4 Aquatic Invertebrates

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4.1 Summary

In August 2017, 26 samples of aquatic invertebrates were collected from nine springs, doubling previous sampling effort and increasing the number of sampled springs from 15 to 21. At least 496 aquatic invertebrate taxa have now been collected, nearly half of which were first collected in 2017. The species pool at individual springs and across the springs would further increase with additional sampling. The springs were large compared to the sampling effort and sampling effort has been uneven across the range of springs, so it is difficult to compare invertebrate communities of the springs, but at present there is little evidence of subgroups of springs based on their aquatic invertebrate faunas, excepting that springs in the central Kimberley remain relatively poorly sampled. An analysis of the distribution and habitat associations of the invertebrates is hampered by low survey effort at other types of wetlands in the Kimberley and the paucity of readily accessible aquatic invertebrate data for northern Australia. Most individual species are likely to be widely distributed in the region, but a small suite of species is likely to be rare and possibly restricted to these springs or other groundwater discharge areas in the Kimberley. There was some overlap with composition of similar organic mound springs at Walyarta, but with many species known only from the Kimberley or Walyarta springs. The composition of the aquatic invertebrate fauna of the Kimberley Mound Springs is unlikely to be replicated in other wetlands within the region or elsewhere in Western Australia.

4.2 Background

4.2.1 Aquatic invertebrate survey in the Kimberley Region

There are very few published studies of aquatic invertebrates of the Kimberley Region. Williams (1979) undertook some early survey work and summarised the little that was known from the Kimberley region at that time, listing only 70 species from across the Kimberley and north-eastern Northern Territory. There has been some taxonomic work undertaken which has added to knowledge of particular groups (e.g. Watts, 1987; Andersen & Weir, 1998; Dean, 2001) and some taxonomically targeted surveys (Merrifield, Slack-Smith & Wilson).

The lower Ord River has been extensively surveyed as part of water resource allocation planning for the Ord Irrigation Area (Storey, 2002; Storey & Lynas, 2007; Buckle *et al.*, 2010). The Buckle et al. (2010) study only considered macroinvertebrates at family level but Storey (2002) listed 171 species of macroinvertebrate (microinvertebrates were not considered). Five Kimberley wetlands were included in baseline surveys (including of aquatic invertebrates) as part of a federally funded “Inland Aquatic Integrity Resource Condition Monitoring (IAI RCM) project”: These being Lake Eda (Department of Environment and Conservation, 2009e), Airfield Swamp (Department of Environment and Conservation, 2009a), Parrys Lagoon (Department of Environment and Conservation, 2009c), a swamp at the Ngallagunda Community (Department of Environment and Conservation, 2009d) and Le Lievre Swamp (Department of Environment and Conservation, 2009b). The Ngallagunda wetland is close to Gibb River Spring sampled by Bennelongia (2017). That project only processed the benthic samples (so excluded microinvertebrate groups) but plankton samples were collected and could be processed to improve knowledge of those wetlands. A total of 168 macroinvertebrate species were collected from these wetlands.

A substantial program of river condition assessment using aquatic invertebrates was undertaken across Australia, including 65 sites in the Kimberley, but this involved only family level identifications (Kay *et al.*, 1999; Smith *et al.*, 1999), except for a few insects (especially caddisflies and mayflies) used for taxonomic research.

The Kimberley region is the western extent of the wet/dry tropics so studies of aquatic invertebrates of the Northern Territory and northern Queensland are likely to be useful when assessing distribution and conservation status of species found in the Kimberley, although few studies have published species lists from these areas either. Humphrey et al. (2008) list 581 species for the whole 'northern tropical rivers' (Kimberley to north Queensland), of which they found 292 records from tropical Western Australia. However, the authors also encountered the issue of inaccessible aquatic invertebrate data and the list excludes microinvertebrates (ostracods, copepods, cladocerans, rotifers and protists), mites, and most hemiptera and diptera, which together comprise a large proportion of wetland aquatic invertebrate communities. It also focussed on rivers rather than lentic wetlands. Finlayson et al. (2006), collating information from Humphreys and Dostine (1994), Corbett (1996) and unpublished data, noted the presence of 600 species of macroinvertebrate and 300 species of rotifers, copepods and cladocera in the Kakadu region, but did not provide a species list. I It is likely that several thousand aquatic invertebrates inhabit northern Australian wetlands.

4.2.2 Invertebrate sampling history of Kimberley mound springs

There have been 44 aquatic invertebrate samples collected across four 'projects' between 1993 and 2018. These are listed in Table 1 and described below:

1. Halse et al. (1996) sampled three spring sites during a survey of invertebrates and waterbirds of Victoria-Bonaparte wetlands in 1993. These were a site on the northern side of Long Spring ("Rainforest Swamp"), a small isolated spring ('Edge Swamp") on the edge of the mudflats 1 km north of Long Spring and Brolga Spring. Invertebrates were sampled by taking two 50 metre long sweep net samples; using 53 µm and 110 µm mesh nets.

2. Between 1999 and 2003 staff of Species and Communities Branch, led by Sally Black, sampled invertebrates at several sites across all five of the areas listed above. Unfortunately, there are very few documents surviving from those 1999-2003 surveys (see Appendix 1) and we lack precise coordinates for some of the sampling sites. Most of these collections involved use of a 250 µm mesh net so was biased towards macroinvertebrates. The 2003 collection from Kachana Spring was collected by Andrew

Storey and included a coarse net sample and a fine net plankton sample (A. Storey per. comm.) so more planktonic microinvertebrates were collected.

3. In May 2016 DBCA staff were unavailable to undertake field work so Bennelongia Environmental Consultants were contracted to sample invertebrates from six springs in the central Kimberley (Bennelongia Environmental Consultants, 2017). Five of these appear to be the same as springs sampled by Sally Black for DBCA (then CALM). One core sample was collected from each spring, with 10 buckets of pumped interstitial water put through a 53µm mesh net. If collected, protozoans and rotifers were not identified from these samples and cladocerans were only partially identified.

4. In 2017 DBCA staff (Ecosystem Science Program, Wetlands Section of Environmental Management Branch and Species and Communities Branch) sampled seven springs on Carlton Hill Station, plus Bunda Bunda Spring and Big Spring in the West Kimberley. Twenty six samples were collected (methods below).

Springs sampled for invertebrates between 1993 and 2017 (and flora in 2017) have been given six character codes with the prefix KMS in Table 1, for consistency with other DBCA wetland projects, but in this chapter springs are mostly referred to by the names used in the original projects. It appears that 17 individual springs have been sampled.

4.3 2017 Methods

Seven springs along the Victoria-Bonaparte coast were sampled between 1st and 4th of August 2017, with Bunda Bunda Spring on the Dampier Peninsula sampled on 7th August and Big Spring on the 9th August (Table 3). Figure 7 has a selection of photos illustrating the field work.

4.3.1 Physico-chemical sampling

At each spring pH, temperature and conductivity were measured where surface water was most substantial – generally where the benthic and plankton samples were collected. From the same location three water samples were collected. An unfiltered 150 ml sample was collected for analysis of total nitrogen and phosphorus. Another water sample (mostly 400-500 ml) was filtered through a glass fibre filter paper for chlorophyll (with the filter paper frozen for later analysis of chlorophyll) and the filtrate further filtered (through a 0.45 um filter paper) and the filtrate then also frozen for analysis of total filterable phosphorus and nitrogen. Ideally the nutrient and chlorophyll samples would have been frozen but we had difficulty keeping these frozen for the first few days after collection. A third unfiltered water sample was used for analysis of nephelometric turbidity.

The depth at which the benthic invertebrate sample was collected was recorded and this usually equated to the maximum depth of the water body, which were mostly small ponds or inundated herb/sedge/grasslands under a tree canopy.

Table 3. Locations and details of sampling sites and invertebrate samples taken in 2017.

Site code	Site name	Sampling location	Latitude	Longitude	Benthic sample	Plankton sample	Interstitial sample
KMS0018	Big Spring	Saturated fine organic substrate on eastern side of main spring body	16˚58'45"S	123˚57'12"E			pumped 80L of interstitial water from a core sample
		Mangrove swamp on western side of main spring body with patchy but dense beds of Characeae and submerged vascular plants	16˚58'53"S	123˚56'52"E	10 m sweep	10 litres of scooped water	
KMS017	Bunda Bunda Spring	Shallow inundated area with sparse patchy mangrove fern beneath canopy of xxxxxxx providing dappled shade	17˚09'08.0"S	122˚19'22.9"E	10 m sweep	10 litres of scooped water	pumped 80L of interstitial water from a core sample
KMS010	Potential spring 9	A densely vegetated spring with little surface water. Sampled in a shallow area of dense sedges and *Typha* under canopy of xxxxxx.	14˚54'09.5"S	128˚42'15.0"E		10 lites of scooped water	pumped 80L of interstitial water from a core sample
KMS011	Attack Spring	through 40 metres of *Phragmites* - in clearing of dead *Typha* under *Melaleuca* and ground consisting of thick floating root mat. Corer penetrated through root mat, releasing water	14°53'48.60"S	128°41'4.80"E			pumped 80L of interstitial water (core 1)
		As above but about 20 metres to the west, still under *Melaleuca* canopy. Core taken in area of soft peaty material and plankton sample from a small boggy area with dense Characeae.	14˚53'48.2"S	128˚41'04.1"E		Plankton #2: 10 lites of scooped water from a small pond	pumped 80L of interstitial water (core 2)
		Within dense stand of *Phragmites* along the eastern edge of the spring	14˚53'47.6"S	128˚41'06.9"E	10 m sweep	Plankton #1: 10 lites of scooped water	
KMS012	Potential spring 6 = Enigma Spring	Core sample taken from saturated peat in relatively open area with dense mangrove fern.	14˚52'51.3"S	128˚40'36.5"E			pumped 64L of interstitial water from a core sample
		Plankton sample taken from small muddy puddles in clayey substrate	14˚52'48.3"S	128˚40'38.4"E		4 metres of sweeping while trying to catch fish	
KMS013	Long Spring/Rainforest Spring	Dense stand of *Typha* in north-eastern part of the spring near site EK06 in McKenzie (1991)	14˚53'43.5"S	128˚39'40.2"E		10 lites of scooped water	
		A site in from the mid-eastern edge of Long Spring, consisting of a substantial pool with sparse Typha and pond lilly leaves and very dense leaf litter under canopy of Melaleuca and with palms on the fringes.	14˚54'07.6"S	128˚39'39.7"E	10 m sweep	10 lites of scooped water	pumped 80L of interstitial water
KMS014	Potential spring 1	Large body of open water with no vegetated cover other than a patch of Typha, fringed by xxxxxxxx.	14˚52'54.5"S	128˚33'36.5"E	10 m sweep	10 m sweep	
KMS015	King Gordon Spring	A relatively deep pool under *Melaleuca* and palms with dense covering of leaf litter and some pond lilly leaves.	14˚54'43.6"S	128˚35'37.7"E	10 m sweep	10 lites of scooped water	pumped 80L of interstitial water
KMS016	Bamboo Spring	An extensive area of open water with very little canopy cover on the western side of the spring, with very dense submerged macrophytes.	14˚54'26.6"S	128˚37'18.2"E	10 m sweep	10 lites of scooped water	

Figure 7. Field photos. A, Adam Turnbull at Brolga Spring; B, Long Spring (southern site); C, King Gordon Spring; D, Big Spring (western side); E, sampling interstitial fauna at Enigma Spring , showing bund created around top of bore hole to minimize surface water inflows; F, pond at Bamboo Spring; G, corer in sediment before being withdrawn; H, Collecting a benthic sample at Attack Spring.

4.3.2 Invertebrate sampling

Three types of invertebrate sample were collected, depending on the amount of water present, with the aim of collecting at least one of each sample type at each spring.

Where possible, two samples of surface water aquatic invertebrates (a benthic and a plankton sample) were taken at each of the nine spring sites (both samples covering the same area of the wetland). Most previous DBCA wetland biodiversity survey work has involved sweeping both nets through the water for a total of 50 metres. However, that volume of muddy material would have been too much to sort through in the lab and would have caused excessive disturbance in the small pool areas present in the springs. Instead we have tried to use a reduced but standard method on these springs. Most plankton (water column) samples were collected by scooping up water in 900ml jugs and passing this through a 50 um mesh net, to give a total of 10 litres of collected water. The exception was 4 metres worth of sweep netting using the same mesh size net at Potential Spring 6 and 10 m sweeping at Potential spring 1. All benthic samples were collected by sweeping a 250 um mesh net through the water column and stirring up the substrate and benthic debris for a distance of 10 metres. Coarse inorganic sediment and coarse organic matter were removed from the benthic sample prior to sample preservation by washing debris and elutriating in buckets before passing the water back through the net. Samples were then preserved in 100% ethanol in the field and returned to the laboratory for processing.

Interstitial fauna was sampled at seven of the springs (Table 3), using methods similar to those employed by Bennelongia Environmental Consultants (2017). At each of these sites, an auger was used to extract an approximately 0.5 metre deep core of 8 cm diameter and the resultant hole was allowed to fill with water (which normally happened quickly). Using a manual bilge pump, eighty litres of water (8 x 10L buckets) was pumped out through a 110 µm mesh net and the contents of the net placed into 2 litre pots and preserved with 100% ethanol. The exception was Potential Spring 6 where only 64 litres were collected due to the volume of material remaining in the net. Interstitial samples were normally taken in areas of saturated peat without significant surface water. Where ingress of surface water was a problem it was impeded by creating a bund around the top of the hole. There was no need to excavate an area around the top of the holes in order to ensure the hole filled, as was undertaken by Bennelongia (2017). These samples were taken back to the laboratory for processing and identification of microfauna.

4.3.3 Processing and identification of invertebrate samples

Samples were washed with tap water and sieved through either 250 µm, 90 µm and 50 µm sieve sizes (for the core and plankton samples) or 2 mm, 500 µm and 250 µm sieve sizes (benthic samples). Each sieve fraction was examined separately (except for the 50 µm fractions from plankton and core samples), and representatives of each discernible species removed and preserved in 100% ethanol.

All protozoans, cladocerans and rotifers were identified by Russell Shiel, from specimens picked from samples in Perth and from residues of the plankton samples sent to him in Adelaide (including the 50 µm fractions not sifted in the DBCA lab). For residues, the first 200 animals encountered were identified and then the rest of the residue was scanned for additional species.

All taxa were identified to the lowest taxonomic level possible using keys and voucher specimens and undescribed taxa were assigned morphospecies names based on previous survey work by DBCA. All harpacticoids and some ostracod genera and selected specimens from the orders Hemiptera, Coleoptera and Trichoptera were also sent to relevant experts (see acknowledgements).

4.3.4 Specimen curation

All specimens removed from the samples (other than rotifers and cladocerans) have been retained and are stored in ethanol in glass vials with Western Australian Museum standard labels within larger ethanol filled jars. A subset of specimens representing most species was set aside for deposition in the Western Australian Museum. Rotifers and cladocerans have been retained by R. Shiel for the time being. A few other specimens have been retained by taxonomists.

4.3.5 Data management and analysis

All data analysis was performed using R (R Development Core Team, 2018), with code and input csv data files available at https://github.com/AdrianMP62/KMS7analyses. R packages used were vegan 2.5-2 (Oksanen *et al.*, 2018), Ternary 1.0.2 (Smith, 2018), iNEXT (Hsieh, Ma & Chao, 2018) and eulerr (Larsson *et al.*, 2018). Raw invertebrate data is provided below as Appendix 4.

4.4 Results

4.4.1 Water chemistry

Environmental data is provided in Table 4. Ionic composition data (and derivatives such as sum of major ions) and lab measured conductivity were analysed but are not presented as the ionic composition was significantly unbalanced and therefore results unreliable. This is likely to due to precipitation of ions prior to analysis.

Irrespective of measurement problems all springs were fresh, with field measured conductivity mostly ranging from 116.4 to 1071 µS/cm, except for Potential Spring 1 which was saline at 30000 µS/cm.

Nutrient concentrations were not excessive. Total nitrogen concentrations varied from 0.15 to 2.8 mg/L. When analysed this included very little nitrate, nitrite and ammonia but this could have been caused by difficulties keeping these samples frozen, so these forms of nitrogen could have been assimilated by microbial growth. Total phosphorus concentrations ranged from 0.026 to 0.3 mg/L, with soluble reactive phosphorus being below detectable limits in most samples, although the same caveat re difficulties of freezing of water applies. Chlorophyll concentrations were also low (chlorophyll plus phaeophytin mostly <0.02 mg/L).

The two exceptions were samples taken in areas with less canopy cover where greater photosynthesis was possible (Potential Spring 1 and the west side of Bunda Bunda Spring).

Five of the eight sites had slightly acidic water (pH 5.73 to 6.75). Other sites were about neutral to slightly alkaline (up to 8.34).

A fuller assessment of water chemistry at these springs to determine if they differ in character would involve replicate samples taken at various points at each spring, particularly at points representing different hydrological situations (isolated ponds, flowing vents, moats etc).

Table 4. Environmental data for springs sampled in 2017.

	Chemistry Centre analysis code	Detectable limit	Unit	KMS008 Big Springs 09 Aug 2017 collected at plankton/benthic sample site	KMS017 Bunda Bunda Spring 07 Aug 2017 collected at plankton/benthic sample site	KMS10 Potential Spring 9 01 Aug 2017 collected at plankton sample site	KMS11 Attack Spring 01 Aug 2017 collected at plankton #1 sample site	KMS11 Attack Spring 02 Aug 2017 collected at plankton #2 sample site	KMS12 Potential Spring 6 02 Aug 2017 collected at plankton sample site	KMS13 Long Spring 03 Aug 2017 collected at plankton #1 sample site	KMS13 Long Spring 03 Aug 2017 plankton #2/benthic sample site	KMS14 Potential Spring 1 04 Aug 2017 collected at plankton/benthic sample site	KMS15 King George Spring 04 Aug 2017 collected at plankton/benthic sample site	KMS16 Bamboo Spring 04 Aug 2017 collected at plankton/benthic sample site
LABORATORY MEASUREMENTS														
Cholorophyll	WL177	0.001	mg/L	0.001	0.035	0.004	0.005		0.008	0.002		0.043	0.008	0.011
Phaeophytin	WL177	0.001	mg/L	0.001	0.011	<0.001	0.006		0.006	0.002		0.009	<0.001	0.003
Nitrogen - ammonia	iAMMN1WFIA	0.01	mg/L	<0.01	0.01	0.06	0.02		<0.01	<0.01		<0.01	<0.01	0.01
Nitrogen - nitrite	iNTRN1WFIA	0.01	mg/L	<0.01	<0.01	<0.01	0.01		<0.01	<0.01		<0.01	<0.01	0.01
Nitrogen - nitrate	iNTAN1WCALC	0.01	mg/L	0.01	0.01	0.06	0.02		<0.01	<0.01		<0.01	0.01	<0.01
Nitrogen total	iNP1WTFIA	0.01	mg/L	0.31	0.71	1.8	1.9		1	1.6		2.8	0.15	2
Phosphorus soluble reactive	iP1WTFIA	0.01	mg/L	0.01	0.02	0.08	<0.01		<0.01	<0.01		<0.01	<0.01	<0.01
Phosphorus total	iPP1WTFIA	0.005	mg/L	0.042	0.057	0.15	0.18		0.19	0.094		0.3	0.026	0.16
Turbidity	iTURB1WCZZ	0.5	NTU	24	26	21	8.7		11	6.2		31	12	8.9
FIELD MEASUREMENTS														
Depth			cm	20	5	10		10	10	10	40	10	70	40
Salinity			mg/L	354	97.9	148	215	235	51.9	583	497	19300	466	334
Conductivity			µS/cm	354	191.7	286	407	444	116.4	1071	909	30000	855	629
pH (field)				8.18	6.3	5.8	6.2	5.73	7.01	6.4	6.59	7.89	6.75	8.34
Temperature			˚C	24	25	22	26.7	23.7	27.7	25	22.9	19		21.3
Emergent macrophyte cover			%	5	20	90	0	50	20	100	5	1	2	5
Submerged macrophyte cover			%	40	0	0	0	50	0	0	0	0	2	90
benthic cover of coarse organic matter (leaves and sticks)			%	25	15	80	-	-	0	0	100	0	100	20
Other habitat						few logs				dense typha roots	dense roots and a few logs		few logs	few logs

4.4.2 Aquatic habitats

Most of the surface water expressions sampled for invertebrates were shallow (≤ 10 cm). The southern-most sampling location at Long Spring was 40 cm deep, as was the area on the edge of Bamboo Spring. The deepest site was the area sampled at King Gordon Spring (70 cm).

Most of the areas of open water large enough to sample had some emergent macrophytes (generally sedges), ranging from very sparse (estimated ≤ 5% of the areas sampled for invertebrates) to very dense (≥ 90%, e.g. at Potential Spring 9 and at one of the Long Spring sites – a dense area of *Typha*). Most sampling locations were under moderately dense canopies of trees, but the pools had dappled light. Few sites had substantial growth of submerged macrophytes, exceptions being the more open sites on the western sides of Big Spring and Bamboo Spring, plus the area on the northern edge of Attack Spring where the benthic sample was collected. Potential Spring 1 and the site on the edge of Bamboo Spring lacked significant canopy cover.

Sediment samples were not taken for quantitative analysis, but most substrates appeared to be fine-grained and dense clay-like organic matter under coarse organic litter covering 15-100% of the surface. At Attack spring the plankton sample was collected from a muddy area near the edge of the spring and potential Spring 1 also had inorganic fine muddy sediments. At Long Spring we noted the composition of the depth profile, with coarser organic sediments (recognisable plant debris) in the first 10 cm, then more consolidated fine-grained organic sediments for 50 cm, then a layer of sand at 60 cm.

4.4.3 Aquatic invertebrates

4.4.3.1 Regional mound spring aquatic invertebrate diversity

Appendix 4 contains the raw invertebrate identification data from all samples collected from 1993 to 2017. A total of 355 aquatic invertebrate taxa were collected in 2017, including 217 that had not previously been collected from Kimberley mound springs.

Up to 2003, 232 species had been collected from the springs. The six interstitial samples collected in 2016 by Bennelongia (2017) increased the total to 279 and the 2017 sampling (26 samples) increased the total to 496 (Figure 8). This an approximately linear trend of increasing total richness with increasing number of samples. These figures are derived after taxonomic alignment between the various datasets, including lumping to genus or tribe where inconsistent morphospecies names were used across the various projects (e.g. some pentaneurine and *Tanytarsus* chironomids, *Cypretta* and *Ilyodromus* ostracods and *Hydraena* beetles). The actual number of species collected by these samples, if these inconsistencies were resolved, would almost certainly be over 530. This is quite high diversity when it is considered that 200 samples from 100 sites collected only just over 1000 species during the Pilbara Biological Survey (Pinder *et al.*, 2010) and Pinder et al. (2004) collected about the same from 200 Wheatbelt wetlands.

Statistical estimators of species pool size were applied to this data, but without rotifers and protozoans since these were not collected for the 1999-2001 samples. This reduced dataset contained 412 species and the iNEXT routine of Hsieh et al. (2016) estimated that the total species pool (excluding rotifers and protozoans) would be around 580 species and that collection of the additional species would require an additional 100 or so samples. With the current rotifer and protozoan count of 84 species it is clear the total species pool utilising these springs could be well over 700. This estimate should be used with caution as the method assumes equal sampling types and effort, and this was certainly not the case, but further sampling would definitely increase the diversity of aquatic invertebrates known from these wetlands.

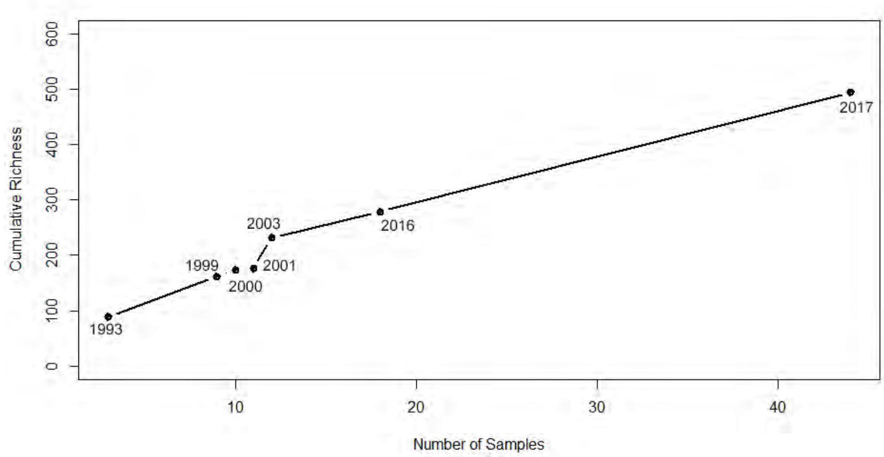

Figure 8. Cumulative number of species collected from Kimberley mound springs between 1999 and 2017, by year. Points are cumulative richness values in 1993, 1999, 2000, 2001, 2003, 2016 and 2017.

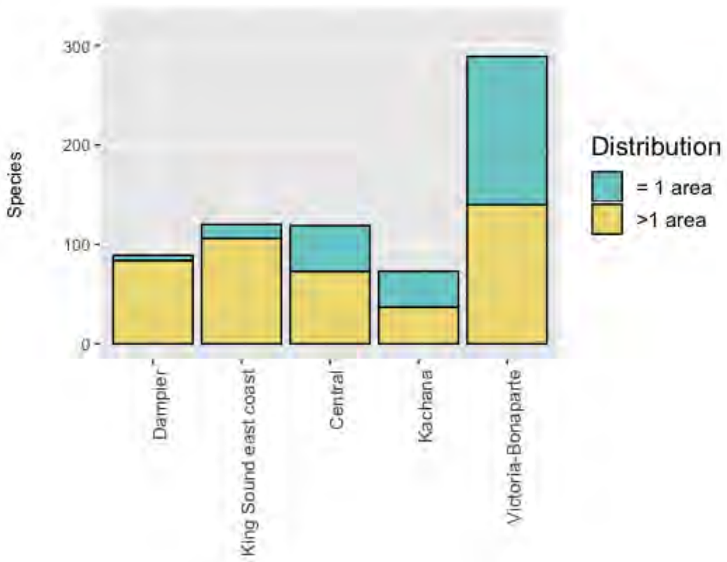

Figure 9. Number of species (other than rotifers and protozoans) recorded from springs in each of the five areas mentioned above showing the proportion (top segments) of those currently known only from that area. Numbers above the columns are the number of springs/number of samples.

Figure 9 shows the total number of species now known from mound springs in each of the five areas listed above (excluding rotifers and protozoans because they were not collected in most samples collected in 1999-2001). The number of species known from each area will reflect sampling effort and is not the focus of the graph. More important is the proportion of an area's species richness currently known only from that area (within the Kimberley Mound Spring dataset). This suggests that the central springs, Kachana Spring and the Victoria-Bonaparte springs have a greater proportion of their aquatic invertebrate fauna not present in other spring areas. By contrast, springs on the Dampier Peninsula (Bunda Bunda Spring and Lollywell Spring) and the east coast of King Sound (Big Spring and Lollywell Spring) have very few species not represented in springs from one or more of the other areas. Unlike richness, the proportion of species known only from one spring is not closely related to sampling effort, with the single sample from Kachana Spring having the same proportion of 'restricted' species (55%) as the 24 samples from the Victoria-Bonaparte coast (54%) and much higher than the 5 samples from each of the Dampier Peninsula and King Sound coast springs. In total 63% of species have been collected from just one of the five areas, but two-thirds of those were only collected in one sample, so the apparently higher 'uniqueness' of the invertebrate faunas of some spring complexes should be viewed as indicative at this stage. Many of the species known only from one area of springs do have broad distributions and occur in other wetland habitats.

4.4.3.2 Sample richness and composition

Richness of aquatic invertebrates within each of the 43 samples from Kimberley mound springs collected since 1993 is shown in Figure 10. In these plots, samples are grouped according to sample type across the different projects: benthic samples only (1999-2001), plankton and benthic samples combined (1993, 2003 and 2017), core samples only (2016 and 2017) and plankton or benthic samples separately (2017 only).

Sampling between 1999 and 2001. The lack of rotifers and protozoans and the relatively low diversity of microcrustacea (Figure 10A) reflects that fact that only a coarse mesh net (250 μm mesh) was used. Composition was therefore strongly insect dominated. Richness per sample varied between 12 and 43 which is low in comparison with later samples.

Samples with plankton and benthic samples combined (1993, 2003 and 2017*).* Figure 10B shows richness of invertebrate where both a plankton and a benthic sample has been collected at each spring, with data from the two samples combined. This was the case for three Victoria-Bonaparte springs sampled in 1993 by Halse et al (1996), Kachana Spring sampled by Andrew Storey[1] in 2003 and 7 springs sampled by us in 2017 (Big and Bunda Bunda Springs in the West Kimberley and five on the Victoria-Bonaparte coast), with Long Spring sampled in both 1993 and 2017. In 1993 and 2003 specimens from the benthic and plankton samples were combined before identification so there is no possibility of using the two samples separately. There are differences in sampling effort between 1993 (50 metre sweep net samples for plankton and benthic), 2003 (unknown sampling effort) and 2017 (10 metre benthic sweep and 10 litre plankton sample). The 1993 samples from Brolga Spring, Edge Swamp and Long Spring had lower richness (41 to 60 species) than most other samples in Figure 10B, despite the greater sampling effort, and few invertebrates other than insects,

[1] Andrew Storey, Wetland Research and Management

microcrustacea and rotifers. The 2003 sample from Kachana Spring was much richer and more diverse, with more water mites than other samples included on this graph but relatively few microcrustacea. Of the sites sampled in 2017 Potential Spring 1 had lowest richness (41 species) and was more insect and microcrustacean dominated, reflecting its higher salinity (30 mS/cm, 19.8 ppt). However, its fauna is almost entirely a subset of the freshwater fauna found in the other springs, with the exception of four rotifers, *Hexarthra brandorfi*, *Brachionus plicatilis* s.l., *Brachionus angularis* and *Cephalodella forficula* and an unidentified hemipteran '*Micronecta* KMS1'. *Brachionus plicatilis* s.l. is a complex of mostly saline water taxa. Presence of these rotifers probably reflects the more open water habitat as much as the higher salinity of this site. The other six springs sampled in 2017 were freshwater springs and had richness varying from 77 to 131 species. For these combined samples the richest springs were Attack Spring and Long Spring.

Figure 11 provides richness of combined benthic+plankton samples from the Walyarta springs (Quinlan *et al.*, 2016) and from the Kimberley region, with the additional species collected where an interstitial sample was also taken. This figure excludes Potential Spring 1 as it has a very different character. The Kimberley samples all had higher richness than the richest of the Walyarta samples, despite the latter involving significantly more sampling effort. This figure also shows the relatively small proportion of the fauna collected only in interstitial samples, although there may be a unique element to the interstitial fauna.

2017 plankton and benthic samples. Figure 10C shows richness by taxonomic group of invertebrates from benthic samples and plankton samples separately, for springs sampled in 2017. Benthic samples were richer which is not surprising considering the greater sample size (10 metres of sweep netting) compared to the plankton samples (10 litres of scooped water). Benthic samples were dominated by insects, mites and microcrustacea (especially ostracods). Plankton samples had relatively fewer insects, a similar number of microcrustacea (but more cladocerans) and had more rotifers and protozoans. The saline Potential Spring 1 had lowest richness in both sample types. Excluding this site, benthic and plankton samples had an average richness of 79 and 62 species respectively. Two plankton samples were taken at two of the springs. At Attack Spring a plankton sample was taken from a pool on the mound (P2) and another was taken from the *Phragmites* filled moat on the north-east side of the spring (P1). These two samples were the highest richness plankton samples with 81 and 89 species and included more microcrustacea than any other samples collected from Kimberley mound springs (23 and 26 species). Two plankton samples were also collected from Long Spring; one from the dense stand of inundated *Typha* on its north-eastern extent (P1) and another from a pool on the drier mound to the south (P2). These had similar total richness (71 and 65 species respectively) but the sample from the mound had fewer microcrustacea and more rotifers.

Interstitial samples collected in 2016 and 2017. Figure 10D shows invertebrate richness within samples of interstitial water pumped from holes in the peat (see Methods) in 2016 (central Kimberley) and 2017 (Victoria-Bonaparte coast). These samples contained relatively few species compared to surface water samples and were much more dominated by insects and microcrustacea. Interstitial samples collected in the central Kimberley in 2016 (Bennelongia Environmental Consultants, 2017) had higher total richness, mainly due to the higher number of insects. Bennelongia (2017) noted that they sometimes had to excavate an area around the ~50 cm deep core hole[2] to allow faster seepage of interstitial water and noted that this may have resulted in surface water species being collected. In 2017 there rarely a problem with the cored holes not filling fast enough and tops of the holes were not expanded. We also tried to take these interstitial samples in areas away from surface water but still in areas of saturated peat to minimise collection of invertebrates from surface water. This may explain the smaller number of insects collected in 2017, even though some taxa collected in 2017 interstitial samples were clearly surface water species (e.g. the damselfly *Ceriagrion aeruginsum* and *Glyptophysa* snails). The Victoria-Bonaparte interstitial samples had numerous species of annelids whereas none were present in the Bennelongia 2016 samples. In 2017, the richest interstitial samples were from Potential Spring 9 (48 species) and from Long Spring (41 species).

Together, the eight interstitial samples collected in 2017, contained 103 species, somewhat less than the 124 species from the six samples collected in 2016 in central Kimberley springs. Of the species collected in 2017, almost a third (31 species) were collected much more frequently (≥3x) in interstitial samples than in plankton or benthic samples and most of those (26) were collected only from interstitial samples. Most of those 31 species are sediment dwellers such as fly larvae, harpacticoid copepods and aquatic earthworms (oligochaetes) which would be expected to occur within the peat substrate. Others were mostly unidentified mites (which may have been living within the peat substrate matrix) plus five species of adult insects (beetles and hemipterans) which were likely to have been washed in from surface water.

In Figure 11 it can be seen that the interstitial samples did not significantly increase richness already revealed by collection of plankton and benthic samples.

Figure 12 shows occurrence of species across the three sampling methods (benthic, plankton and core samples) employed in 2017, using a reduced dataset so that there are five samples of each type collected from the same five springs (289 species). Only 13% of species were collected by all three sample types, showing the value of using multiple methods. Some caution is required here, however, since 71% of the 174 species that were collected only in one sample type were collected only once within this restricted dataset, so logically could not have occurred in more than one sample type.

M. Curran, Benelongia Pty Ltd

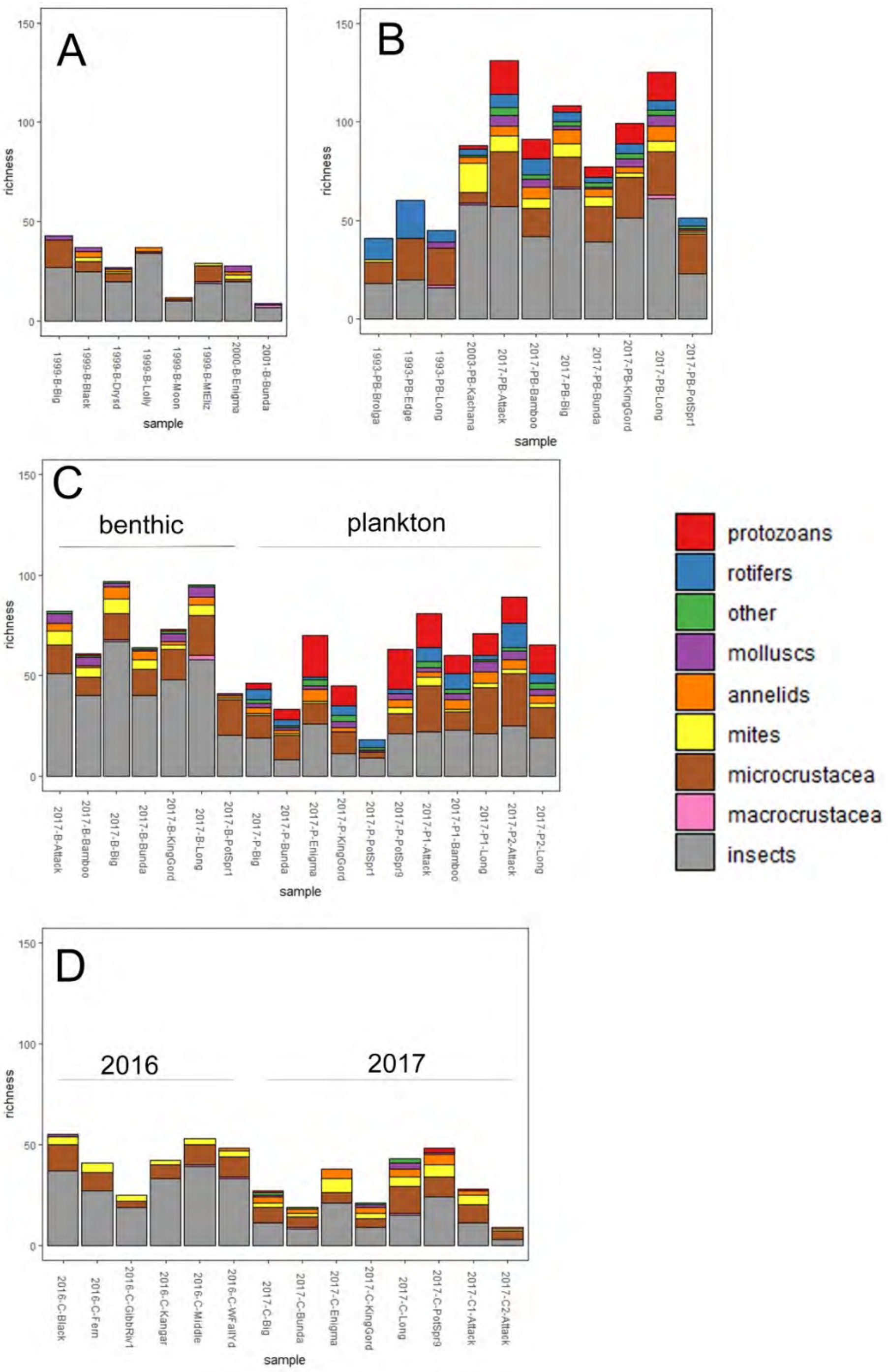

Figure 10. Richness of major taxonomic groups in subsets of similar sample type. A, Samples collected between 1993 and 2001; B, Combined plankton+benthic samples collected in 1993, 2003 and 2017; C, Individual plankton or benthic samples collected in 2017; D, Interstitial samples collected in 2016 (central Kimberley) and 2017 (Victoria-Bonaparte coast).

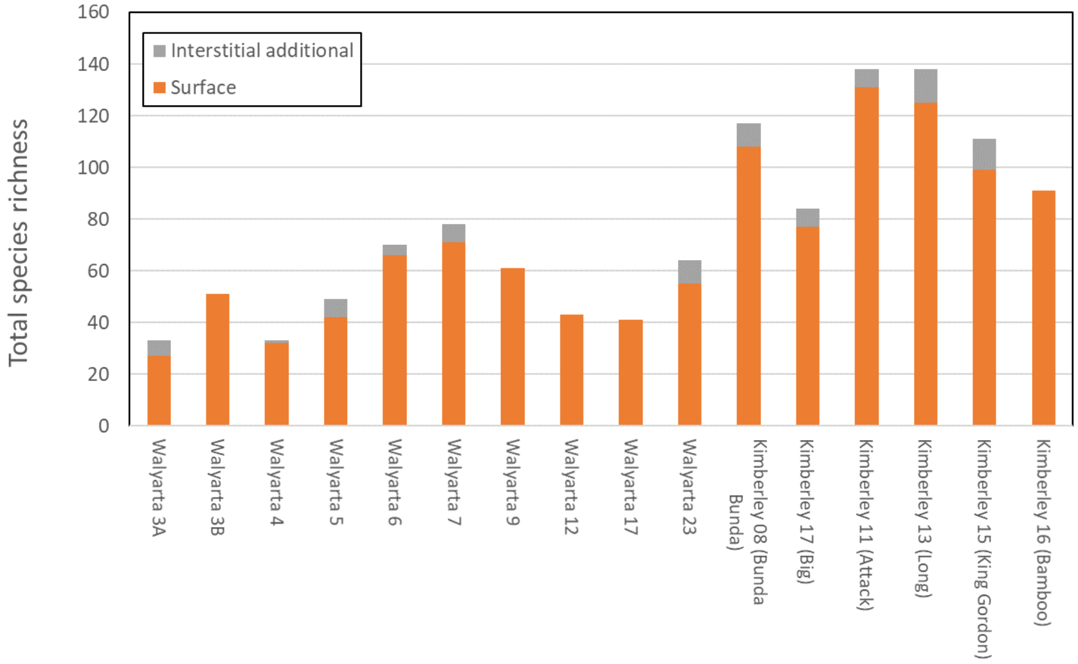

Figure 11. Richness of invertebrate samples collected from Walyarta springs in 2015 (10 left columns) and Kimberley springs sampled in 2017 (six right columns). Orange segments are richness of a combined plankton and benthic sample and grey segments are the additional species collected from an interstitial sample. Absence of grey segments means no interstitial sample was collected for that site.

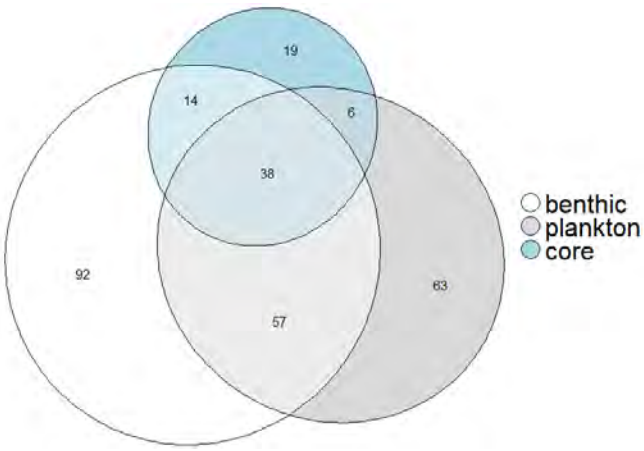

Figure 12. Relative proportions of the total species pool collected by the three sample types, each type represented by one sample collected at each of the same five springs. Ellipses are proportional to the total number of species collected by the five samples of each type. Drawn using the eulerr 5.0.0 R package by Larsson et al. (2018), with a test to confirm that the size of each segment is exactly proportional to the number of species it represents.

The differences between sample types are reflected in an ordination of the individual 2017 samples (Figure 13) produced using the vegan package for R (Oksanen *et al.*, 2018) with Bray-Curtis dissimilarity. In this plot, the plankton and benthic samples from the saline site 14 (Potential Spring 1) are placed well to the left of the remaining freshwater sites. This reflects the presence in this site of some halophilic species such as the rotifers *Brachionus plicatilis* and salt tolerant species such as the beetle *Berosus australiae*. Otherwise the spread of samples is different within each sample type, so the different sample types are not surrogates of one another. There is no indication from this analysis that the two western springs (Big Spring and Bunda Bunda Spring – sites 1 and 8) have different invertebrate communities to those of the Victoria-Bonaparte springs. Removing species with only one occurrence in the dataset produced an almost identical ordination plot. In both cases the ordination plot had a stress of 0.17 indicating that the analysis could not produce a plot that well represented differences in community composition between all samples. However, a 3D ordination (Figure 14) produced very similar separation of sample types with acceptable stress (0.12).

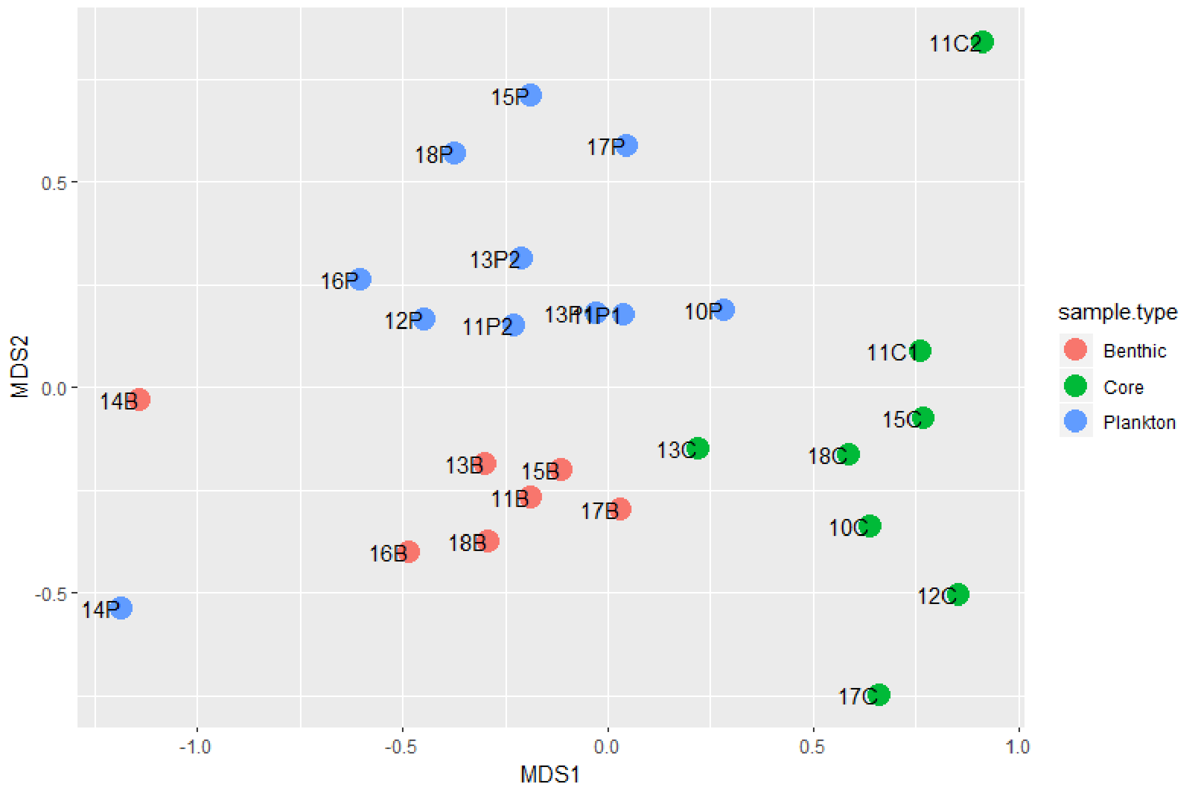

Figure 13. A two-dimensional ordination of invertebrates in all 2017 samples. Site numbers refer to the 'KMS' site codes in Tables 1 and 2. Stress = 0.17.

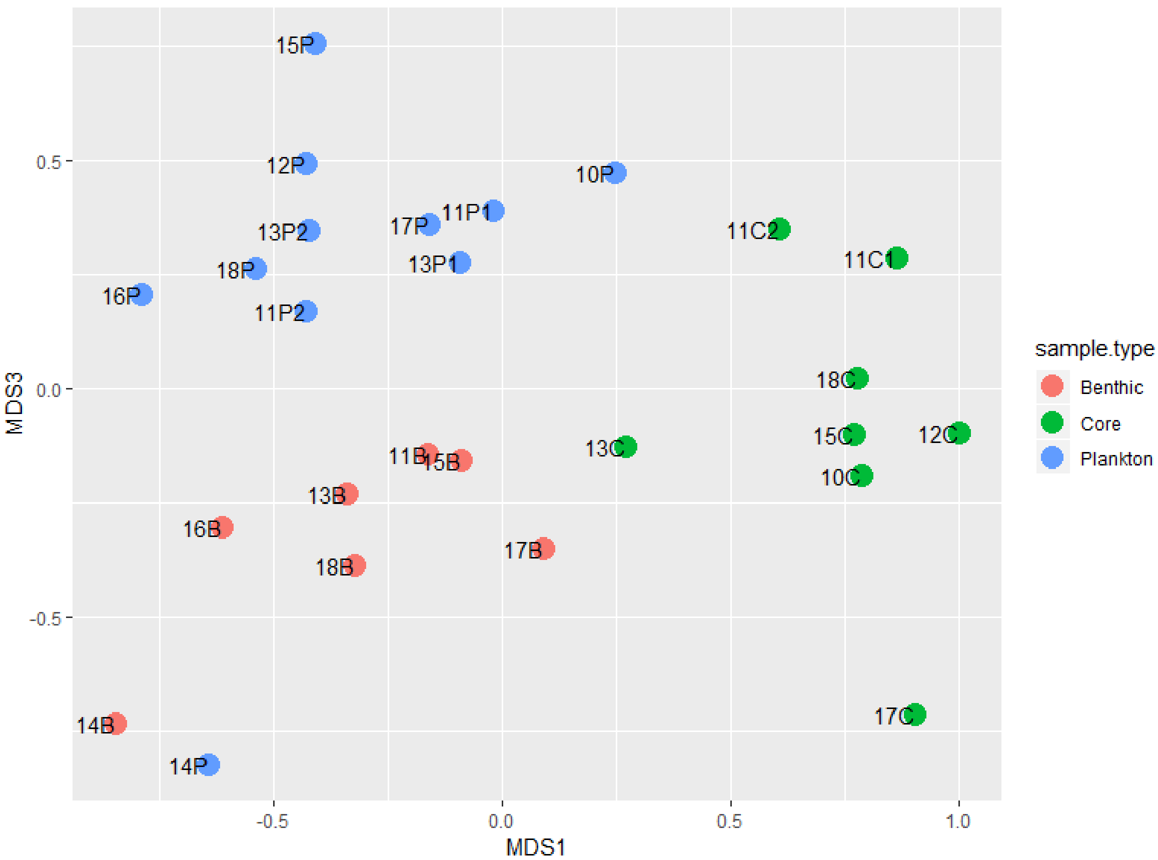

Figure 14. Axis 1 versus axis 3 of a three-dimensional ordination of invertebrates in all 2017 samples. Site numbers refer to the 'KMS' site codes in Tables 1 and 2. Stress = 0.12.

4.4.4 Significant species

None of the species collected are listed as threatened or priority species. However, there has been very little survey of aquatic invertebrates across the Kimberley region and relatively few published studies (with species lists) across northern Australia, making assessments of the distribution and conservation status of Kimberley aquatic invertebrates difficult at present. Nonetheless, some species in these samples have rarely or never been collected in Western Australia (at least in publicly available literature and datasets on Atlas of Living Australia) and some have been rarely collected at all(Table 5).

One of the testate protozoans from Attack Spring, Bamboo Spring and King Gordon Spring is *Difflugia gigantea* Chardez, 1967 and is the first record of this species from Australia (otherwise known from Europe and North America).

Halse et al. (1996) recorded an undescribed species of *Lecane* rotifer from Long Spring (=Rainforest Spring). Whether this is the same species as *Lecane* sp. A or *Lecane* sp. B collected in 2017 is yet to be determined. However, rotifers tend to be widely distributed and so, either way, the 1993 species is not likely to be restricted to these springs.

One of the aquatic earthworm species resembles *Allonais lairdi*, otherwise known from India, South-east Asia and South America, i.e. it is pan-tropical, but the record from Attack Spring is the first for Australia. Worms from Bamboo Spring are only the second Western Australian record of the similarly widespread *Haemonais waldvogeli*, with the only other records from

Australia being Marlgu Billabong (lower Ord River floodplain) and numerous sites in the Murray Darling Basin (Pinder, 2003). Some recent work is demonstrating significant cryptic diversity in supposedly widespread species of aquatic oligochaete, so these specimens may turn out to be distinct Australian lineages. Another oligochaete, from Attack Spring and Long Spring, *Dero* sp. WA5 is similar to *Dero graveli* but may be undescribed.

The anisitsiellid water mite tentatively identified as *Mamersella* sp. is the first record of this genus in DBCA studies and there are no Western Australian records on Atlas of Living Australia. It was recorded only at Attack Spring. The few *Mamersella* records on ALA are also from springs, primarily in the Great Artesian Basin. All previous DBCA records of this family are *Rutacarus* from springs (Pilbara and northern Wheatbelt) and a record of *Sigthoria nilotica* from Kachana Mound Spring in the Kimberley, plus there is an ALA record of *Anisitsiellides* from a spring near Chittering near Perth.

Another water mite, *Arrenurus* sp. WA29 is known only from north-western Australian groundwater fed wetlands: at Walyarta (Quinlan *et al.*, 2016), Nimalarragun wetland near Broome (DBCA report in prep.) plus Big Spring (west Kimberley) and Bamboo Spring (Victoria-Bonaparte) from the present survey. Three other *Arrenurus* have not been previously recorded in DBCA projects and are not described species known from Australia. These are *Arrenurus* sp. WA28 from Long Spring and *Arrenurus* sp. 30 from Big Spring. Bennelongia (2017) recorded an *Arrenurus* from Fern Spring in the central Kimberley and this is here given the code *Arrenurus* sp. WA27 and is also undescribed and not the same as any of the above species. Some of the other water mites may also be new, for example the *Australotiphys* and *Austraturus* from Kachana Spring and the *Axonopsella* from Bunda Bunda Spring.

The ostracod *Strandesia* sp. 653 was recorded from Big Spring in 1999 and again from there and from King Gordon Spring in 2017 but is not known from elsewhere. Other *Strandesia* have also been collected only from Kimberley springs. These are *Strandesia* sp. 360 from Long Spring and a species of uncertain generic identity (*Strandesia*/*Chlamydotheca* sp. 357) collected from Long Spring by Halse et al. (1996), the groundwater fed Nimalarragun wetland north of Broome and other groundwater fed wetlands in the Little Sandy Desert (Pinder & Quinlan, 2013). Other *Strandesia* are found in Pilbara groundwater (Halse *et al.*, 2014) and surface water wetlands in the Pilbara and Carnarvon Basin, especially in temporary waters (Halse *et al.*, 2000, 2014).

An ostracod collected from most of the Victoria-Bonaparte springs sampled in 2017 (but not other springs) belong to the tribe Nealecypridinae. Table 2 in Nagler et al. (2014) suggests these are *Tanycypris*. These are the same as specimens from Long Spring and Edge Spring collected in 1993 that Halse et al. (1996) named *Strandesia ?camaguinensis* Tessler. *Strandesia camaguinensis* has since been designated a junior synonym of the widespread *Tanycypris pellucida* (Nagler *et al.*, 2014) but neither the 1993 specimens nor the 2017 specimens match any of the five described *Tanycypris* in Nagler et al. (2014). *Tanycypris* is an otherwise Eurasian genus other than a species from Madagascar.

Another species of ostracod from several of the Victoria-Bonaparte springs sampled in 2017 appear to be conspecific with '*Herpetocypris* sp. 652' from Big Spring and Black Spring collected in 1999 and specimens collected from the groundwater fed Nimalarragun wetland near Broome in 2018. These appear to belong to the genus *Chrissia* which has not been recorded in Australia but is widespread in Asia and Africa and includes 34 species. In Karanovic

(2012) these specimens key to *Chrissia halyi* Ferguson 1969 from Sri Lanka, but we have not been able to obtain the description of that species for comparison. Most likely our specimens are a new species.

The darwinulid ostracod *Alicenula serricaudata*, is a largely groundwater associated species with a Gondwanan distribution and the records from four of the central Kimberley springs sampled by Bennelongia (2017), plus Bunda Bunda and three of the Victoria-Bonaparte springs in 2017, are the first records for Australia (and the Oceania region) (Martens & Rossetti, 2002).

There is also likely to be undescribed (and probably geographically restricted) species of *Cypretta* and *Ilyodromus* ostracods in this collection, with numerous morphospecies collected and both genera requiring substantial taxonomic research.

The diversity of cyclopoid copepods was notably high at these springs, with ten species recorded in the 2017 survey and twelve species recorded in total across the springs listed in Table 1. For comparison, only seven species have been collected from the mound springs at Walyarta (Storey, Halse & Shiel, 2011; Quinlan *et al.*, 2016), with only four in common. However, Walyarta is a more isolated and confined spring system whereas the springs in Table 1 are distributed over a much larger area and with more extensive surface water. *Microcyclops* sp. TP1 was collected from Long Spring and another wetland on the Victoria-Bonaparte coast by Halse et al. (1996) and was recollected at Long Spring and at King Gordon Spring in 2017. It is an undescribed species not known from elsewhere.

Big Spring had *Mesocyclops woutersi* which has rarely been collected in Australia but is widely distributed in south-east and east Asia (Holynska, 2000). This was collected from the same spring in 1999 and is known from Palm Island in Queensland (Holynska, 2000). The harpacticoid copepod *Canthacamptus grandidieri* is a pan-tropical species, but has rarely been collected in Australia (Hamond, 1987) but was present in Black Spring sampled by Bennelongia (2017) plus Big Spring and several Victoria-Bonaparte Springs in 2017. Hammond (1987) provides some records from north Queensland. Three other harpacticoid copepods are also likely to be undescribed and not previously collected. *Nitokra* '*lacustris*' B07 from Bunda Bunda Spring and three Victoria-Bonaparte Springs (Attack, Long and Potential Spring 9), all from 2017 samples, is part of a species complex. Two species of this complex were recently described from the Yilgarn region of Western Australia (Karanovic *et al.*, 2015) and sp. B07 is likely to be a new species[3]. Canthocamptus sp. B11 was collected from Attack, King Gordon and Enigma Springs (all Victoria-Bonaparte). *Schizopera* sp. B37 was collected only from Potential Spring 1. These last three species are known only from the Kimberley mound springs at present.

A new species of *Karualona* cladoceran (water flea) was collected from three of the Victoria-Bonaparte springs (Attack Spring, Long Spring and King Gordon Spring). This has been provided to an overseas taxonomist for description. This may be what Halse et al. (1996) called '*Alona* n. sp. B' from "Grassed Pool" which is also on the Victoria-Bonaparte coast and may receive some fresh groundwater discharge. Another cladoceran resembles the pan-

[3] Jane McRae pers. comm. Jan 2019.

tropical *Guernella raphaelis* Richard 1892 (Macrotrichidae). This was collected from Potential Spring 9, Long Spring, King Gordon Spring and Attack Spring and represents the first records of this species from Australia. However, as with other 'widespread' species, some cryptic diversity can be expected with greater endemism than the current taxonomy would indicate (Frey, 1988; Elmoor-Loureiro *et al.*, 2010). Halse et al. (1996) recorded two undescribed species of *Macrothrix* cladocerans (also Macrotrichidae), from Edge Swamp and Long Spring, but no undescribed members of this genus were collected in 2017. The *Picropleuroxus quasidenticulatus* from Big Spring, and four Victoria-Bonaparte springs is a new record for WA. There are few other Australian records, although it has a broader oriental/neotropical distribution (Kotov *et al.*, 2013).

The atyid shrimp *Caridina spelunca*, which is restricted to groundwater associated habitats in the central Kimberley, was found by Bennelongia (2017) from Middle Spring and Waterfall Spring. This has not been collected from the Victoria-Bonaparte Springs or the western Kimberley Springs.

The dytiscid beetle *Enochrus fuscatus* (syn. *Enochrus malabarensis*[4]) is widely distributed across coastal regions of northern and north-eastern Australia (plus a record from northern South Australia), but the only other published Western Australian records are those from the Walyarta springs ((Quinlan *et al.*, 2016). This species occurred at almost all of the Walyarta springs but the record from King Gordon Spring is the first for the Kimberley Region. Another beetle *Laccophilus seminiger* was collected by us at Potential Spring 9 and we are unaware of any rother records of this from Western Australia.

The above taxa were not evenly spread across the springs (**Error! Reference source not found.**) but this may be at least partly due to uneven sampling effort. Many of these species are microinvertebrates and smaller mites that will be disproportionately collected in surface water with fine mesh plankton nets which have not been used at any of the central springs or at Lollywell Spring. Attack Spring and Long Spring had disproportionate representation of these species (13 and 15 species respectively) and this was not entirely due to the fact that an extra plankton sample was collected at each of these springs in 2017, since the second plankton sample taken at each of these sites only added 1 additional species from this list.

4.4.5 Invertebrates associated with groundwater

Few clearly stygophilic species have been collected from Kimberley mound springs, but a some are known to be associated with interstitial habitats that are permanently saturated due to groundwater discharge.

The endemic shrimp *Caridina spelunca* is known from caves and springs in the central Kimberley and was recorded from two springs (Waterfall Spring and Middle Spring) by Bennelongia (2017).

[4] Chris Watts, South Australian Museum, pers. comm.

Table 5. Occurrence of rarer species across the Kimberley springs

	FAMILY	IDENTIFICATION	BundaBunda	Lolyywell	Big	Mt Elizabeth	Moon	Black	Drysdale 1a (Fern)	Gibb River	Waterfall Yard	Middle	Kangaroo	Kachana	Potential Spr 9	Attack	Long	Enigma	Potential Spr 1	King Gordon	Bamboo	Brolga	Edge
Protozoa	Difflugiidae	*Difflugia gigantea*														1				1	1		
Rotifers	Lecanidae	*Lecane* sp. nov. LS1															1						
Oligochaetes	Naididae	*Dero* WA5 (cf. *graveli*) KMS														1	1						
	Naididae	*Allonais* cf. *lairdi*														1							
	Naididae	*Haemonais waldvogeli*																			1		
Mites	Anisitsiellidae	*Mamersella* sp.														1							
	Anisitsiellidae	*Sigthoria nilotica*												1									
	Pionidae	*Australotiphys* sp. K1												1									
	Aturidae	*Austraturus* sp. K1												1									
	Aturidae	*Axonopsella* sp.	1																				
	Arrenuridae	*Arrenurus* sp. 29			1																1		
	Arrenuridae	*Arrenurus* sp. 27						1	1								1						
	Arrenuridae	*Arrenurus* sp. 28															1						
Crustacea	Chydoridae	*Picropleuroxus quasidenticulatus*			1										1	1	1		1				
	Chydoridae	*Karualona n. sp.*														1	1			1			
	Macrotrichidae	*Guernella raphaelis*													1	1	1		1	1			
	Cyprididae	*Tanycypris* sp.														1	1			1	1	1	1
	Cyprididae	*Chrissia* sp.			1			1								1	1	1			1		
	Cyprididae	*Strandesia* sp. 653			1															1			
	Cyprididae	*Strandesia* sp. 360															1						
	Darwinulidae	*Alcenula serricaudata*	1					1	1		1	1			1	1	1						
	Cyclopidae	*Microcyclops* sp. TP1															1			1			
	Cyclopidae	*Mesocyclops wouters*i			1												1						
	Canthocamptidae	*Canthocamptus grandidieri*			1			1							1	1	1	1		1			
	Canthocamptidae	*Canthocamptus* sp. B11														1		1		1			
	Diosaccidae	*Schizopera* sp. B37																	1				
	Ameiridae	*Nitokra* sp. B07	1												1	1	1						
	Atyidae	*Caridina spelunca*				1					1	1											
			3	0	6	1	0	4	2	0	2	2	0	3	5	13	15	3	3	8	5	1	1

Two rarely collected harpacticoid copepods, *Phyllognathopus volcanicus* and *Elaphoidella grandidieri*, are known only from Kimberley mound springs in Australia. The latter has been collected from western, central (Bennelongia Environmental Consultants, 2017) and Victoria-Bonaparte springs and is a pan-tropical species (Gaviria & Aranguren, 2007). The records of *Phyllognathopus volcanicus* from Big Spring and Potential Springs 6 and 9 are the first for Australia but the species is also known from interstitial habitats in New Zealand (Lewis, 1984). Both of these species are likely to require permanent interstitial habitats.

Darwinulid ostracods are generally collected from groundwater or from habitats maintained by groundwater or hyporheic flows. All DBCA records are from groundwater influenced sites such as river pool sediments and springs. The three darwinulid species, *Alicenula serricaudata*, *Penthesilenula braziliensis* and *Vestalenula marmonieri*, collected from Kimberley mound springs all have supra-Australian distributions. The *Alicenula serricaudata* records from the 2016 and 2017 mound spring samples are the first of this genus and pan-tropical species for Australia. Candonid ostracods also generally inhabit groundwater (Karanovic, 2007) and an unidentified (female) specimen was collected from Potential Spring 1.

The water mite family Anisitsiellidae tend to be associated with stygal and interstitial habitats in Australia and all DBCA records of this family are from springs. The Kimberley mound spring records of two anisitsiellids, *Sigthoria nilotica* and *Mamersella* sp. are the only records from DBCA projects. *Sigthoria nilotica*, another pan-tropical species (Harvey, 1998), was collected from Kachana Spring in 2003 and is known from a hot spring in the Northern Territory (Smit & others, 1998). There are records from other habitats in eastern Australia but the identity of those is uncertain (Harvey, 1990). *Mamersella* occur in 'streams, seepages and springs'

(Harvey, 1998) and the only described species from Australia, *Mamersella ponderi* Harvey 1990 is restricted to Great Artesian basin mound springs. The single specimen from Attack Spring is not *M. ponderi* and could be a new undescribed species.

Many other species, such as some of the cyclopoid copepods and oligochaetes, are regularly found in groundwater samples (e.g. from bores well away from wetlands) but are not restricted to subterranean waters.

The paucity of clearly stygal species does not detract from the critical importance of groundwater discharge for maintaining the nature of the wetlands (permanently saturated peat deposits and ponding water under tall tree canopies) and for the distinctive communities they support.

4.4.6 Composition in relation to other wetlands

Understanding distributions of aquatic invertebrates and the conservation significance of invertebrate communities in the Kimberley region is hampered by the fact that there have been very few published studies of the region that have involved species level identification (see Introduction) and published the data.

There is certainly significant pan-tropical, Oriental and Australo-papuan/Australasian elements to the fauna of these springs, as for the Kimberley and tropical Australian regions more generally. Examples are the copepod crustacean *Mesocyclops woutersi* (widespread in south-east and east Asia - Holynska (2000)), the cladoceran *Pseudosida szalayi* (south, south-east and east Asia - (Korovchinsky, 2010)), the water mite *Sigthoria nilotica* (otherwise Africa, South and South-east Asia – Harvey (1990)) and the aquatic earthworm *Allonais lairdi* (otherwise Neotropical and Oriental - Martin et al. (2008)).

The idea that many species are widespread does need to be tempered by the increasing understanding that there is significant genetic evidence for cryptic species with narrower ranges. For example, the aquatic annelid *Branchiodrilus hortensis* (Stephenson, 1910) was thought to be a pan-tropical species (with records in the Kimberley) but recent studies (Martin *et al.*, 2018) have shown this to be made up of several genetically distinct species with more limited distributions. Unfortunately no Kimberley specimens were included in that analysis. Recent work on ostracods is also showing much greater species diversity, partly through genetic analyses, than previously thought (Martens, Halse & Schön, 2013; Halse & Martens, 2019).

It is likely that most of the species collected from these springs will occur in other types of wetlands and rivers in the Kimberley and most (especially those from the Victoria-Bonaparte coast) are likely to have distributions that extend east into at least the Northern Territory. Most of the dragonflies and damselflies, for instance, have distributions that extend across at least tropical/subtropical Australia, although there are some exceptions: e.g. the damselfly *Nososticta koongarra* is known only from the Kimberley and the Northern Territory tropics (Theischinger & Endersby, 2009). Distributions of many other aquatic invertebrates are not so well documented.

Of the 581 species listed for 'northern tropical rivers' by Humphrey et al. (2008), 75 have been recorded from Kimberley mound springs, but many taxonomic groups are not included in Humphrey et al.'s (2008) list.

A project to provide baseline condition and biodiversity data at 44 significant wetlands in Western Australia included five wetlands in the Kimberley: Lake Eda, Airfield Swamp, Parrys Lagoon, a swamp at the Ngallagunda Community and Le Lievre Swamp (see references provided in the Introduction). These are primarily fed by rainfall/surface water sources rather than groundwater. A total of fifteen benthic samples were collected from these wetlands in 2008 (three per wetland). Together, samples from these sites had 155 distinct macroinvertebrate taxa (microinvertebrates were not identified due to time constraints). Of these, at least 40% have been collected from Kimberley Mound Springs, although some differences in taxonomic resolution hinder a full comparison at this stage. This shared component represents about 20% of the equivalent taxa from the mound springs.

Storey (2002) collected 171 macroinvertebrate taxa from 58 samples collected from the lower Ord River downstream of Kununurra to the river adjacent to Parry Lagoons. Only 16 (9%) of these have been recorded from Kimberley mound springs, though this will be a slight underestimate due to differences in taxonomic resolution. This component in common represents only about 5% of the equivalent range of invertebrates from the mound springs, which is not surprising given that the Ord sites were all riverine.

Figure 15 is a plot from a three-dimensional ordination with aquatic invertebrate data collected from Kimberley springs in 2017 (the six sites with both plankton and benthic data) and equivalent data from the Walyarta mound springs sampled in 1999 (Storey *et al.*, 2011) and 2015 (Quinlan *et al.*, 2016). This analysis used a dataset that was taxonomically aligned and consisted of 304 species. This shows that invertebrate communities of the Kimberley springs were distinct from those of the Walyarta springs. Interestingly, the plot suggests the difference between the Kimberley springs and those of Walyarta is no greater than the turnover in species between the 1999 and 2015 Walyarta samples. However, it can be seen from

Figure 16 that over two-thirds of species (within the taxonomically aligned joint dataset) collected from the Kimberley springs were not collected at Walyarta and that 60% of species collected from one or both Walyarta datasets were not collected from the Kimberley Springs. The actual number of species occurring in the Kimberley springs but not in the Walyarta springs would be even higher because the joint dataset excludes some speciose groups (due to taxonomic issues) likely to exhibit significant endemism (e.g. *Cypretta* and *Ilyodromus* ostracods). Also, a large proportion of the species collected from just one of the three datasets were singleton species (occurring in just one sample) so would not have influenced similarity between sites represented in Figure 15.

Although it is early days in terms of aquatic invertebrate survey in the Kimberley, the picture at present is that these springs support a high diversity of aquatic invertebrates and, while most of the individual species are likely to be widely distributed in at least the region, there is a suite of species that is rare and more likely to be represented in these springs than other wetland types in at least the Kimberley. Furthermore, the composition of the springs' aquatic invertebrate communities is unlikely to be replicated in other types of wetlands anywhere in Australia.

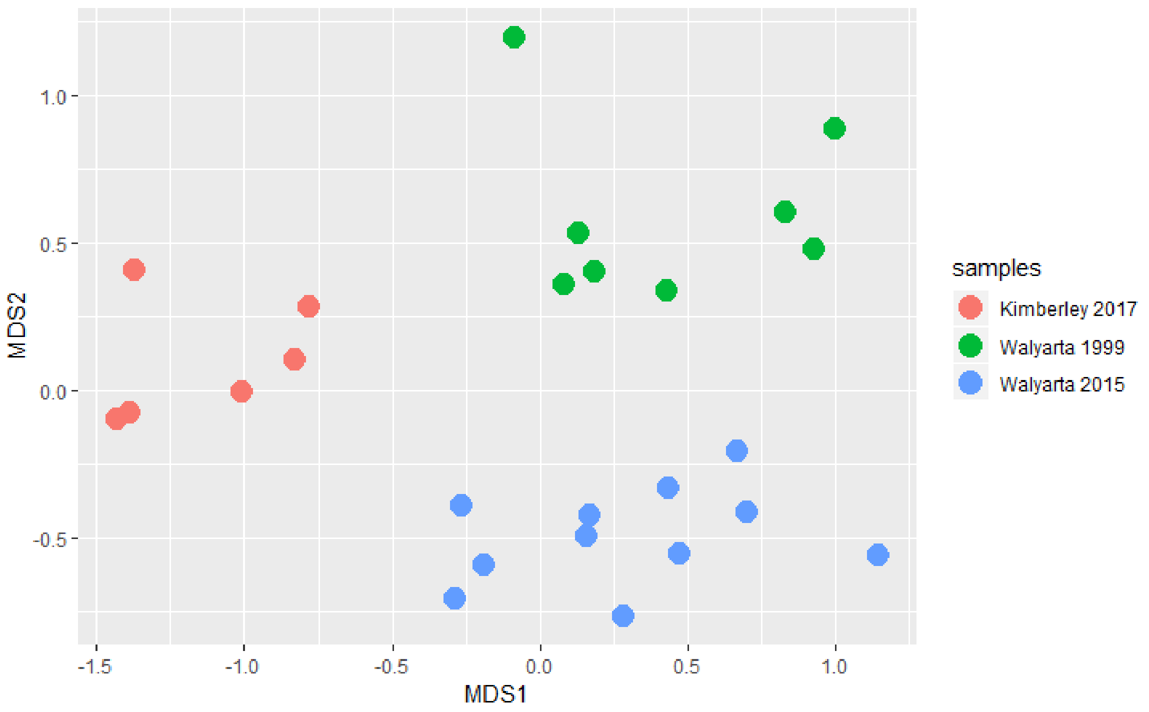

Figure 15. Axes 1 and 2 of a three-dimensional ordination of all surface water samples involving combined plankton and benthic samples collected from springs at Walyarta and in the Kimberley region. Stress = 0.1.

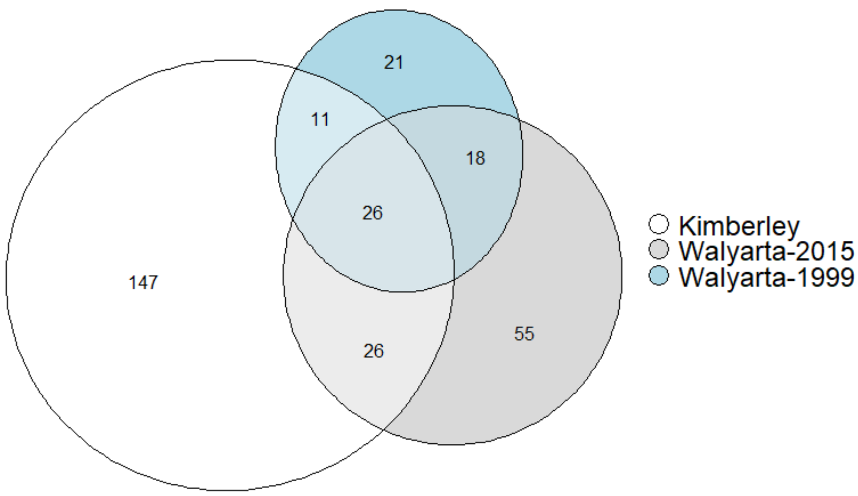

Figure 16. Relative proportions of the total species pool collected from Walyarta (1999 and 2015) and Kimberley mound springs. Circles are proportional to the total number of species within each of the three datasets (after taxonomic alignment). Drawn using the eulerr 5.0.0 R package by Larsson et al. (2018), with a test to confirm that the size of each segment is proportional to the number of species it represents.

4.5 Glossary

Benthic sample. A sample taken with a coarse mesh net (usually 250 μm) to sample invertebrates living amongst the mud, aquatic plants and organic detritus as well as those larger animals swimming in the water. The coarse mesh allows rapid sweeping through all habitats without the net becoming clogged up with fine particulate matter, but some smaller animals pass through the net. These samples primarily target macroinvertebrates.

Plankton sample. A sample taken with a very fine mesh net (usually 50 to 100um) used to sweep more slowly through the water to catch invertebrates in the water column or aquatic plants, including the microinvertebrate species such as rotifers and protozoans.

Interstitial. Referring to species that live within (as opposed to on or above) wetland substrates.

Microcrustacea. Species of ostracod, copepod and cladocera.

Microinvertebrates. Microcrustacea plus rotifers and protozoans

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Appendix 4. Aquatic invertebrate data matrix

HIGHER GROUP	FAMILY	Identification	Species code	KMS002 Mount Elizabet 14/09/1999 B	KMS003 Moon 14/09/1999 B	KMS004 Black 26/05/2016 C	KMS004 Black 18/09/1999 B	KMS005 Native Wells 19/09/1999 B	KMS006 Lollywell 18/07/1999 B	KMS007 Enigma 1/10/2000 B	KMS009 Kachana 6/09/2003 P+B	KMS010 Pot.Spring 9 1/08/2017 C	KMS010 Pot.Spring 9 1/08/2017 P	KMS011 Attack 1/08/2017 C1	KMS011 Attack 1/08/2017 C2	KMS011 Attack 1/08/2017 P1	KMS011 Attack 2/08/2017 B	KMS011 Attack 2/08/2017 P2	KMS012 Enigma 2/08/2017 C	KMS012 Enigma 2/08/2017 P	KMS013 Long 18/02/1993 P+B	KMS013 Long 3/08/2017 B	KMS013 Long 3/08/2017 C	KMS013 Long 3/08/2017 P1	KMS013 Long 3/08/2017 P2	KMS014 Pot. Spring 1 4/08/2017 B	KMS014 Pot. Spring 1 4/08/2017 P	KMS015 King Gordon 4/08/2017 B	KMS015 King Gordon 4/08/2017 C	KMS015 King Gordon 4/08/2017 P	KMS016 Bamboo 4/08/2017 B	KMS016 Bamboo 4/08/2017 P1	KMS017 Bunda Bunda 27/07/2001 B	KMS017 Bunda Bunda 7/08/2017 B	KMS017 Bunda Bunda 7/08/2017 C	KMS017 Bunda Bunda 7/08/2017 P	KMS018 Big 7/09/1999 B	KMS018 Big 9/08/2017 B	KMS018 Big 9/08/2017 C	KMS018 Big 9/08/2017 P	KMS019 Fern 27/05/2016 C	KMS020 Gibb River 28/05/2016 C	KMS021 Waterfall Yard 29/05/2016 C	KMS022 Middle 29/05/2016 C	KMS023 Kangaroo 30/05/2016 C	KMS024 Brolga 17/02/1993 P+B	KMS025 Edge 18/02/1993 P+B
Protozoa																																															
	Stentoridae	Stentor sp.	BN050199														1																															
	Didinidae	Didinium sp.	BN060101																					1																							
	Arcellidae	Arcella discoides	BP010102									1			1		1		1				1	1												1												
		Arcella megastoma	BP010105									1			1				1				1	1							1							1								
		Arcella vulgaris	BP010106									1					1																														
		Arcella hemisphaerica	BP010104																				1																								
		Arcella bathystoma	BP010109														1																													
		Arcella sp. A	BP0101C0									1			1		1							1					1																	
		Arcella sp. B	BP0101C1													1		1		1													1															
	Centropyxidae	Centropyxis aculeata	BP020101								1	1	1		1		1		1				1	1					1		1				1			1	1								
		Centropyxis ecornis	BP020105								1	1			1				1				1									1															
		Centropyxis cf. aculeata	BP0201B2									1			1		1		1				1	1												1												
		Centropyxis sp. A	BP0201B3									1							1																											
		Centropyxis sp. B	BP0201B4									1							1																											
		Centropyxis kahlii	BP080101									1																																		
	Difflugiidae	Difflugia acuminata	BP030104														1				1																											
		Difflugia australis	BP030107														1		1		1				1						1																	
		Difflugia cf. bryophila	BP0301C2									1							1																											
		Difflugia cf. cylindrus	BP0301B9									1			1		1							1																					
		Difflugia capreolata	BP030108														1		1																													
		Difflugia gigantea	BP030111														1													1		1	1																	
		Difflugia sp. B	BP0301B7									1			1				1				1	1					1		1															
		Difflugia sp. C	BP0301B8									1																																		
		Difflugia sp. D	BP0301C3									1							1										1																		
		Difflugia sp. E	BP0301C4																	1										1																		
		Difflugia sp. F	BP0301C5																										1																		
		Difflugia sp. G	BP0301C6																	1																											
		Difflugia cf. globulosa	BP0301C0														1				1					1																					
		Difflugia cf. pyriformis	BP0301C1														1																													
		Difflugia lacustris	BP030112									1							1					1							1															
		Difflugia mammilaris	BP030113																	1										1																		
		Difflugia urceolata	BP030114																					1																							
	Nebelidae	Nebela dentistoma	BP040104									1							1																											
	Lesquereusidae	Lesquereusia modesta	BP070101									1							1				1								1				1				1								
		Lesquereusia spiralis	BP070102														1		1		1				1	1				1		1				1												
		Lesquereusia sp.	BP070199								1																																				
		Netzelia corona	BP070202																					1																							
		Netzelia tuberculata	BP070201														1								1								1															
	Euglyphidae	Euglypha sp. K1	BP0901A4								1																																				
		Euglypha sp.	BP090199									1																																		
	Actinosphaeriidae	Actinosphaerium sp.	BQ010199														1																													
Hydrozoa																																															
	Hydridae	Hydra sp.	IB010199														1				1					1							1								1								
Turbellaria																																															
		Turbellaria	IF999999														1		1		1			1	1	1		1			1						1					1	1								
Nemertini																																															
		Nemertini	IH999999																										1																		
Nematoda																																															
		Nematoda	II999999								1							1	1		1			1	1			1					1	1	1	1	1	1		1				1									
Tardigrada																																															
		Tardigrada	IR999999														1																													
Rotifera																																															
	Philodinidae	Rotaria sp.	JB041099														1		1		1																											
	-	Bdelloidea	JB999999									1			1		1						1	1							1								1						1	
	Filiniidae	Filinia longiseta	JF020109																																										1	1
	Hexarthridae	Hexarthra intermedia	JF040108																																											1
		Hexarthra brandorffi	JF040101																							1																				
	Testudinellidae	Testudinella patina	JF050201									1			1								1												1										1	1
	Asplanchnidae	Asplanchna brightwelli	JP010199																																											1
	Brachionidae	Anuraeopsis navicula	JP020101																																												
		Anuraeopsis fissa	JP020103																		1																										1
		Brachionus angularis	JP020201																							1																			1	
		Brachionus plicatilis s.l.	JP020219																							1																				
		Brachionus quadridentatus	JP020220																																										1	1
		Brachionus urceolaris s.l.	JP020224								1																																				
		Brachionus sp. C	JP0202C5																																											1
		Plationus patulus	JP020501														1													1		1				1				1								
		Platyias quadricornis	JP020601																		1				1																						1	1
	Lepadellidae	Colurella sp.	JP030199														1																													
		Lepadella (Heterolepadella) sp.	JP0302B1														1																													
		Lepadella sp.	JP030299																					1																							
	Euchlanidae	Euchlanis dilatata	JP030101																																											1
		Euchlanis sp. B	JP060199																																										1	1
		Dipleuchlanis sp. B	JP0602A0																																											1
		Dipleuchlanis propatula	JP060204																					1					1																		
	Flosculariidae	?Sinantherina	JP030699																												1																	
	Lecanidae	Lecane bulla	JP090110														1						1								1		1								1						1	
		Lecane curvicornis	JP090117														1				1																										1
		Lecane hamata	JP090129														1																														1
		Lecane leontina	JP090134																																										1	1
		Lecane ludwigii	JP090136																												1															1	
		Lecane lunaris	JP090138																										1																		
		Lecane papuana	JP090148																										1																		
		Lecane luna	JP090137																																										1	1
		Lecane nitida	JP090143								1																																				
		Lecane quadridentata	JP090154														1																													
		Lecane signifera	JP090159														1																													
		Lecane ungulata	JP090172																																											1
		Lecane sp. nov. LS1	JP0901D9																		1																									
		Lecane [Monostyla] sp.	JP0901F2														1						1																1								
		Lecane sp. A	JP0901G0														1														1																	
		Lecane sp. B	JP0901G1														1																													
		Mytlina acanthophora	JP090101																		1																									
	Mytilinidae	Mytilina bisulcata	JP120102														1																													
		Mytilina ventralis	JP120108																																				1								
	Synchaetidae	Polyarthra sp.	JP150299																												1																	
		Polyarthra dolichoptera	JP150201																																											1
	Notommatidae	Cephalodella forficula	JP130202																							1																				
		Cephalodella sp.	JP130299								1																																				
	Proalidae	Proales sp.	JP140299																												1				1														
	Trichotriidae	Trichotria sp.	JP170299																																											1
	Scaridiidae	Scaridium aff. elegens	JP1801A2																																											1
		Scaridium sp.	JP180199														1																													
Gastropoda																																															
	Phsidae	Physastra sp. (sic)	KG010799																		1																									
	Lymnaeidae	Austropeplea sp.	KG050199																		1	1						1		1	1																	
		Austropeplea lessoni	KG0501A0			1										1																													
	Ancylidae	Ferrissia sp.	KG060199						1			1				1	1						1																							
	Planorbidae	Glyptophysa sp	KG070299														1	1	1		1		1	1	1	1		1		1		1				1	1		1						
		Gyraulus sp.	KG070799		1		1			1			1				1	1		1	1	1	1	1	1	1	1	1	1		1	1	1	1		1	1	1	1	1						
		Leichhardtia sp.	KG071099						1																																				
		Ameriana sp.	KG071199																			1																									
		Helicorbis sp.	KG071299														1	1	1				1		1	1				1		1	1	1																
	Assiminaeidae	Assiminaeidae	KG219999																				1	1																								
	-	Gastropoda sp. 1	KG9999A3								1	1																																	
Polychaeta																																															
	Aeolosomatidae	Aeolosoma sp. 1	LA9999A0														1		1																											
	Aeolosomatidae	Aeolosoma cf travancorense	LA9999A3																				1	1	1							1															
Oligochaeta (aquatic earthworms)																																															
	Naididae	Nais communis	LO050105					1																																						
		Dero digitata	LO050201																				1																								
		Dero nivea	LO050202														1				1										1																	
		Dero furcata	LO050203			1																															1								
		Dero flabelliger	LO050204								1		1																			1																	
		Dero WA5 (cf. graveli)	LO0502A5														1	1	1						1																								
		Allonais pectinata	LO050401								1									1	1												1		1													
		Allonais ranauana	LO050402											1				1																						1								
		Allonais paraguayensis	LO050403	1			1		1	1																												1		1						
		Allonais inaequalis	LO050404										1	1			1	1	1	1	1			1	1	1			1				1					1								
		Allonais cf. lairdi	LO050405													1																															
		Chaetogaster diastrophus	LO050701																				1	1	1														1						
		Aulodrilus pigueti	LO051701						1								1			1		1						1		1																		
		Haemonais waldvogeli	LO052801																											1																	
	Enchytraeidae	Enchytraeidae sp. 1	LO0899C5								1																		1																			
		Enchytraeidae sp. 2	LO0899C6								1																																			
		Enchytraeidae sp. 3	LO0899C7																			1							1											1							
		Enchytraeidae sp. 6	LO0899D0																									1						1												
	Pristinidae	Pristina longiseta	LO150101								1									1					1	1				1		1		1		1		1		1						
		Pristina aequiseta	LO150102								1	1			1			1	1		1	1	1												1	1	1		1	1							
		Pristina proboscidea	LO150103			1		1																																					
		Pristina leidyi	LO150107																													1														
		Pristina sima	LO1501A4								1	1						1																				1							
Oligochaeta (terrestrial earthworms)																																															
	-	Opisthopora	LO989999																	1																											
Hirudinea (leeches)																																															
	Richardsonianidae	Richardsonianidae sp.	LH039999																																								1					
	-	Hirudinea sp.	LH999999														1																													
Acarina (water mites)																																															
	-	Astigmata sp.	MM9999E6																																							1				
	Hydrachnidae	Hydrachna sp.	MM010199														1													1															1	
	Anisitsiellidae	Mamersella sp.	MM080299														1																													
		Sigthoria nilotica	MM080401								1																																				
	Oxidae	Oxus sp.	MM090399																																						1					
	Limnesiidae	Limnesia sp. K1	MM1201B2								1																																				
	Hygrobatidae	Aspidiobates sp.	MM150299								1																																				
		Australiobates nr perplexus	MM1503A8								1																																				
		Australiobates sp. K1	MM1503A9								1																																				
		Coaustraliobates minor	MM150602								1																													1					
		Hygrobates hamatus	MM151301								1																																				
	Unionicolidae	Koenikea sp.	MM160299								1																																				
		Neumania sp.	MM160399								1																			1							1								
	Pionidae	Australotiphys sp. K1	MM1702A1								1																																				
	Aturidae	Austraturus sp. K1	MM1902A3								1																																				
		Axonopsella sp.	MM1903A6																													1														
	Arrenuridae	Arrenurus multicornutus	MM230115																												1	1															
		Arrenurus sp.	MM230199														1		1																										
		Arrenurus sp. 29	MM2301E3																												1							1								
		Arrenurus sp. 27=B07	MM2301E7			1																1																			1					
		Arrenurus sp. 28	MM2301E8																				1																							

HIGHER GROUP	FAMILY	Identification	Species code	KMS002 Mount Elizabet 14/09/1999 B	KMS003 Moon 14/09/1999 B	KMS004 Black 26/05/2016 C	KMS004 Black 18/09/1999 B	KMS005 Native Wells 19/09/1999 B	KMS006 Lollywell 18/07/1999 B	KMS007 Enigma 1/10/2000 B	KMS009 Kachana 6/09/2003 P+B	KMS010 Pot.Spring 9 1/08/2017 C	KMS010 Pot.Spring 9 1/08/2017 P	KMS011 Attack 1/08/2017 C1	KMS011 Attack 1/08/2017 C2	KMS011 Attack 1/08/2017 P1	KMS011 Attack 2/08/2017 B	KMS011 Attack 2/08/2017 P2	KMS012 Enigma 2/08/2017 C	KMS012 Enigma 2/08/2017 P	KMS013 Long 18/02/1993 P+B	KMS013 Long 3/08/2017 B	KMS013 Long 3/08/2017 C	KMS013 Long 3/08/2017 P1	KMS013 Long 3/08/2017 P2	KMS014 Pot. Spring 1 4/08/2017 B	KMS014 Pot. Spring 1 4/08/2017 P	KMS015 King Gordon 4/08/2017 B	KMS015 King Gordon 4/08/2017 C	KMS015 King Gordon 4/08/2017 P	KMS016 Bamboo 4/08/2017 B	KMS016 Bamboo 4/08/2017 P1	KMS017 Bunda Bunda 27/07/2001 B	KMS017 Bunda Bunda 7/08/2017 B	KMS017 Bunda Bunda 7/08/2017 C	KMS017 Bunda Bunda 7/08/2017 P	KMS018 Big 7/09/1999 B	KMS018 Big 9/08/2017 B	KMS018 Big 9/08/2017 C	KMS018 Big 9/08/2017 P	KMS019 Fern 27/05/2016 C	KMS020 Gibb River 28/05/2016 C	KMS021 Waterfall Yard 29/05/2016 C	KMS022 Middle 29/05/2016 C	KMS023 Kangaroo 30/05/2016 C	KMS024 Bridge 17/02/1993 P+B	KMS025 Edge 18/02/1993 P+B
		Arrenurus sp. 30	MM2301E9																																			1									
Acarina (other mites)																																															
	Halacaridae	Halacaridae	MM249999									1	1	1			1	1	1				1	1					1					1	1				1		1						
	Pezidae	Pezidae	MM259999											1																																	
	Eniochthoniidae	Eniochthoniidae - Acarina KMS4	MM3999A0									1	1	1	1	1	1	1				1	1	1	1			1	1		1			1		1		1	1	1							
	Uropodidae	Uropodidae - Acarina KMS2	MM4099E7									1							1																												
	-	Acarina KMS1	MM9999A0				1			1																																					
	-	Oribatida sp.	MM9999A1	1		1	1	1		1	1	1		1		1	1		1			1												1	1			1			1	1	1	1	1		
	-	Trombidioidea	MM9999A6			1						1	1						1							1			1													1	1	1	1		
	-	Oribatida group 5	MM9999C0								1																																				
	-	Oribatida sp. 4	MM9999C1								1																																				
	-	Oribatida group 3	MM9999C5								1																																				
	-	Mesostigmata KMS1	MM9999E8													1	1																														
	-	Mesostigmata sp.	MM999999			1																																				1	1				
	-	Acarina KMS3	MM9999E9																1																												
	-	Acarina KMS5	MM9999F0																			1	1		1									1				1									
	-	Acarina KMS6	MM9999F1																			1																									
	-	Acarina KMS7	MM9999F2									1		1		1			1				1																								
	-	Acarina KMS8	MM9999F3																1									1																			
	-	Acarina KMS9	MM9999F4																																			1									
Cladocera (water fleas)																																															
	Sididae	Diaphanosoma sp.	OG010199										1					1				1		1		1											1										
	Sididae	Diaphanosoma cf. unguiculatum	OG0101A3																		1																									1	1
		Latonopsis brehmi	OG010201										1																																		
		Latonopsis sp.	OG010299																																											1	
		Pseudosida szalayi	OG010402																																												1
		Sarsilatona papuana	OG010501										1			1		1			1	1		1		1		1																			1
	Chydoridae	Alona intermedia	OG030228															1																1													
		Alona rectangula novaezelandiae	OG030205																		1																										
		Alona cf. rigidicaudis s.l.	OG0302A9	1																																											
		Alona aff. costata	OG0302A2																																												1
		Alona cf. longinqua	OG0302B1	1																																											
		Alona setigera	OG030214																																												1
		Alona cf. guttata	OG0302E4											1		1																															
		Alona sp. A	OG0302F5																																												1
		Alona sp. B01	OG0302F6																																					1		1		1		
		Alona sp. B02	OG0302F7																																								1			
		Alona sp. B03	OG0302F8																																								1			
		Alona sp. B04	OG0302F9																																								1			
		Chydorus cf. sphaericus	OG0309A5													1		1				1		1	1	1				1		1															
		Dadaya macrocops	OG031002													1		1																													
		Dunhevedia crassa	OG031201															1				1		1	1	1				1		1							1	1	1						1	1
		Kurzia longirostris	OG031602																		1							1									1										
		Leydigia sp.	OG031899																																		1										
		Leydigia aff. ciliata	OG0318A3																																												1
		Oxyurella singalensis	OG032201									1				1		1				1	1	1	1	1																					
		Rak sp.	OG032799	1																																											
		Karualona karua	OG033201																																					1							
		Karualona n. sp.	OG033299												1			1				1	1	1	1	1				1		1														1	1
		Picropleuroxus quasidenticulatus	OG033303										1			1						1		1	1	1													1								
		Coronatella sp.	OG033799																						1					1						1											
		Camptocercus australis	OG030701																																						1						
	Daphniidae	Ceriodaphnia cornuta	OG040101															1																		1	1			1							
		Ceriodaphnia sp.	OG040199																																		1									1	
		Ceriodaphnia sp. A	OG0401B0											1			1	1										1						1		1			1								
		Ceriodaphnia sp. B	OG0401B1													1																						1									
		Simocephalus elizabethae	OG040505																																			1		1							
		Simocephalus sp.	OG040599																																											1	
	Ilyocryptidae	Ilyocryptus spinifer	OG050105													1				1			1	1	1			1						1		1											
		Ilyocryptus (sml)	OG0501A6	1				1																1																							
		Ilyocryptus sp.	OG050199			1																																			1		1	1			
	Macrotrichidae	Grimaldina brazzai	OG060101													1		1			1	1		1		1																					
		Macrothrix breviseta	OG060201													1		1																													
		Macrothrix triserialis	OG060202																		1																										
		Macrothrix williamsi	OG060218																			1		1	1	1				1		1															
		Macrothrix sp. A	OG0602C1																		1																										1
		Macrothrix sp. B	OG0602C2																		1																										1
		Macrothrix sp. A	OG0602A3	1																																											
		Macrothrix sp. B (VB)	OG0602A4																																		1										
		Macrothrix sp.	OG060299																																								1				
		Guernella raphaelis	OG060601										1			1		1				1		1		1		1		1																	
	Moinidae	Moina cf. micrura	OG0701A1																																												1
		Moina aff weismanni	OG0701A5																																											1	1
		Moinodaphnia macleayi	OG070201															1			1	1				1																					
Ostracoda (seed shrimps)																																															
	Limnocytheridae	Limnocythere sp.	OH010299																								1									1											
	Darwinulidae	Penthesilenula sp.	OH050299			1						1														1		1						1	1	1					1		1	1	1		
		Vestalenula marmonieri	OH050399									1		1	1	1		1				1	1	1	1			1	1	1				1		1		1	1	1							
		Alicenula sp.	OH050499			1						1		1		1							1	1										1	1						1		1	1			
	Ilyocyprididae	Ilyocypris australiensis	OH060101																																												1
	Candonidae	Candonopsis tenuis	OH070101			1		1									1			1		1	1	1				1													1						
		Candonidae	OH079999																							1																					
	Cyprididae	Cypretta baylyi	OH080501				1														1																1				1						1
		Cypretta sp. BOS584	OH0805G5			1																																				1	1			
		Cypretta sp. BOS586	OH0805G6																																								1			
		Cypretta sp. BOS588	OH0805G7																																						1			1			
		Cypretta sp.	OH080599														1					1	1	1	1						1	1		1				1									
		Cypretta sp. 654	OH0805A9													1	1	1					1		1						1						1	1		1							
		Cypretta sp. KMS1	OH0805F6															1																													
		Cypretta sp. KMS3	OH0805F8															1																													
		Cypretta sp. KMS4 (long)	OH0805F9																			1																									
		Cyprinotus cingalensis	OH080604						1	1							1			1	1					1					1	1														1	1
		Bennelongia australis lineage	OH0803B9			1																																			1						
		Heterocypris sp.	OH081099																							1																					
		Strandesia sp. 653	OH0816A0																									1									1	1		1							
		Strandesia sp. 360	OH0816A9																		1																										
		Strandesia/Chlamydotheca gen nov 357	OH0816B0																		1																										
		Ilyodromus viridulus	OH081906	1			1	1																													1										
		Ilyodromus sp 365	OH0819B7																																												1
		Ilyodromus sp. KMS4=BOS583	OH0819D8			1																1																			1	1			1		
		Ilyodromus sp. KMS2	OH0819D9																	1																											
		Ilyodromus sp. KMS1=BOS585	OH0819E0			1																												1									1	1			
		Ilyodromus sp. BOS591	OH0819E3			1																																									
		Ilyodromus sp. KMS5	OH0819E1													1	1	1													1																
		Ilyodromus sp. KMS3	OH0819E2																															1													
		Ampullacypris oblongata	OH082001				1																																								
		Cypris subglobosa	OH082401																																												1
		Stenocypris cf. bolieki	OH082702																																			1									
		Stenocypris major	OH082703													1		1													1						1										
		Tanycypris sp.	OH083599													1	1	1			1			1				1			1	1						1								1	1
		Chrissia sp.	OH083699				1									1	1	1		1		1	1	1	1						1						1										
	-	Ostracoda (Unident.)	OH999999																																	1											
Copepoda																																															
	Diaptomidae	Diaptomus sp.	OJ120199																		1																										
	Cyclopidae	Microcyclops varicans	OJ310101			1		1			1		1		1	1	1	1				1		1	1			1	1	1	1	1		1	1	1	1	1		1	1		1		1		1
		Microcyclops sp. TP1	OJ3101A8																		1									1																	
		Ectocyclops phaleratus	OJ310503			1	1				1	1	1	1		1	1		1	1			1	1				1			1			1	1	1	1		1		1		1		1		
		Macrocyclops albidus	OJ310601								1																																				
		Mesocyclops australiensis	OJ310701																																												
		Mesocyclops notius	OJ310702																																											1	
		Mesocyclops brooksi	OJ310703			1																				1						1				1						1					
		Mesocyclops darwini	OJ310708	1																														1		1		1					1				
		Mesocyclops papuensis	OJ310715	1								1	1	1		1	1	1	1	1	1	1	1	1	1		1	1		1	1				1	1					1						
		Mesocyclops woutersi	OJ310716																					1													1	1	1	1							
		Mesocyclops sp.	OJ310799								1																																				
		Mesocyclops sp. LS2	OJ3107A5																		1																									1	
		Tropocyclops prasinus	OJ310902																																	1											
		Eucyclops australiensis	OJ311001		1						1																															1			1		
		Paracyclops chiltoni	OJ311102									1	1	1	1	1	1		1	1		1	1		1			1	1					1		1				1					1		
		Paracyclops sp. 8	OJ3111A6														1																														
		Paracyclops sp.	OJ311199																					1																							
		Thermocyclops sp. LS1	OJ3116A2																		1																										1
	Canthocamptidae	Canthocamptus grandidieri	OJ610112			1						1	1			1		1	1	1			1						1										1								
		Canthocamptus sp. B11	OJ6101A4											1			1			1								1		1																	
		Mesochra sp. 267	OJ6103A2																		1																										
		Cletocamptus dietersi	OJ610402																							1	1											1		1							
	Diosaccidae	Schizopera sp. B37	OJ6302B0																							1																					
	Ameiridae	Nitokra sp. B07	OJ6401B2									1		1										1											1			1									
	Phyloognathopidae	Phyllognathopus volcanicus	OJ820101									1							1																				1								
	-	Harpacticoida sp. 1	OJ6999A9								1																																				
Amphipoda																																															
	Talitridae	Talitridae	OP019999																			1	1												1			1									
Malacostraca (shrimps)																																															
	Atyidae	Caridina nilotica	OT010304																			1																									
		Caridina spelunca	OT010309																																							1	1				
		Caridina serratirostris	OT010305	1																																											
Malacostracoda (prawns)																																															
	Palaemonidae	Macrobrachium australe	OT020105								1																																				
Decapoda																																															
	Parathelphusidae	Holthuisana transversa	OX510105																		1												1														
Coleoptera																																															
	Noteridae	Canthyhydrus bovillae	QC080101																																												1
		Hydrocanthus australasiae	QC080201					1																																							
		Neohydrocoptus subfasciatus	QC080301			1	1	1									1		1				1					1			1			1	1						1			1			
		Notomicrus tenellus	QC080401									1							1																												
	Dytiscidae	Laccophilus sharpi	QC090101						1									1		1								1			1			1													
		Laccophilus seminiger	QC090102										1																																		
		Laccophilus clarki	QC090105														1	1		1	1	1						1			1	1		1			1	1									1
		Laccophilus cingulatus	QC090106																			1						1																			
		Laccophilus transversalis	QC090110																			1						1																			
		Laccophilus sp.	QC090199																																											1	
		Hydrovatus opacus	QC090303								1																																				
		Hydrovatus ovalis	QC090307	1						1																																					
		Hydrovatus sp.	QC090399									1				1	1																														
		Hydrovatus sp. B01	QC0903A6																																								1			
		Hydrovatus sp. B02	QC0903A7																																								1			
		Hydrovatus opacus	QC090303																																												
		Hydrovatus ovalis	QC090307																			1	1	1				1						1				1									
		Hydrovatus sp.	QC090399																																												
		Hydrovatus nigrita	QC090302										1											1														1									
		Hydrovatus fasciatus	QC090306																			1	1	1				1						1	1			1	1								
		Hydrovatus weiri	QC090308																			1						1						1	1												
		Hydrovatus rufoniger politus	QC090309																																1				1								
		Hydrovatus sp. B01	QC0903A6																																												
		Hydrovatus sp. B02	QC0903A7																									1											1								
		Hydrovatus parallelus (=B03 of Bennelongia 2017)	QC0903A8																									1											1			1					
		Hyphydrus elegans	QC090401																			1																									
		Hyphydrus lyratus	QC090402																			1						1																			

HIGHER GROUP	FAMILY	Identification	Species code	KMS002 Mount Elizabet 14/09/1999 B	KMS003 Moon 14/09/1999 B	KMS004 Black 26/05/2016 C	KMS004 Black 18/09/1999 B	KMS005 Native Wells 19/09/1999 B	KMS006 Lollywell 18/07/1999 B	KMS007 Enigma 1/10/2000 B	KMS009 Kachana 6/09/2003 P+B	KMS010 Pot.Spring 9 1/08/2017 C	KMS010 Pot.Spring 9 1/08/2017 P	KMS011 Attack 1/08/2017 C1	KMS011 Attack 1/08/2017 C2	KMS011 Attack 1/08/2017 P1	KMS011 Attack 2/08/2017 B	KMS011 Attack 2/08/2017 P2	KMS012 Enigma 2/08/2017 C	KMS012 Enigma 2/08/2017 P	KMS013 Long 18/02/1993 P+B	KMS013 Long 3/08/2017 B	KMS013 Long 3/08/2017 C	KMS013 Long 3/08/2017 P1	KMS013 Long 3/08/2017 P2	KMS014 Pot. Spring 1 4/08/2017 B	KMS014 Pot. Spring 1 4/08/2017 P	KMS015 King Gordon 4/08/2017 B	KMS015 King Gordon 4/08/2017 C	KMS015 King Gordon 4/08/2017 P	KMS016 Bamboo 4/08/2017 B	KMS016 Bamboo 4/08/2017 P1	KMS017 Bunda Bunda 27/07/2001 B	KMS017 Bunda Bunda 7/08/2017 B	KMS017 Bunda Bunda 7/08/2017 C	KMS017 Bunda Bunda 7/08/2017 P	KMS018 Big 7/09/1999 B	KMS018 Big 9/08/2017 B	KMS018 Big 9/08/2017 C	KMS018 Big 9/08/2017 P	KMS019 Fern 27/05/2016 C	KMS020 Gibb River 28/05/2016 C	KMS021 Waterfall Yard 29/05/2016 C	KMS022 Middle 29/05/2016 C	KMS023 Kangaroo 30/05/2016 C	KMS024 Brolga 17/02/1993 P+B	KMS025 Edge 18/02/1993 P+B
		Hyphydrus sp.	QC090499																		1																									1	
		Clypeodytes sp.	QC090899																			1						1																			
		Hydroglyphus daemeli	QC090904																	1						1		1																			
		Hydroglyphus godeffroyi	QC090905						1								1			1	1			1				1																	1		
		Hydroglyphus trifasciatus	QC090906																															1				1									
		Hydroglyphus leai	QC090907						1																	1												1		1							
		Hydroglyphus basalis	QC090909																							1																					
		Hydroglyphus grammopterus	QC090910																							1																				1	
		Limbodessus compactus	QC091001							1									1																			1		1							
		Limbodessus sp.	QC091099									1																																			
		Sternopriscus sp.	QC091899								1																																				
		Megaporus ruficeps	QC092105							1																								1				1									
		Copelatus nigrolineatus	QC092704																																			1									
		Copelatus clarki	QC092708			1				1																																			1		
		Copelatus sp.	QC092799									1																																			
		Eretes australis	QC092901																		1																										
		Hydaticus consanguineus	QC093008								1																											1									
		Hydaticus quadrivittatus	QC093012								1																				1																
		Rhantaticus congestus	QC093201																												1																
		Onychohydrus atratus	QC093402						1																																						
		Onychohydrus sp.	QC093499																			1																									1
		Cybister tripunctatus	QC093602																												1							1									
		Neobidessodes mjobergi	QC094103																									1																			
		Neobidessodes flavosignatus	QC094105																							1																					
		Dytiscidae sp. A	QC0999A0																																										1
		Dytiscidae sp. B	QC0999A1																		1																										
	Gyrinidae	Macrogyrus sp.	QC100199																		1																										1
		Dineutus australis	QC100301																			1																									
	Hydrophilidae	Spercheus sp.	QC110399																																										1
		Berosus australiae	QC110401																							1																					
		Berosus debilipennis	QC110407																		1																										
		Berosus pulchellus	QC110422																							1						1															
		Berosus sp.	QC110499						1																						1																
		Regimbartia attenuata	QC110701							1			1			1	1	1				1			1			1			1			1			1	1									
		Paranacaena horni	QC110902					1			1																															1		1		
		Chaetarthria nigerrimus	QC111001			1																																									
		Enochrus eyrensis	QC111102					1																																							
		Enochrus deserticola	QC111105			1	1		1		1					1	1	1			1																	1								1	1
		Enochrus esuriens	QC111106			1	1																																								
		Enochrus fuscatus	QC111115																									1																			
		Enochrus sp.	QC111199										1											1				1																			
		Helochares sp.	QC111299																	1																											
		Paracymus pygmaeus	QC111601	1		1	1	1	1	1	1			1		1	1			1		1		1				1						1				1			1	1	1				
		Paracymus sp.	QC111699																		1																										1
		Hydrophilus bilineatus	QC111803																1																												
		Sternolophus marginicollis	QC111901				1																					1										1									
		Sternolophus australis	QC111902								1																																				
		Coelostoma fabricii	QC112001											1																																	
		Chasmogenus nitescens	QC112101																1																												
		Hydrophilidae	QC119999					1																																							
	Hydraenidae	Hydraena sp. K1	QC1301A2								1																																				
		Hydraena sp. BO2	QC1301A5			1																																					1	1		
		Hydraena sp. BO3	QC1301A6																																									1		
		Hydraena sp. BO4	QC1301A7																																									1		
		Hydraena sp. BO5	QC1301A8			1																																		1	1				
		Hydraena sp. BO6	QC1301A9			1																																									
		Hydraena sp. KMS1	QC1302A3																																			1									
		Hydraena sp. KMS2	QC1302A4																					1																							
	Scirtidae	Scirtidae	QC209999			1	1		1		1	1	1	1		1	1		1		1	1		1				1	1	1				1	1		1	1	1		1	1	1	1	1		1
	Limnichidae	Limnichidae	QC359999																					1																							
	Hydrochidae	Hydrochus decoris	QCA00109								1																																				
		Hydrochus obscuroaeneus	QCA00121								1																																				
		Hydrochus sp.	QCA00199						1	1																											1										
		Hydrochus group 4	QCA001B2								1							1				1																									
		Hydrochus group 3 sp. B01	QCA001B3																																									1		
		Hydrochus group 4 sp. B01	QCA001B4																																						1					
	Chrysomelidae	Chrysomelidae	QCAH9999																1					1														1									
	Brentidae	Nanophyes sp.	QCAM9998		1				1																																						
Diptera (True flies)																																													
	Tipulidae	Tipulidae	QD019999			1																			1																1				1		
		Tipulidae type D	QD0199A3										1																																		
		Tipulidae type K1	QD019984								1																																				
		Tipulidae type KMS 'A'	QD019988																											1								1		1							
		Tipulidae type KMS 'B'	QD019989													1						1																1									
		Tipulidae type KMS 'C'	QD0199C0																1																												
		Tipulidae type KMS 'D'	QD0199C1																1																												
	Chaoboridae	Corethrella sp.	QD050499									1																	1						1			1	1			1		1	1		
		Chaoboridae	QD059999															1													1																
	Culicidae	Anopheles annulipes s.l.	QD070101														1			1					1													1						1			
		Anopheles (Anopheles) bancrofti	QD070106										1				1					1		1	1			1						1				1		1							
		Anopheles novaguinensis	QD070115				1																																								
		Anopheles sp.	QD070199						1		1																					1															
		Tripteroides atripes	QD070201								1																																				
		Aedes sp.	QD070599										1											1																							
		Culex annulirostris	QD070709																	1	1																	1		1						1	1
		Culex bitaeniorhynchus	QD070710																																									1			
		Culex starckeae	QD070712																											1																	
		Culex crinicauda	QD070713														1	1													1	1						1									
		Culex squamosus	QD070716																									1																			
		Culex sp.	QD070799	1			1	1																			1																				
		Culex (Lophoceraomyia) sp.	QD0707A8																					1																							
		Culex ?pullus	QD070717			1																																				1			1		
		Coquillettidia xanthogaster	QD070805											1		1																							1			1			1		
		Uranotaenia lateralis	QD071401																																							1					
		Uranotaenia sp.	QD071499										1			1																		1													
		Culicidae sp. KMS1	QD0799A1									1	1																																		
	Ceratopogonidae	Bezzia sp.	QD090499	1		1	1		1	1	1																										1				1		1	1	1		
		Culicoides sp.	QD090899				1																																								
		Nilobezzia sp.	QD092099						1		1																														1	1					
		Atrichopogon sp. 2	QD0927A0	1			1																																								
		Forcipomyia sp.	QD092899							1																															1	1	1	1			
		Forcipomyia sp. KMS1	QD092884									1	1			1							1																								
		Forcipomyia sp. KMS2	QD092885																										1																		
		Dasyhelea sp.	QD092999								1	1		1		1	1	1				1		1	1				1		1	1		1				1			1		1	1			
		Clinohelea sp.	QD090699			1																																					1	1	1		
		Monohelea sp.	QD091999																																						1	1	1	1	1		
		Stilobezzia sp.	QD092699																																								1				
		Ceratopogonidae sp. KMS1 (?Bezzia)	QD099982													1	1	1	1										1		1	1		1				1	1								
		Ceratopogonidae sp. KMS2 (?Monohelea)	QD099983														1			1		1				1		1						1				1									
		Brachypogon sp.	QD093299																																						1	1			1		
		Ceratopogonidae sp. KMS3	QD099984																																			1									
		Ceratopogonidae sp. KMS4 (?Allusaudomyia)	QD099985														1																					1									
		Ceratopogonidae sp. KMS6 (?Stilobezzia)	QD099987											1																																	
		Ceratopogonidae sp. KMS7 (?Culicoides)	QD099988											1																																	
		Ceratopogonidae sp. KMS8 (?Culicoides)	QD099989															1						1				1	1	1																	
		Ceratopogonidae sp. KMS9 (?Nilobezzia)	QD0999C0									1	1				1	1				1	1			1	1	1			1							1									
		Ceratopogonidae sp. KMS10 (?Clinohelea)	QD0999C1														1			1																											
		Ceratopogonidae	QD099999									1	1		1	1			1				1		1								1		1				1	1							
	Simuliidae	Cnephia aurantiacum	QD100302								1																																				
	Psychodidae	Psychodinae sp. KMS1	QD1299A5																																			1									
		Psychodinae sp. KMS2	QD1299A6														1																														
		Psychodidae sp.	QD129999			1																																									
	Scatopsidae	Scatopsidae	QD159999									1																																			
	Tabanidae	Tabanidae	QD239999			1	1				1						1			1		1					1	1			1	1		1				1		1					1		
	Stratiomyidae	Stratiomyidae	QD249999			1			1				1						1			1	1		1			1		1				1		1	1	1									1
	Empididae	Hemerodromia sp.	QD350199								1																																				
	Dolichopodidae	Dolichopodidae	QD369999			1		1									1		1																												
		Dolichopodidae sp.	QD3699A3								1																																				
	Syrphidae	Syrphidae	QD439999														1									1																					
	Ephydridae	Ephydridae	QD789999																																										1	
		Ephydridae sp KMS1	QD7899C7									1					1									1												1									
	Muscidae	Muscidae sp. KMS 1	QD8999B7																					1																							
		Diptera sp. E	QD9999A3									1							1																												
		Diptera (other)	QD9999A4												1																								1								
	Chironomidae	Clinotanypus crux	QDAE0101														1					1	1					1						1													
		Tanypus sp.K1	QDAE03A0														1	1				1				1		1																			
		Fittkauimyia disparipes	QDAE0401								1																	1																			
		Pseudosmittia? sp. B01	QDAF31A0			1																																				1	1				
		Djalmabatista sp.	QDAE0699								1																																				
		Procladius paludicola	QDAE0803	1	1			1	1		1						1			1						1	1				1	1		1		1					1	1	1	1	1	1	1
		Procladius sp.	QDAE0899																			1																									
		Ablabesmyia notabilis	QDAE1102								1																							1	1												
		Paramerina levidensis	QDAE1201																														1														
		Paramerina parva	QDAE1202								1																																				
		Paramerina sp.A (parva?)	QDAE12A0																			1	1											1				1		1							
		Paramerina sp. B01	QDAE12A6			1																																			1	1	1	1	1		
		Paramerina sp. B02	QDAE12A7			1																																									
		Larsia albiceps	QDAE1701								1							1							1																					1	
		Larsia sp. K1 (KMS)	QDAE17A1								1																																				
		Pentaneurini sp.	QDAE9998	1			1	1	1																												1										
		Pentaneurini sp. P1	QDAE99A8										1			1	1	1				1		1	1			1		1				1		1		1		1							
		Pentaneurini sp. K1	QDAE99C4													1	1	1				1		1							1	1						1									
		Pentaneurini sp. K2	QDAE99C5																												1	1															
		Pentaneurini sp. K3	QDAE99C6									1	1						1																			1	1								
		Pentaneurini sp. K4	QDAE99C7									1	1										1					1	1					1				1	1								
		Pentaneurini sp. K5	QDAE99C8											1					1										1																		
		Pentaneurini sp. B01	QDAE99C9																																						1	1			
		Pentaneurini sp. B02	QDAE99D0			1																																			1	1	1	1	1		
		Pentaneurini sp. B03	QDAE99D1																																						1	1	1	1	1		
		Pentaneurini sp. B04	QDAE99D2			1																																									
		Rheocricotopus cf. P1	QDAF01A1								1																																				
		Parakiefferiella variegatus	QDAF0301								1																																				
		Parakiefferiella sp.	QDAF0399				1																																								
		Parakiefferiella sp. K1	QDAF03A7									1		1	1	1																															
		Parametriocnemus ornaticornis	QDAF1101								1	1							1										1																		
		Corynoneura sp.	QDAF0699			1																																									
		Orthocladiinae	QDAF9999										1																																		
		Orthocladiinae SO3 sp.	QDAF99C5					1																																							
		Riethia sp.	QDAG0199			1											1		1																												
		Cladotanytarsus sp.	QDAH0399									1																							1						1		1				
		Cladotanytarsus sp. K4	QDAH03A6																																										1	
		Tanytarsus sp.	QDAH0499																									1									1										
		Tanytarsus sp. C (bispinosus)	QDAH04A2				1																										1														
		Tanytarsus sp. P1	QDAH04B2								1																																				
		Tanytarsus 'K12'	QDAH04B4								1											1			1									1		1		1		1							
		Tanytarsus sp. P6	QDAH04B6																			1	1																								
		Tanytarsus sp. P9	QDAH04C1													1	1	1		1			1								1	1															
		Tanytarsus sp. B02	QDAH04E6			1																																			1						
		Tanytarsus sp. B03	QDAH04E7																																				1		1	1	1		