Aquatic Invertebrates of Katjarra in the Birriliburu Indigenous Protected Area.

Report to the Birriliburu Native Title Holders and Central Desert Native Title Services

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Contents

Abstract

A survey of aquatic invertebrates was undertaken as part of a larger biological survey of Katjarra (Carnarvon Range) in collaboration with the Birriliburu native title holders. This work has vastly increased the number of aquatic invertebrate species known from this area, from 59 to 169, and is the most comprehensive survey of aquatic habitats in a Western Australian desert range. The fauna was largely a subset of that found in the Pilbara, but with proportionally greater representation of insects, especially beetles, water bugs and fly larvae. The fauna showed less similarity to the aquatic fauna of central Australian ranges. Overall, the fauna consisted of widespread species, but with strong representation of species with northern Australian distributions. Dominance of insects with high powers of dispersal reflects the isolated nature of the area combined with persistence of some wetlands, but insufficient extent of some habitat (such as aquatic plant communities and flowing water) has probably also reduced the likelihood of successful colonization of some groups. Eight species are potentially new and some of these may be locally endemic.

1. Introduction

In 2012/13 the Birriliburu native title holders, along with Central Desert Native Title Services and the Department of Parks and Wildlife collaborated on a biological survey of Katjarra (Carnarvon Range), within the Birriliburu Indigenous Protected Area.

Katjarra is a complex of sandstone outcrops about 150 km NNW of Wiluna in the Little Sandy Desert, straddling the Lake Carnegie and Lake Disappointment catchments. Within these ranges are a variety of wetlands, including gnammas, rockholes within episodically flowing creeks, spring fed creeks and pools and other expressions of groundwater. Just to the north of the range is Lake Kerrylyn, an episodically filled saline playa. Some of the groundwater fed wetlands are probably permanent under the current climate (e.g. Katjarra Spring = Virgin Springs and Talbot Rockhole) while others would dry periodically (e.g. Yamada Soak was dry in August 2004). Some of the rockholes in creeks would retain water for extended periods after rains (years if topped up periodically) but would probably dry during extended low rainfall periods and some of the gnammas would be seasonally filled (though deeper ones may be semi-permanent).

This report presents results of the aquatic invertebrate component of the survey. It is a small but significant contribution to understanding the composition, biogeography and habitat associations of aquatic invertebrates in Western Australia's deserts, which are poorly known compared to most other areas of the state, including other arid zones such as the southern Carnarvon Basin (Halse *et al.* 2000) and Pilbara (Pinder *et al.* 2010). To date, the main source of knowledge of the fauna of WA's desert wetlands is a survey of selected wetlands (including two sites within Katjarra) undertaken in 2004 to identify arid zone wetlands to include on the Directory of Important Wetlands of Australia (DIWA)[1] (Elscot *et al.*

[1] http://www.environment.gov.au/water/topics/wetlands/database/diwa.html

2009). A number of other recent studies of rockpools have focused on the Wheatbelt, Nullabor and Yilgarn rather than the deserts (Timms 2012ab) but provide some comparative data. Other work has been more sporadic and limited, including environmental impact surveys based around salt lakes, reviews of particular taxa (Halse & McRae 2004; Timms, Pinder & Campagna 2009) and work on Lake Gregory in the Tanami Desert (Halse, Shiel & Williams 1998; Department of Environment and Conservation 2009). The Pilbara Biological Survey included three sites in Karlamilyi National Park east of the Pilbara between the Little and Great Sandy deserts. Relevant work in other states includes surveys of wetlands in central Australian ranges (Davis, Harrington & Friend 1993; Davis 1997; Brim-Box *et al.* 2008).

2. Methods

2.1 Site selection and timing of sampling

Field work was undertaken in July 2012 and May 2013. During the first trip eight sites were sampled for aquatic invertebrates and one extra site was sampled for water chemistry. On the second trip invertebrates were sampled at three of the 2012 sites and at seven additional sites. Eighteen invertebrate samples were collected in total (Table 1). The locations of all fifteen sites are shown on

Figure 1 and photos are presented on Plates 1 to 4. Table 1 also lists sites sampled in 2004, including two additional locations on Warritin Creek.

Table 1. List of locations visited in 2004 and/or 2012/13. * = sampled for invertebrates but data for pools combined. # = not sampled for invertebrates. Coordinates measured using GPS and datum GDA94. Site name also includes reference to survey marker number assigned to locality by Peter Muir (1988).

2012/13 site number	Site name	2004 Elscot *et al.* (2009)	Dates 2012	Dates 2013	Coordinates	
1	Virgin Springs – PM65	Virgin Spring	25/07	22/05	25° 06' 54.4"	120° 43' 19.3"
2	Yamada Soak Site 1	Yamada#	25/07		25° 06' 24.6"	120° 42' 51.8"
3A	Talbot Rockhole (Pool) – PM39		25/07		25° 08' 12.4"	120° 44' 35.2"
3B	Talbot Rockhole (Stream)		25/07	21/05	25° 08' 13.4"	120° 44' 35.3"
4	Good Camp Rockhole 1		26/07		25° 15' 27.5"	120° 39' 05.1"
5	Good Camp Rockhole 2 – PM40	Good Camp#	26/07	18/05	25° 15' 29.2"	120° 39' 09.3"
6	Upper Kanatukul gnammas		26/07		25° 15' 47.5"	120° 39' 12.0"
7	Kanatukul (creek in gorge) #	Serpents Glen#	26/07		25° 15' 45.8"	120° 39' 10.1"
8	Warritin Creek Rockhole (lower)	SE Pools (1)#	26/07		25° 16' 41.1"	120° 41' 30.7"
9	Warritin Creek Rockhole (upper)	SE Pools (5)*		17/05	25° 16' 30.8"	120° 41' 30.3"
10	Warritin Creek Rockholes (mid)	SE Pools (4)*		17/05	25° 16' 33.4"	120° 41' 30.2"
11	Yamada Soak Site 2			19/05	25° 06' 23.5"	120° 42' 54.4"
12	No. 2 Rockhole			20/05	25° 04' 55.0"	120° 30' 41.8"
13	Waterfall Rockhole – PM34			20/05	25° 05' 17.4"	120° 39' 37.4"
14	Lake Kerrylyn #			21/05	25° 02' 29.1"	120° 44' 36.1"
15	Snakehole gnamma			18/05	25° 15' 49.7"	120° 39' 04.1"
-	Warritin Creek Rockhole	SE Pools (2)*				
-	Warritin Creek Rockhole	SE Pools (3)#				

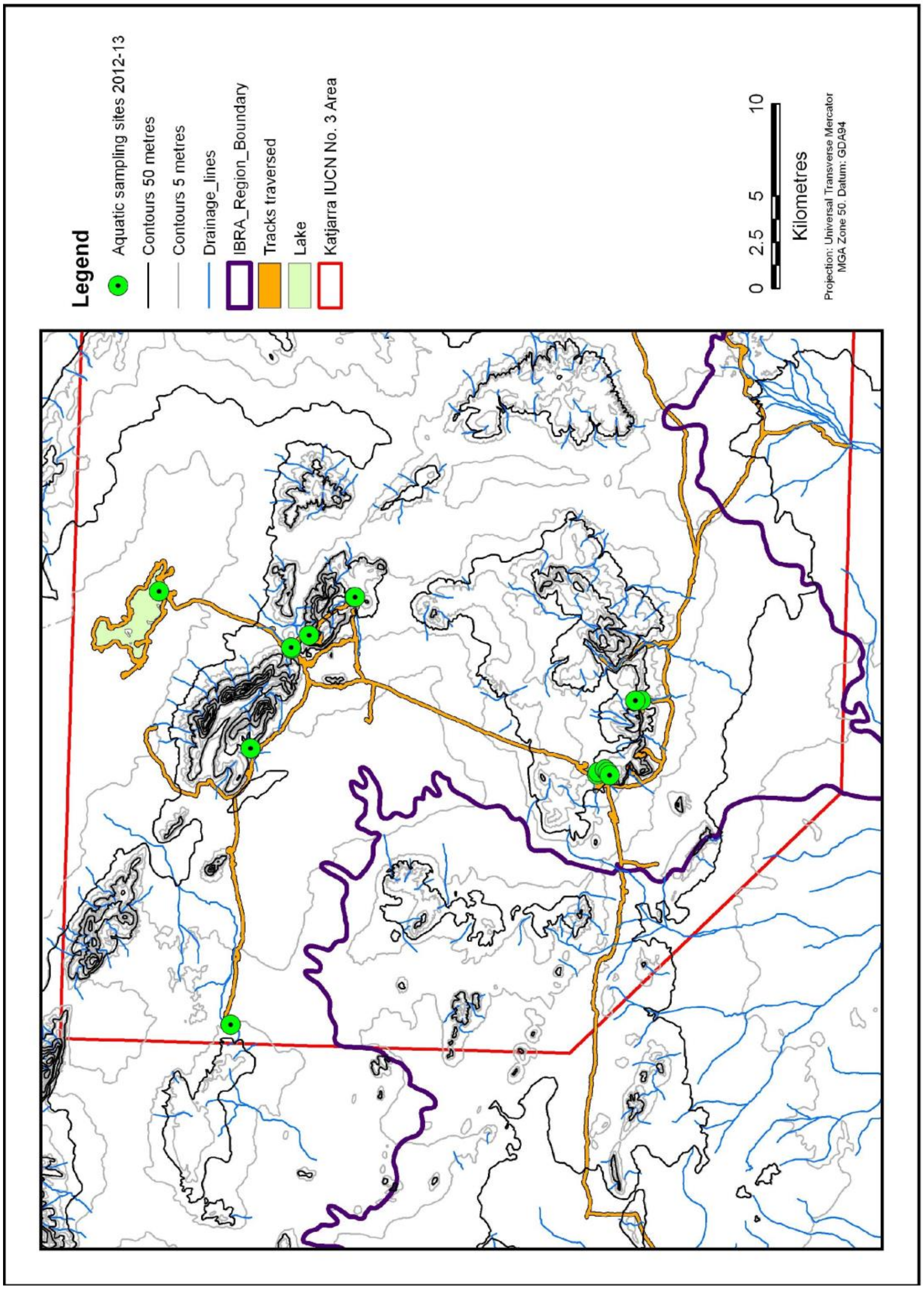
Legend
Aquatic sampling sites 2012-13
Contours 50 metres
Contours 5 metres
Drainage_lines
IBRA_Region_Boundary
Tracks traversed
Lake
Katjarra IUCN No. 3 Area
0 2.5 5 10
Kilometres
Projection: Universal Transverse Mercator
MGA Zone 50. Datum: GDA94

Figure 1. Map showing locations of aquatic invertebrate sampling sites at Katjarra.

2.2 Sampling

At each location pH, surface water temperature, turbidity and conductivity were measured in-situ using a hand held meter. Water samples were collected for analysis of nutrients (total and total filterable nitrogen and phosphorus) and chlorophyll (as a measure of the amount of algae in the water column) by The Chemistry Centre of Western Australia using APHA methods 4500N-C,I, 4500J,G and APHA 10200 (American Public Health Association, American Water Works Association & Water Environment Federation 2012). As a result of a brief rain event while undertaking field work in 2013, a small volume of water pooled in an area of Lake Kerrylyn (Plate 4cd) but not enough for a water sample to be collected. A water sample was also not collected at site 15.

At each site, the percent areal cover of submerged and emergent aquatic plants was estimated. Sediment was described by estimating percent areal cover of silt/clay, sand/gravel, cobble/pebble, boulders and bedrock. Maximum depth was measured with a graduated pole. Sites that had been scored for habitat characteristics in 2012 (sites 1 and 5) were not re-scored in 2013. Talbot Rockhole Pool was not scored for habitat or substrate characteristics because of its depth.

At most sites, invertebrates were sampled using sweep nets with mesh sizes of 50 microns and 250 microns (1/20 and 1/4 mm). The fine mesh net was used to sample animals swimming in the water column whereas the coarser net was used to sample animals in all habitats (e.g. sediments and aquatic plants). The amount of sampling depended on the size of the wetland but aimed to sample all habitats present without disturbing the whole wetland. The small gnammas (sites 6 and 15) were sampled by disturbing the sediment and passing a few litres of the water and suspended material through a fine mesh net. At the largest site (Katjarra Spring), a total of 50 metres of sweep netting (with each mesh size) was used in 2012, combining all habitats from the base of the rock to the upper-most pools in a single sample, but in 2013 smaller habitat-specific samples (flowing water, sand, pools with sedge and rockface seepage) were collected at this site. At intermediate sized sites the samples consisted of several metres of sweep netting with both net types. Before preserving the samples, coarse inorganic sediment was removed by elutriating in buckets and coarse organic matter was removed by washing the debris in clean water before passing that water back through the net. All benthic (250 micron mesh net) samples were preserved in 100% ethanol and all plankton (50 micron mesh net) samples were preserved in 10% buffered formalin.

2.3 Sample processing and identification

All samples were passed through a series of sieves in the laboratory: 2mm, 500 and 250 μm mesh sizes for the benthic samples and 250, 90 and 50 μm for the plankton samples. The contents of each sieve was searched under a dissecting microscope and representatives of each recognizable species were removed. All species were identified to the lowest taxonomic unit possible. Where species could not be identified as a described species, then morphospecies codes were used that are compatible with previous DPaW projects, including a survey of the Pilbara (Pinder *et al.* 2010). A few taxa, such as flatworms and roundworms could not be identified. Rotifers were identified for the 2012 samples but not for those collected in 2013 due to time and cost constraints. A voucher collection of these specimens is being collated and this will be deposited in the Western Australian Museum.

3. Results and discussion

3.1 Water chemistry

Water chemistry data is presented in Table 2. All sites sampled in 2012 and 2013 were fresh, (salinity < 1g/L). pH ranged from acidic (4.76 at Virgin Spring) to slightly alkaline (8.1 at Gully 2). Five sites exhibited a circum-neutral pH (6.5 to 7.5).

Nitrogen and phosphorus concentrations were generally low, with most sites having total filterable nitrogen concentrations between 80 and 580 µg/L and total filterable phosphorus concentrations between 5 and 20 µg/L. There are no water quality standards for arid zone wetlands in Australia, but these nutrient concentrations are mostly below values that would trigger concern in south-western Australia (ANZECC and ARMCANZ 2000). Notable exceptions were No. 2 Rockhole (site 12) with higher levels of total filterable nitrogen and phosphorus (1700 µg/L and 30 µg/L respectively) and Kanatukul Creek (site 7) with higher total filterable nitrogen (1400 µg/L). Both of these sites also had high total nitrogen concentrations (1900 µg/L and 1400 µg/L). The higher nutrient concentrations at No. 2 Rockhole may be related to use of the area by livestock. No. 2 Rockhole was also more turbid (69.8 NTU) than the remaining sites (which had an average of 5.85). Higher nitrogen at Kanatukul may be associated with processes occurring in the extensive bacterial mats.

3.2 Habitats

Data on habitats within the pools are presented in Table 2. Water depth varied between 7 cm and 85 cm for most sites, with an average depth of 41 cm. Exceptions were Warritin Creek Rockhole 1 (1.15 m) and Talbot Rockhole (depth >1 m). In May 2013 the area had received some recent rainfall and, in general, depth appeared to be slightly greater than in 2012.

Only three sites (Virgin Spring and Warritin Creek Rockholes 1 and 2) had either emergent or submerged aquatic vegetation. At these sites, coverage was still quite low with scores of only 1 or 2 (<20% or 20-40% cover).

Substrates at most sites were dominated by “sand+gravel”, with small amounts of leaves and sticks (usually < 20% by area). Most sites had areas of bedrock, reflecting the underlying geology of the area. Yamada Soak Site 1 differed from the remaining sites in that its substrate was dominated by rich organic sediment (60 – 80%) and high cover (60 – 80%) of leaves and sticks.

Plate 1: Virgin Spring (site 1): (a & b) Upper pools (c) water trickling down rocky slope, (d) bedrock pool, (e) pool with aquatic plants and (f) water seeping from sandstone rockface.

Plate 2: Other northern Katjarra sites: (a) main area of Yamada Soak (site 2), (b) Yamada Soak hollow in calcrete (site 11), (c) Talbot Rockhole (site 3A) and (d) Talbot Rockhole stream (site 3B).

Plate 3: Southern Katjarra sites: (a) Good Camp Rockhole 1 (site 4), (b) Good Camp Rockhole 2 (site 5), (c) Warritin Creek Rockhole 1 (site 8), (d) Warritin Creek Rockhole 2 (site 9), (e) Warritin Creek Rockhole 3 (site 10) and (f) Snakehole gnamma (site 15).

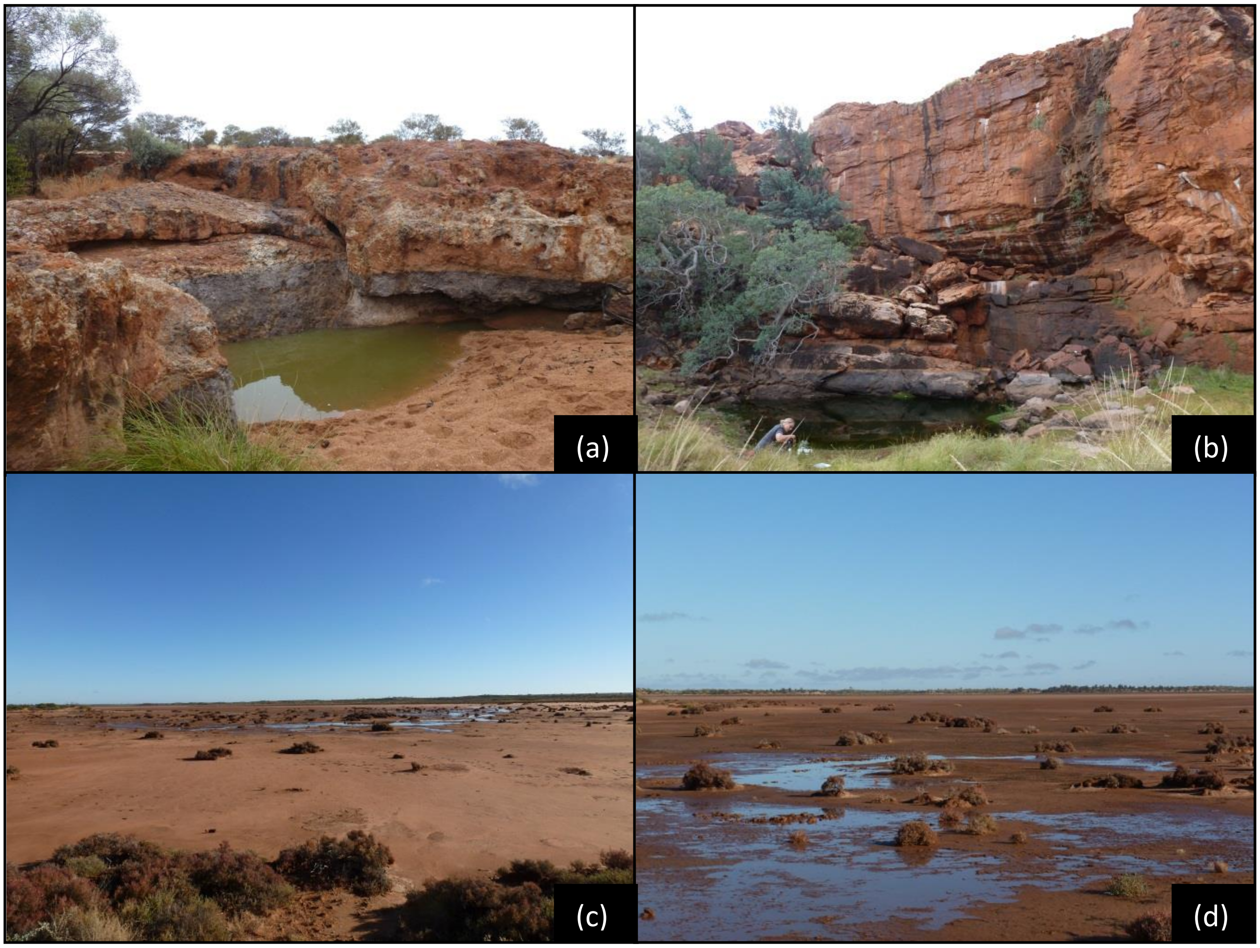

Plate 4: Sampling sites west and north of Katjarra: (a) No 2 Rockhole (site 12), (b) Gully 1 (site 13) and (c & d) Lake Kerrylyn (site 14).

3.3 Aquatic invertebrates

3.3.1 Diversity

Appendix 1 contains all of the aquatic invertebrate data for 2012 and 2013, plus data for two samples from Warritin Creek and Katjarra Spring sampled in 2004 (Elscot *et al.* 2009). Plates 5 and 6 show some of the invertebrate species collected. The number of taxa collected in 2012 and 2013 was 125 and 105 respectively, with 78 collected in both years to give a total of 152. The two 2004 samples had a combined total of 59 taxa, of which 15 were not recorded in 2012/13, bringing the total number of taxa known from the ranges to 167. Several of these are higher order groups, such as nematodes and flatworms, which may represent multiple species, so the figure of 168 is conservative.

There are few other studies of Australian arid zones with which to compare our data, especially for similar types of wetlands. Davis *et al.* (1993) sampled seven streams in the George Gill Range in central Australia in two seasons and collected 109 taxa while Davis (1997) collected 75 taxa from 20 sites in the

West McDonald Ranges in central Australia, to give a total richness of 130 species (Brim-Box *et al.* 2008). Given that the level of taxonomic resolution was lower for some groups in the central Australian studies, but more sites were sampled over a greater area, the central Australian ranges and Katjarra probably have comparable levels of aquatic invertebrate diversity, although there are considerable differences in composition.

At Kajarra, species richness at a site varied between 9 and 73 in 2012/13, with an average of 40. The 2004 samples yielded 32 and 42 taxa. The richest sites (≥ 45 species) tended to be those with greater water volume: the Warritin Creek rockhole sampled in 2012, Katjarra Spring, Good Camp Rockhole 2 and the Talbot sites. The smallest sites (Yamada 2, Snakehole and Kanatukul gnammas) had lowest richness (≤ 15 species). While sampling effort was greater at larger wetlands, the differences in richness would generally reflect the size of the wetlands and greater habitat diversity in larger wetlands. In central Australia Davis *et al.* (1993) recorded between 11 and 64 species per site and Davis (1997) recorded 4 to 26 per site, with the range also reflecting wetland size and sampling effort. The most similar sites in the Pilbara (rockholes and low-flow springs) and two wetlands in Karlamilyi National Park had between 14 and 128 species (average 71) for the same range of taxa (Pinder *et al.* 2010), but many of these were more extensive wetlands with greater habitat diversity and/or were connected to river systems.

3.3.2 New species

Eight potentially novel species were collected.

The ***Australocamptus*** copepod from Virgin Spring and Talbot Rockhole stream was confirmed as being new by Jane McRae (Bennelongia Pty Ltd). Only three other *Australocamptus* have been described, all from groundwater in the Yilgarn Region (Karanovic 2004). It is possible that this species is the same as one of three others awaiting description, but *Australocamptus* tend to have very restricted distributions and specimens from the Little Sandy Desert have not been examined previously. Specimens should be sent to Tom Karanovic (South Korea) for formal description but funds are required for this. This species probably inhabits the groundwater that maintains the two Katjarra wetlands from which it was collected (on either side of the same range).

Phreodrilid oligochaetes are a Gondwanan group of worms that are rare in surface waters of the arid zone and these are the first specimens of this family collected in arid Western Australia outside of the Pilbara. Several species are endemic to the Pilbara where they occur in groundwater and wetlands with groundwater influence (Pinder 2008). By contrast, phreodrilids have not been recorded in groundwater of the Goldfields/Yilgarn, probably because the calcrete aquifers of these regions tend to be saline and they are not present in the southern Carnarvon Basin. The single phreodrilid specimen from Katjarra Spring is very likely to be a new species but the only specimen was immature.

The ***Ainudrilus*** worm from Talbot Rockhole stream belongs to an unresolved complex of similar species but there are some features of the Katjarra specimens that suggest it might be different to those seen from elsewhere.

Table 2. Water chemistry and habitat data for Katjarra wetlands sampled in 2012/13. See Table 1 for site names and dates.

Site	1	1	2	3A	3B	3B	4	5	5	6	7	8	9	10	11	12	13
Year	2012	2013	2012	2012	2012	2013	2012	2012	2013	2012	2012	2012	2013	2013	2013	2013	2013
Water chemistry																	
Surface temperature (°C)	14	18.6	16	17.2	16.3	21	13.1	12.5	18.2	17.5	17.6	18.6	26.1	19.1	26.2	17.8	18.1
Field Conductivity (µS/cm)	57	47.5	193.1	176.5	175.5	188.2	185	138.3	130.8	109.9	52.6	61.5	59.6	93.7	394	57.6	23.3
Field Salinity (g/L)	0.03	0.02	0.08	0.08	0.08	0.08	0.08	0.06	0.05	0.05	0.02	0.03	0.02	0.04	0.17	0.02	0.01
Field pH	5.07	4.76	6.31	6.5	6.48	6.22	6.84	5.55	6.01	5.12	5.66	5.12	4.88	4.81	6.65	7.33	8.1
Total Filterable Nitrogen (µg/L)	90	*	310	80	140	*	580	410	260	110	1400	180	100	360	330	1700	350
Total Filterable Phosphorus (µg/L)	5	*	5	5	5	*	5	5	10	5	5	5	10	10	20	30	10
Total Nitrogen (µg/L)	90	*	550	80	140	*	590	490	280	110	1400	180	100	400	610	1900	370
Total Phosphorus (µg/L)	5	*	40	10	10	*	5	5	20	10	5	5	10	20	60	50	20
Turbidity (NTU)	3.4	1.6	19.1	2	3.6	5.2	2.2	25	6	3.1	-	3.5	2.6	3.3	-	69.8	1.3
Chlorophyll-a (µg/L)	5	*	5	5	1	*	1	20	3	1	1	2	1	6	6	15	2
Chlorophyll-b (µg/L)	5	*	2	5	5	*	1	2	0.5	5	5	5	0.5	2	2	6	0.5
Chlorophyll-c (µg/L)	5	*	5	5	5	*	5	5	1	5	5	1	0.5	2	0.5	2	0.5
Phaeophytin-a (µg/L)	5	*	3	5	5	*	5	4	0.5	5	5	1	2	3	3	5	0.5
Habitat																	
Depth of invertebrate sample (cm)	30	21	<10	100+	>150	25	61	20	45	20	-	115	50	67	7	85	60
Submerged macrophyte cover (%)	0	0	0	0	-	0	0	0	-	0	-	1	2	0	0	0	0
Emergent macrophyte cover (%)	1	1	0	0	-	0	0	0	-	0	-	0	0	0	0	0	0
											-						
Substrate											-						
Silt+Clay	1	-	0	-	-	0	0	0	-	0	-	0	0	0	0	0	0
Sand+Gravel	1	-	0	-	-	2	0	4	-	2	-	5	4	4	1	5	3
Pebble+Cobble	1	-	1	-	-	1	4	2	-	2	-	1	1	2	1	0	0
Boulder	1	-	0	-	-	4	1	0	-	0	-	0	1	0	0	0	0
Bedrock	4	-	2	-	-	0	2	1	-	3	-	0	1	0	5	1	4
Organic Soil	1	-	4	-	-	0	0	0	-	0	-	0	1	0	0	1	1
Benthic Mats	0	-	0	-	-	0	0	0	-	0	-	0	0	0	0	0	0
Particulate organic matter	1	-	2	-	-	0	0	5	-	2	-	0	0	0	0	0	0
Litter (leaves and sticks)	1	-	4	-	-	1	1	1	-	1	-	2	1	1	2	1	1
Logs	0	-	0	-	-	0	0	0	-	0	-	0	0	0	0	0	1

For sediment and aquatic vegetation, values in this table represent %areal cover as follows: 0 = none present, 1 = 0 to 20%, 2 = >20 to 40%, 3 = >40 to 60%, 4 = >60 to 80%, 5 = >80%. * = no water samples collected. - = habitat measures not recorded.

Plate 5: Invertebrate fauna observed or collected in the field; (a) Dragonfly adult (*Diplacodes haematodes*), (b) Dragonfly adult (*Orthetrum caledonicum*), (c) Giant Water Bug (*Lethocerus distinctifemur*) at Good Camp Rockhole 2 (CRS005), and (d) Water Scorpion (*Laccotrephes tristis*) at Virgin Spring.

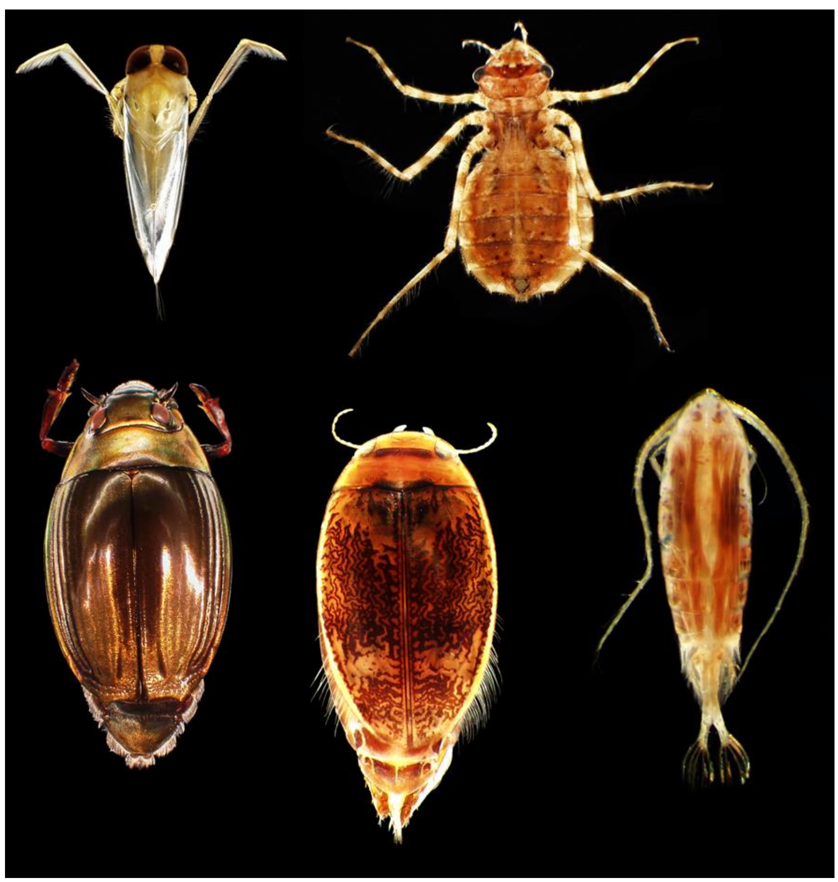

Plate 6: Aquatic invertebrate species recorded at Katjarra. Clockwise from top left, *Anisops thienemanni* (backswimmer), *Hemicordulia tau* (dragonfly), *Boeckella triarticulata* (copepod), *Laccophilus sharpi* (beetle) and *Macrogyrus gibbosus* (whirligig beetle).

Ostracods belonging to the genus *Cypricercus* may also be new. Specimens collected from Warritin Creek by Elscot *et al.* (2009) were given the name *Cypricercus* sp. 415, which was first used for specimens collected in the mid-West (Halse *et al.* 2000; Pinder *et al.* 2004) and later for specimens from a wetland near the south coast (Cale, Halse & Walker 2004). Specimens collected from Warritin Creek in 2012/13 (and named ***Cypricercus* type 2**) are probably the same as those collected in 2004 but are sufficiently different from other 'sp.415' to suggest that it may be a separate species. ***Cypricercus* type 1**, from several Katjarra sites, does not match any other *Cypricercus* in the extensive DPaW ostracod collection.

The ***Micronecta*** hemipteran from Good Camp Rockhole 1 looks sufficiently different to the closest species, *Micronecta gracilis* (collected from other Katjarra), to warrant further examination, but it has not yet been sent to the relevant taxonomist.

One of the tanypod chironomids (non-biting midges) from Talbot Rockhole stream is most similar to a species known as '**Pentaneurini genus V20'** (Leung, Pinder & Edward 2011) that is common in south-western Australian streams. However, the Katjarra specimens are clearly a different species not previously collected by DPaW.

Finally, the ***Ecnomus*** trichopteran is clearly allied to *Ecnomus pilbarensis* but is sufficiently different for David Cartright (the Australian expert on this family) to suspect that it may be something new. Molecular analyses would be required to confirm.

Talbot Rockhole and the associated stream (sites 3A and 3B) were notable for having five of these eight species. Good Camp Rockhole had three of these species and all other sites had ≤2.

3.3.3 Species associated with groundwater discharge

Two of the above species are presumed to also inhabit the groundwater feeding Virgin Spring and Talbot Rockhole: the phreodrilid oligochaete and the *Australocamptus* copepod. Phreodrilids commonly occur in groundwater and their occurrence in arid-zone wetlands is generally associated with groundwater discharge. This species is very likely to be a relictual occurrence since the family is of Gondwanan origin and would not occur in any surrounding wetlands not also associated with groundwater discharge. In this respect, the phreodrilid is equivalent to the presence of *Sclerocyphon fuscus* (Psephenidae: water pennies) in central Australia (Davis 1986; Brim-Box *et al.* 2008) although that species is also known from the temperate south-east. All three described species of *Australocamptus* (plus three other known but undescribed species) are known only from groundwater (one in the Yilgarn and two in eastern Australia) [2] and the Katjarra specimens have the same elongate body form that would suggest that it is adapted for a subterranean life. The cyclopoid copepods *Mesocyclops brooksi* and *Microcyclops varicans* are also regularly found in groundwater.

[2] Dr Tom Karanovic, Hanyang University, South Korea, email 9 Aug 2013.

3.3.4 Composition and biogeography

The 2012/13 fauna was dominated by insects (75%: blue segments in Figure 2), particularly beetles (Coleoptera) and fly larvae (Diptera). Crustacean were the next dominant group (14%: green segments in Figure 2), with most of these being water fleas (Cladocera) and seed shrimps (Ostracoda). There were also several water mites (7%) and aquatic earthworms (2%) but only a single species of mollusc. These figures (and those for other regions below) exclude rotifers and protozoans since they were not identified in 2013, but five rotifers and four protozoans were present in 2012. In the Pilbara and Wheatbelt regions, insects comprised only 55% and 43% of the fauna respectively and crustaceans comprised 43% of species in both regions. The Katjarra fauna is clearly much more insect dominated. In the central Australian studies, insects comprised 65% of the fauna and crustaceans 18%, although these figures are less certain due to incomplete identification of many taxa (especially the crustaceans).

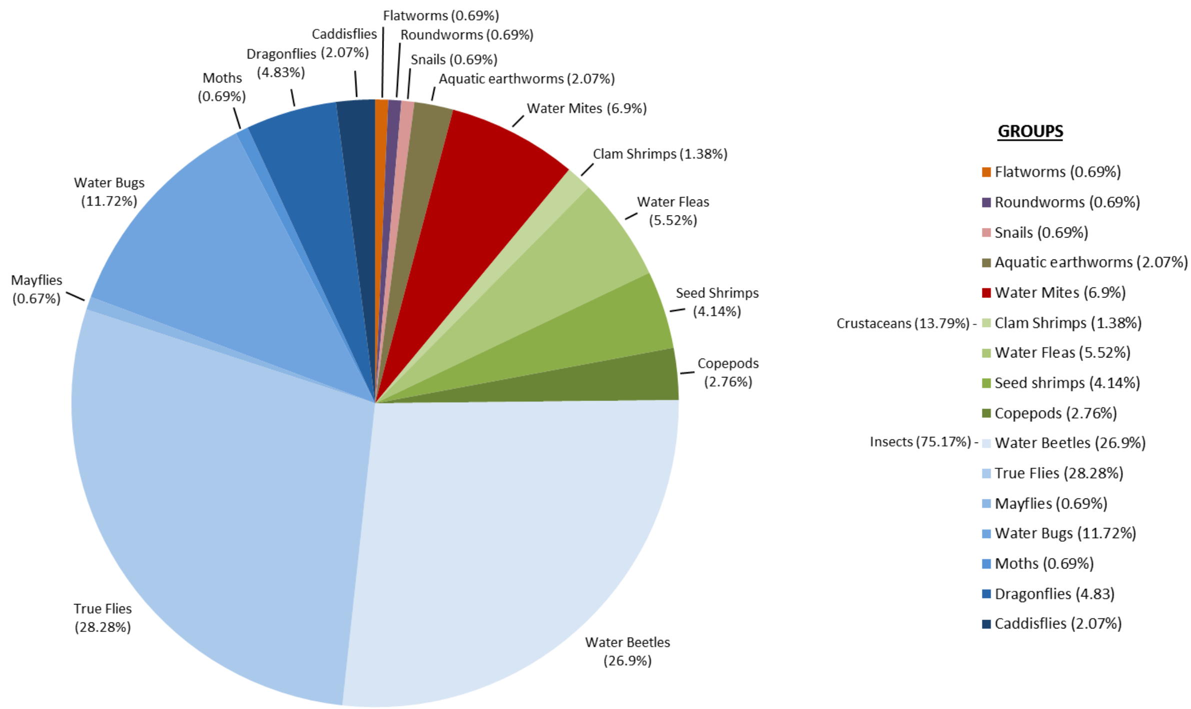

Figure 2. Proportional richness of major groups of aquatic invertebrates at the Katjarra wetlands sampled in 2012/13, excluding rotifers and protozoans.

Comment on biogeographic affinities is hampered by a lack of comprehensive survey in many parts of the inland and north of Australia and incompleteness of current data compilations such as Atlas of Living Australia (http://www.ala.org.au/), though the latter was used here to assist with species distributions. About a third of the species collected at Katjarra are distributed very widely across Australia. On available evidence, 23% have northern Australian distributions that extend into the arid zone, a few of which (e.g. the beetle *Tiporus lachlani*) may be north-western species rather than species that occur more widely across northern Australia. Only 7% have southern (and usually also eastern) Australian distributions that also extend into the arid zone, including a few that are south-western endemics such as the mosquito *Culex latus*. Only one species, the whirligig beetle *Macrogyrus gibbosus*, appears to be an inland arid zone specialist, but the eight species that appear to be new and undescribed (see above) may also have primarily inland distributions. For most of the remaining one third of species we can say little about their wider distributions, mostly because they could not be formally identified (especially the fly larvae).

Of the 115 Katjarra taxa for which taxonomic resolution allows comparison, 99 (86%) were also recorded in the Pilbara by Pinder *et al.* (2010). This suggests that the Katjarra fauna is largely a subset of that occurring in the Pilbara, albeit much more insect dominated. Katjarra species not occurring in the Pilbara are otherwise widespread in south-western or southern/eastern Australia or are the potentially new species listed above.

In contrast to the Pilbara, only 24 species were common to Katjarra and the central Australian wetlands studied by Davis (1997) and Davis *et al.* (1993). The central Australian wetlands had another 68 species not collected at Katjarra while Katjarra had 67 not recorded in central Australia. While this is likely to be an underestimate of similarity there are clearly major differences in the faunas of the two regions. Species in common are mostly ones with very broad Australian distributions. The central Australian lists contain some entire phyla or orders that were absent at Katjarra, including cherubin shrimps (*Macrobrachium*), shield shrimps (Notostraca), leeches and sponges. Several widespread families were also present in central Australia but absent at Katjarra, including sphaerid clams, several snail families, thaumeliid flies, simulids (black flies), caenid and leptophlebiid mayflies, gomphid dragonflies and psephenids (water penny beetles). These groups, except for the thaumeliids and water pennies, are also present in the Pilbara and many additional families are present in the Pilbara but absent from Katjarra. Absence of these groups in Katjarra is probably a combination of the small size of the range, its geographic isolation, the low number and small size of the wetlands and low aquatic habitat diversity. The Pilbara region, in addition to being much larger, has many larger, more permanent and highly connected wetlands with greater habitat diversity. This is also true, albeit to a lesser extent, of the central Australian ranges, which include the headwaters of the Finke and Hugh Rivers and numerous springs and pools within shaded gorges. Most of these missing groups are weakly flying insects or passive dispersers (reliant on wind, floods or other animals to disperse) that may never reach Katjarra (or not recolonise after local extinction). For instance, while the central Australian wetlands had nine snails and clams and the Pilbara 19, Katjarra had just one (from a particularly sandy pool where it could perhaps take refuge from drought in the sediments). A virtual lack of aquatic plant communities in Katjarra may have contributed to there being just seven species of dragonflies and damselflies at Katjarra (compared to17 in central Australia and 36 in the Pilbara), despite this group being known to disperse very widely in the arid zone[3]. Leptophlebiid mayflies and black flies are associated with flowing streams, which are almost absent at Katjarra, other than trickling water at Katjarra Spring. By contrast, other groups were disproportionately well represented at Katjarra. The 39 beetles represent a third of the entire Pilbara beetle fauna and is more than the 27

[3] E.g. lack of genetic divergence between central Australian and Pilbara species of some dragonflies: Amy Smith, Monash University, pers. comm., via email.

recorded in central Australia. Hemipterans show a very similar pattern, but these and the beetles are generally strong flyers and are generally not associated with flow or aquatic macrophytes. The large number of beetles and hemipterans at Katjarra suggests that there has been sufficient permanent water over many years to allow these to colonize and maintain populations. Nonetheless, occasional severe droughts may have eliminated less active dispersers that had managed to reach the area.

Two of the Katjarra sites were small gnammas (Snakehole gnamma and the upper Kanatukul gnammas) so it is interesting to compare the faunas of these (and the other wetlands) to the Yilgarn/Goldfields gnammas studied by Timms (2012ab). In those studies, 54 species were recorded on the seven most northerly and easterly granite rocks in the 200 to 300 mm rainfall zone. Of those species, only 12, almost all widespread insects and none being seasonal/ephemeral wetland specialists, occurred in Katjarra wetlands and none of them occurred in the above gnammas. The only species recorded from Katjarra that could be considered temporary wetland specialists are the juvenile (unidentifiable) clam shrimp from Snakehole gnamma and the non-biting midge *Paraborniella tonnoiri* (from both of the above gnammas plus shallow bedrock pools at Katjarra Spring). However, this type of habitat has probably been under sampled at Katjarra. Visits to the area soon after good rains would probably reveal other temporary wetland specialists, including other ostracods, fairy shrimp and shield shrimps. Lake Kerrylyn, when it floods, will also have a distinct fauna.

4. Conclusions

The Katjarra wetlands support a fauna that is at least as rich as those in the much larger George Gill and West MacDonald ranges west of Alice Springs. However, the fauna is not as phylogenetically diverse, lacking numerous groups with poor dispersal capabilities which indicates long term isolation from other surface waters. The fauna appears to be largely a subset of that occurring in the Pilbara, albeit one much more dominated by widespread insects, but with a few additional southern elements and some potentially new species. Most notable of the likely new species are phreodrilid oligochaetes, which may represent a relictual occurrence of a largely mesic group, and the new species of presumably stygophilic *Australocamptus* copepod. These two species indicate that sampling of groundwater in the region could reveal a distinctive stygofauna. Sampling within a few weeks of good rains might reveal additional rock pool specialists using shallow ephemeral pools on the tops of the ranges.

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