis	X													
Berosus nutans	X													
Berosus spp.(larvae)	X												X	
Chostonestes gigas	X													
Coleoptera sp.	X							X						**X**
Copelatus ferrugineus	X													
Copelatus melanarius	X													
Cybister tripunctatus	X													
Dineutus australis	X													
Dytiscidae sp.					X									
Dytiscidae sp.1											X			
Dytiscidae sp.2											X			
Enochrus maculiceps	X													
Eretes australis	X													
Haliplus sp.	X													
Hydrophilus brevispina	X													
Hyphydrus elegans	X													
Limnozenus zealandicus	X													
Liodessus gemellus	X													

	Lake Carey catchment wetlands (Timms *et al.* 2006)	Lake Maitland (Outback Ecology 2007)	Lake Maitland (Gregory 2007)	Lake Way (Toro Energy 2011)	Lake Cowan (Curtin University of Technology 1999)	Lake Carey (Gregory 2007)	White Flag (Gregory 2007)	Lake Way (Gregory 2007)	Lake Miranda (Gregory 2007)	Lake Kopai (Gregory 2007)	Black Flag Lake (Gregory 2007)	Lake Zot (Curtin University of Technology 1999)	Lake Yindarlgooda (Campagna 2007)	Lake Lefroy (Phoenix 2014a)
Macrogyrus australis	X													
Megaporus ?nativigi	X													
Megaporus howitti	X													
Necterosoma penicillatum	X													
Rhantus suturalis	X													
Sciritidae sp. (larvae)	X													
Spercheus platycephalus	X													
Sternolopus immarginatus	X													
Sternopriscus multimaculatus	X													
INSECTA: DIPTERA														
Aedes sp.	X													
Anopheles sp.	X													
Ceratopogonidae sp.	X							X						
Ceratopogonidae sp.1 (black)											X			
Ceratopogonidae sp.2					X						X			
Chironomidae sp.							X		X					
Chironominae sp.									X					
Culex sp.	X													

	Lake Carey catchment wetlands (Timms *et al.* 2006)	**Lake Maitland (Outback Ecology 2007)**	**Lake Maitland (Gregory 2007)**	**Lake Way (Toro Energy 2011)**	**Lake Cowan (Curtin University of Technology 1999)**	**Lake Carey (Gregory 2007)**	**White Flag (Gregory 2007)**	**Lake Way (Gregory 2007)**	**Lake Miranda (Gregory 2007)**	**Lake Kopai (Gregory 2007)**	**Black Flag Lake (Gregory 2007)**	**Lake Zot (Curtin University of Technology 1999)**	**Lake Yindarlgooda (Campagna 2007)**	**Lake Lefroy (Phoenix 2014a)**
Culicidae sp.								X			X			
Culicidae sp. 2					X									
Dasyhelea sp.														X
Diptera sp. (larvae)	X													
Simuliidae sp.	X													
Stratiomyidae sp.	X													
Tabanidae sp.	X								X					
unidentified Chironomini	X													
unidentified Tanypodinae	X													
unidentified Tanytarsini	X													
INSECTA: EPHEMEROPTERA														
Cloeon sp.	X													
INSECTA: HEMIPTERA														
Agraptocorixa eurynome	X													
Agraptocorixa parvipunctata	X													
Anisops calcaratus	X													
Anisops gratus	X													
Anisops stali	X													

	Lake Carey catchment wetlands (Timms *et al.* 2006)	**Lake Maitland (Outback Ecology 2007)**	**Lake Maitland (Gregory 2007)**	**Lake Way (Toro Energy 2011)**	**Lake Cowan (Curtin University of Technology 1999)**	**Lake Carey (Gregory 2007)**	**White Flag (Gregory 2007)**	**Lake Way (Gregory 2007)**	**Lake Miranda (Gregory 2007)**	**Lake Kopai (Gregory 2007)**	**Black Flag Lake (Gregory 2007)**	**Lake Zot (Curtin University of Technology 1999)**	**Lake Yindarlgooda (Campagna 2007)**	**Lake Lefroy (Phoenix 2014a)**
Anisops thienemanni	X													
Anisops sp.	X													
Corixidae sp.											X			
Micronecta sp.	X								X					
Notonectidae sp.1											X			
Notonectidae sp.2											X			
INSECTA: ODONATA														
Anisoptera sp.								X						
Austrolestes aridus	X													
Diplacoides bipunctata	X													
Hemianax papuensis	X													
Hemicordulia tau	X													
Trapezostigma loewii	X													
Xanthoagrion erythroneurum	X													
Zygoptera sp.								X						
INSECTA: TRICHOPTERA														
Helicopsychidae									X					
Triplectides australicus	X													
MOLLUSCA: GASTROPODA														

	Lake Carey catchment wetlands (Timms *et al.* 2006)	Lake Maitland (Outback Ecology 2007)	Lake Maitland (Gregory 2007)	Lake Way (Toro Energy 2011)	Lake Cowan (Curtin University of Technology 1999)	Lake Carey (Gregory 2007)	White Flag (Gregory 2007)	Lake Way (Gregory 2007)	Lake Miranda (Gregory 2007)	Lake Kopai (Gregory 2007)	Black Flag Lake (Gregory 2007)	Lake Zot (Curtin University of Technology 1999)	Lake Yindarlgooda (Campagna 2007)	Lake Lefroy (Phoenix 2014a)
Coxiella sp.								X						
Glyptophysa sp.	X													
Isidorella sp.	X													
Potamopyrgus sp.	X								X					
unidentified gastropod	X													
OLIGOCHAETA														
Oligochaeta sp.	X													
INVERTEBRATE TOTAL	**118**	**4**	**NA**	**6**	**15**	**NA**	**6**	**14**	**10**	**NA**	**25**	**6**	**11**	**6**