A survey of aquatic invertebrates of Nimalarragan wetland north of Broome

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Contents

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1 Background

Nimalarragan wetland lies at the south-eastern extent of the Willie Creek tidal mudflats, 20 km north of the town of Broome. It forms one component of the Wirrjinmirr/Willie Creek wetland system. It is one of two main areas of open water formed where fresh groundwater discharge forms shallow wetland basins through dissolution of carbonate muds on the edges of the tidal flats (Mathews, Semeniuk & Semenuik, 2011). Immediately east of these basins groundwater discharge, which presents as a narrow creek at its landward extent, supports *Melaleuca* thickets with waterlogged soils and shallow ponding of water in litter-filled hollows. These waterlogged *Melaleuca* habitats resemble those on the organic mound springs (including Big Springs, 70 km further north along Dampier Peninsula) but the morphology of the Nimalarragan wetland complex is very different from those mound springs. The largest water body is on the edge of the high tide mark and there is likely to be occasional mixing of wetland and tidal waters and the wetland is sometimes contiguous with surface water further out on the flats including shallow samphire marshes and tidal creek pools.

Nimalarragan is listed on the Directory of Important Wetlands of Australia (DIWA), where the freshwater lake and the *Melaleuca* woodland are listed as Nimalaica Swamp. Nimalarragan is also a Priority 4 ecological community on the list of Priority Ecological Communities maintained by Department of Biodiversity, Conservation and Attractions (DBCA).

Bunding has been used to hold back areas of fresh water for stock drinking water, although the bunding is not complete and only holds back water when depths are lower. Higher water levels inundate areas west of the bund and the open wetland still dries out completely at times (Figure 1).

This report documents a survey of aquatic invertebrates of Nimalarragan wetland conducted over three days in early May 2018. This was undertaken in conjunction with surveys of vertebrates (reported separately), vegetation (English 2018) and flora (analysed with the flora component of a survey of Kimberley organic mound springs by Lyons *et al*. (2019)).

The survey arose following discussions between the Department of Biodiversity, Conservation and Attractions and the Yaruwu Park Council on how to address some of the objectives and associated recommendations relating to bilarra (wetlands) and *Melaleuca* thickets (murrga-yirr-garnburr) in the Joint Management Plan for Yawuru Birragun Conservation Park (Department of Parks and Wildlife, 2016). These are:

Management arrangements for bilarra (wetlands)

Management objective: To increase understanding of, and to maintain or improve, the condition and ecological function of bilarra in the Yawuru Birragun Conservation Park.

> *Strategy 4.* Carry out (in collaboration with water resource management agencies and/or other external researchers) wetland mapping, monitoring and research to increase understanding of bilarra values and condition, and to facilitate assessments and reporting of management effectiveness (e.g. against performance measures described below).
>
> *Strategy 6.* Investigate the feasibility of and management options for removal of artificial structures from Nimalarragun. Remove or modify those structures if this will help to meet the objectives of this management plan.

Management arrangements for murrga-yirr-garnburr (*Melaleuca* thickets)

Management objective. To maintain, and where necessary improve, the condition of murrga-yirr-garnburr in the Yawuru Birragun Conservation Park

> *Strategy 3.* Carry out research and monitoring to establish the baseline condition of murrga-yirr-garnburr within the Yawuru Birragun Conservation Park and to help identify significant threats (e.g. document extent, species richness, composition and abundance, and the effects of threatening processes).

There has been relatively little survey of aquatic invertebrates in Kimberley inland waters, and fewer with species level identifications. Pinder *et al.* (2019) provide a brief summary of survey effort for wetlands invertebrates in the region. This survey of Nimalarragan is a small but important contribution to understanding regional diversity.

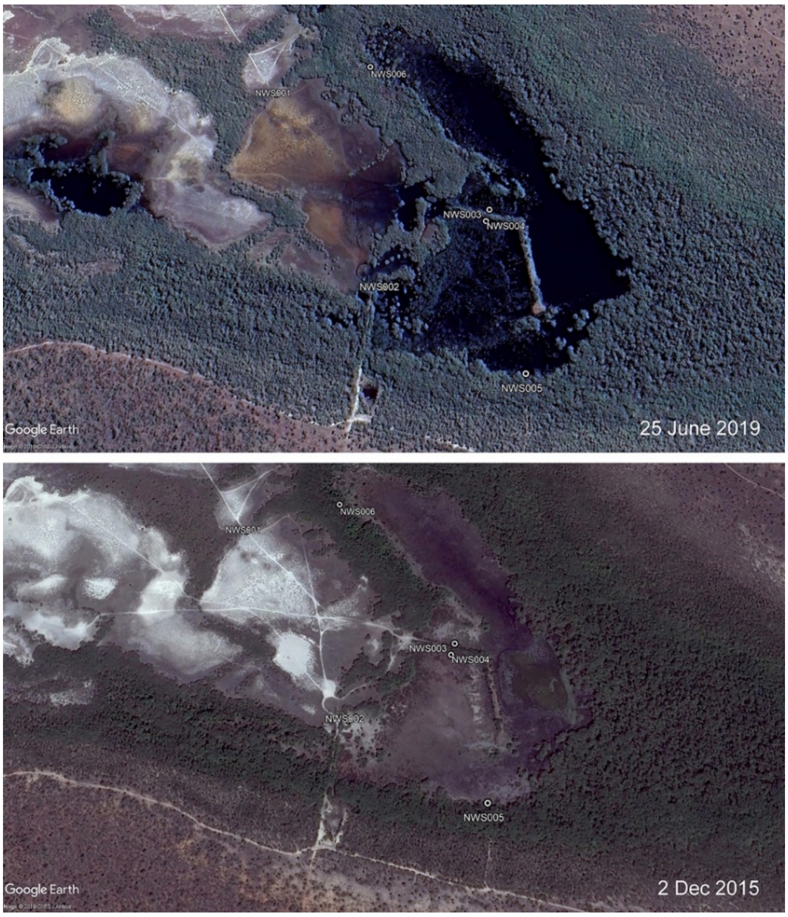

Figure 1. Satellite imagery of Nimalarragan wetland during a wetter period (25 June 2018, five weeks after the visit for this survey) and a drier period (2 Dec 2015). Imagery from Google Earth, downloaded 27 June 2019.

2 Methods

2.1 Sampling locations

Six locations were sampled for invertebrates and associated environmental data (Table 1 and Figure 2). These are described in section 3.1 and Figure 3 shows photos of four of these sites.

2.2 Data management and analysis

Data from this project will be placed on DBCA's BioSys database with some original documents placed on Data Catalogue. Analyses undertaken in R (R Development Core Team, 2018), and associated analysis datasets are also available at https://github.com/AdrianMP62/Nimalarragan.

2.3 Water chemistry and habitat characterization

At each site an unfiltered water sample was collected for analysis of the concentration of major ions, alkalinity, colour and turbidity. An additional water sample was collected at five sites for analysis of total (unfiltered) nitrogen and phosphorus. A further water sample of 500 to 1000 ml was collected (at 4 sites) and passed through a glass fibre filter paper and the paper retained for analyses of chlorophyll. Of the resulting filtrate 150 ml was further filtered through a 0.45 µm acetate filter paper for analysis of total filterable nitrogen and phosphorus. Ideally, these samples would have been frozen between collection and analysis, but this proved difficult in the field. Samples were frozen at the end of each day but briefly defrosted in transport back to Perth.

Concentrations of major ions were converted to milliequivalents per litre to determine composition.

Percent cover of submerged and emergent aquatic plants, and organic debris, was estimated visually in the field within each area sampled for invertebrates. Maximum depth of the area sampled for invertebrates was noted.

Table 1. dates and coordinates for sites sampled for aquatic invertebrates.

SiteCode	Date	Latitude Deg	Latitude Min	Latitude Sec	Longitude Deg	Longitude Min	Longitude Sec
Site 1	8/05/2018	17.00	46	34.30	122	15	30.30
Site 2	8/05/2018	17.00	46	47.13	122	15	37.60
Site 3	9/05/2018	17.00	46	42.60	122	15	44.00
Site 4	9/05/2018	17.00	46	42.60	122	15	44.00

Site 5	10/05/2018	17.00	46	52.07	122	15	46.01
Site 6	10/05/2018	17.00	46	32.29	122	15	36.65

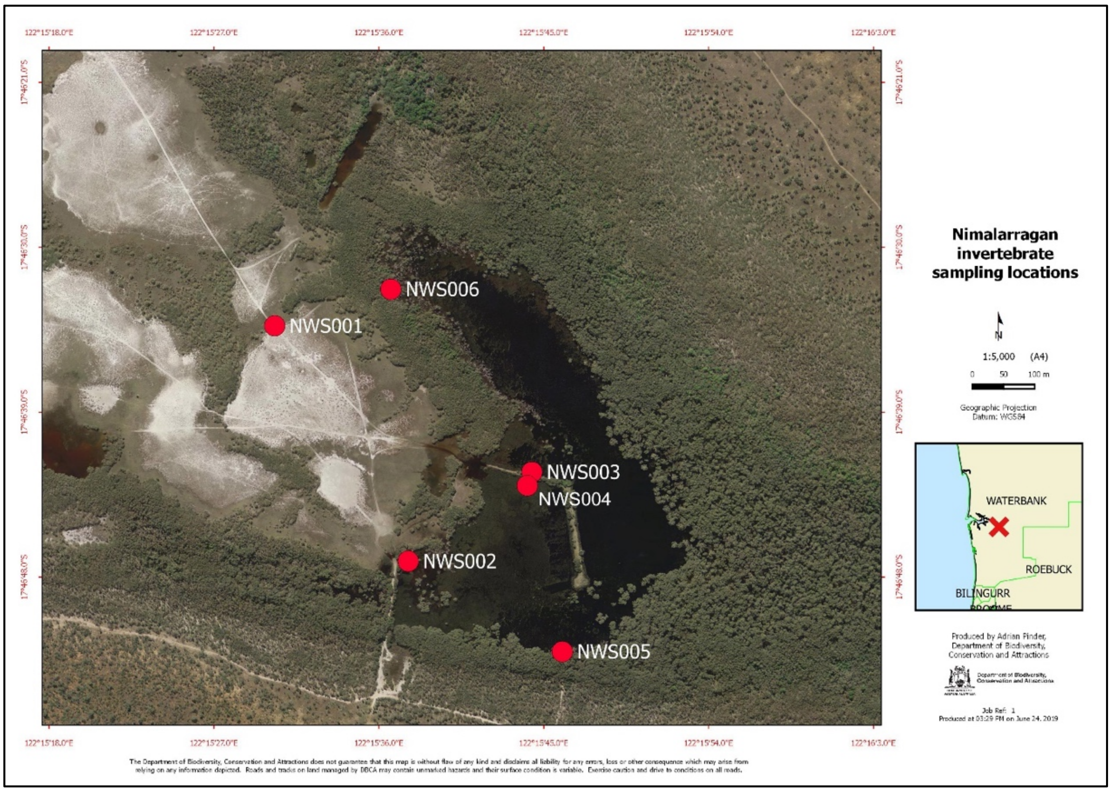

Figure 2. Aerial photo showing invertebrate sampling locations.

2.4 Invertebrate sampling

Twelve invertebrate samples were collected; two samples at each location.

Each pair of samples included a plankton sample and a benthic sample. The plankton sample involved sweeping a 50 µm mesh net through approximately 50 metres of water, collecting invertebrates in the water column, including amongst aquatic plants. The benthic sample involved sweeping a 250 µm mesh net through approximately 50 metres, including stirring up sediment with the net or feet and sweeping amongst submerged and emergent vegetation, tree trunks, leaf litter and other debris.

3 Results and Discussion

3.1 Habitats sampled

Site 1. A shallow (depth up to 11 cm) area of inundated *Tecticornia* north-west of the bund and bisected by a track running NW-SE. *Tecticornia* covered about half of the area of this site. Sediment was clayey sand and was covered with a thick algal mat. This site was sampled on foot.

Site 2. The area immediately east of the western bund, sampled by boat. Sediment was gritty clay. *Fimbristylis* covered about 50% of the area sampled, *Najas tenuifolia* covered about 10% of the sediment and small leaved floating plants were present but very sparse.

Site 3. An area north of the eastern bund, sampled on foot within two metres of the bund. Depth 1.1 m. Sediment gritty clay and with dense (~80%) cover of leaf litter and sticks, plus about 20% cover of *Fimbristylis* and 20% cover of *Najas tenuifolia*.

Site 4. An area south of the eastern bund, sampled on foot in within two metres of the bund. Depth 1100cm. Sediment gritty clay and with dense (~80%) cover of leaf litter and sticks, plus about 20% cover of *Fimbristylis* and 20% cover of *Najas tenuifolia*.

Site 5. Deep water (up 1.15 m) amongst flooded *Melaleuca*, with 50% cover of dense *Najas tenuifolia* and small areas of *Fimbristylis*. Sediment dark gritty clay with fine organic material, some logs and large branches in water and about 20% cover of leaf litter and sticks.

Site 6. Shallow water (0.08 m) under *Melaleuca* canopy at the western edge of the main north trending waterbody, consisting of small pool areas completely covered with leaf litter and no aquatic plants.

Figure 3. Photos of aquatic invertebrate sampling sites 2 to 5.

3.2 Water chemistry

Site one (the samphire flat) was either slightly brackish or mildly saline depending on whether the field measurement of the laboratory measurement of conductivity is correct. Using the meter in the field conductivity was 3700 µS/cm (converted in meter to 2.58 g/L salinity). The lab measured conductivity was 11700 µS/cm and gravimetric total dissolved solids (primarily major ions) was 6500 g/L. For other sites there was relatively little difference between field and lab measured conductivity. The major anions and cations for this site more or less balanced (4% more anions than cations) so the sum of major ions should be a reasonably reliable indicator of salinity. The sum of major ions was 6733 mg/L which is close to the gravimetric TDS of 6500 mg/L, so the higher lab conductivity is probably more accurate. Otherwise all sites were fresh (1303 to 2110 µS/cm), albeit with slightly higher salinity than for most of the mound springs sampled by Pinder et al. (2019) elsewhere in the Kimberley (116.4 to 1071 µS/cm).

Most sites were slightly alkaline (pH 7.23 to 7.86) but site 1 was very alkaline with a pH of 9.11. pH varies diurnally but at this site the higher pH may be associated with photosynthesis and other biochemical processes occurring within the dense benthic mat. At all sites, chloride dominated anion composition (Cl>HCO>SO4>CO), though less so at site 6 which had slightly elevated bicarbonate, contributing to higher $CaCO_3$ alkalinity (263 mg/L compared to ≤ 141 mg/L at other sites). Amongst the cations, the order of dominance was always Na>Mg>Ca>K.

Sodium comprised a lower proportion of cations at site 6 where there was a higher relative contribution by calcium.

Nitrogen concentrations were reasonably high. Total nitrogen concentrations varied between 1200 and 3400 µg/L whereas the interim trigger range for tropical Australian freshwater wetlands is 350 to 1200 µg/L. Similarly, total phosphorus concentrations were high at 28 to 300 µg/L (compared to an interim trigger range for tropical Australian freshwater wetlands[1] of 10 to 50 µg/L). Of this, total filterable phosphorus concentrations varied between 16 and 48 µg/L (compared to an interim trigger range for tropical Australian freshwater wetlands of 5 to 25 µg/L). Total chlorophyll concentrations (an indicator of phytoplankton concentrations) were reasonably high at 29 to 55 µg/L, with 17 to 35 µg/L being chlorophyll-a (compared to an interim trigger value for tropical Australian freshwater wetlands of 10 µg/L). These interim guidelines for freshwater quality need to be viewed with caution as they were based on limited data and would not have included minimal data from the Kimberley. They are being revised at present. Nonetheless, these nutrient and chlorophyll concentrations do suggest a degree of enrichment with the most likely source of nutrients being historical cattle usage of the site and catchment.

Water was slightly coloured, especially in sites 2 to 6, resulting from humic compounds released from decaying plant matter. Turbidity (cloudiness) was very low.

[1] (Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), 2000)

Table 2. Field and laboratory measured water quality.

	Units	Site 1 8/05/2018	Site 2 9/05/2018	Site 3 9/05/2018	Site 4 9/05/2018	Site 5 10/05/2018	Site 6 10/05/2018
Laboratory analyses							
Sodium	% meq/L	82.62	72.18	71.34	71.15	73.43	65.79
Calcium	% meq/L	4.37	8.97	9.24	9.29	8.32	13.02
Magnesium	% meq/L	11.25	17.76	18.31	18.43	17.10	19.73
Potassium	% meq/L	1.76	1.09	1.10	1.14	1.14	1.46
Total anions	mg/L	2470.2	319.8	325.1	370.6	297.1	458.5
Chloride	% meq/L	95.11	83.63	83.51	83.51	83.90	75.65
Sulphate	% meq/L	2.85	1.13	1.17	1.21	0.77	1.46
Bicarbonate	% meq/L	1.93	15.13	15.22	15.19	15.22	22.82
Carbonate	% meq/L	0.11	0.10	0.10	0.09	0.11	0.07
Total cations	mg/L	4263.0	637.3	646.7	733.3	599.1	953.7
Alkalinity ($CaCO_3$ equivalent)	mg/L	120	123	125	141	115	263
Chlorophyll a	mg/L	0.021	0.017	0.035	0.018	-	-
Chlorophyll b	mg/L	0.003	0.002	0.003	<0.001	-	-
Chlorophyll c	mg/L	0.004	0.002	0.004	0.001	-	-
Phaeophytin-a	mg/L	0.013	0.009	0.013	0.01	-	-
Nitrogen total	mg/L	2.3	1.2	1.2	1.9	3.4	-
Nitrogen total soluble	mg/L	1.6	0.81	0.92	0.93	-	-
Phosphorus total	mg/L	0.028	0.069	0.089	0.15	0.3	-
Phosphorus total soluble	mg/L	0.016	0.023	0.041	0.048	-	-
Electrical conductivity	µS/cm	11700	1680	1690	1900	1530	2270
Total dissolved solids - gravimetric	mg/L	6500	920	980	1100	870	1300
Colour	TCU	38	180	230	250	270	210
Turbidity	NTU	0.6	3.7	4	4.4	7.2	1.6
Field measurements							
Depth	cm	11	57	110	110	115	8
Field Conductivity (uS/cm)	µS/cm	3700	1597	1303	1770	1374	2110
Field pH		9.11	7.76	7.53	7.62	7.23	7.86
Temperature	°C	26	30.9	28	27.6	27.7	29.9

3.3 Invertebrates

3.3.1 Diversity and spatial patterning

At least 157 invertebrate species were collected, including 108 identified to species level and the rest mostly to genus or family level (many of which may represent more than one species). Herein these will all be referred to as ‘species’ for convenience. Between 48 and 83 species were collected at each location (Figure 4), with the lowest richness being the *Tecticornia* flat (site 1) with 48 species and all other sites having at least 59 species. Lower richness would be expected at site 1 given the salinity (Pinder *et al.*, 2005). Sites 4 and 5 had highest richness with 80 and 83 respectively. Average richness was 68 species. Comparing richness with other Kimberley wetlands is difficult due to differences in sampling effort associated with the nature of the habitats. Sampling effort was much lower (10 litres of water for plankton and 10 m sweep net samples for benthic) in Kimberley organic mound springs sampled by Pinder *et al*. (2019) due to the nature and size of the habitats. Nonetheless, a combined plankton and benthic sample from those springs had invertebrate diversity between 78 and 131 (average 106). Combined plankton and benthic samples from Walyarta springs, with sampling effort more like that for Nimalarragan, collected fewer species (27 to 71 species, average 49) (Quinlan, Pinder & Lewis, 2016).

On average, benthic samples collected slightly more species (average 48) than plankton samples (43). Combining data across sites, the plankton and benthic samples collected about the same number of species (108 and 105 respectively), with 55 species in common.

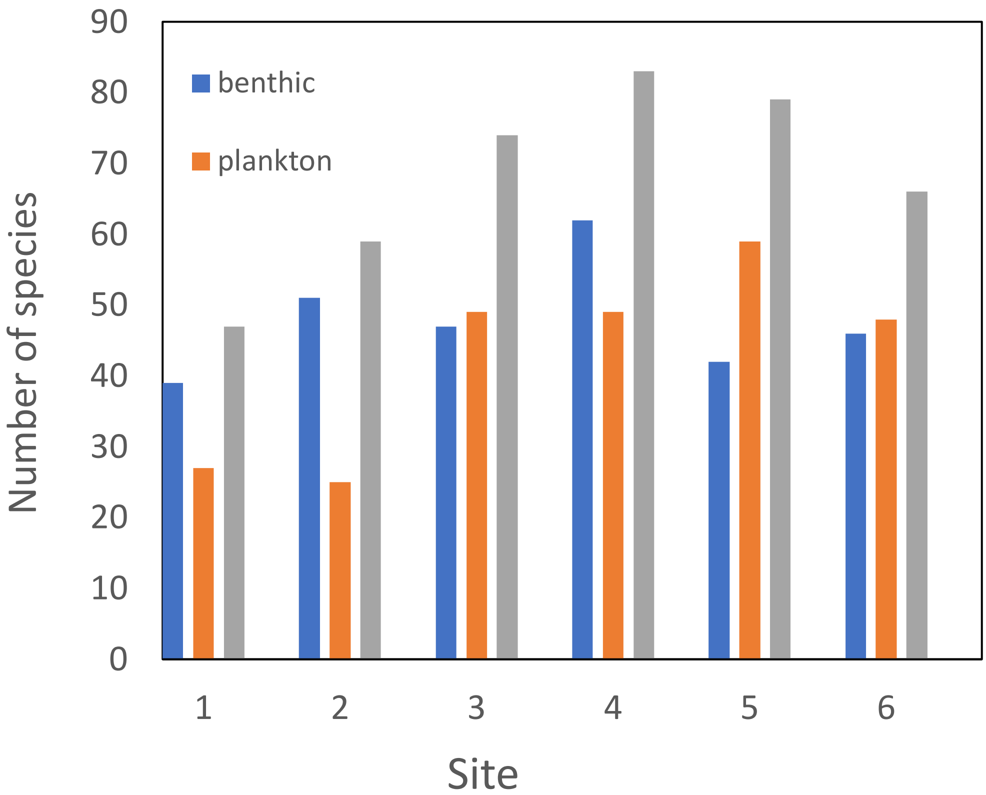

Figure 4. Number of aquatic invertebrate species collected per site in plankton and benthic samples and these samples combined (grey columns).

Sixty species (about a third of the total) occurred at only one site, but these were not evenly distributed across the sites, with three quarters of these singletons in samples from sites 1, 5 and 6 and over a third from site 5 alone.

Site 1 was brackish but few saline water specialists were present, suggesting it may be fresher at times. The rotifer *Lecane plesia* tends to occur in brackish water (Myers, 1936) and was present only in this site. There is only one other Australian record (a brackish-water river pool in the Pilbara (Pinder *et al.*, 2017)) but the species was described from North America (Myers, 1936). The water flea *Dunhevedia crassa* is tolerant of mild salinity and occurred in site 1 but also other sites which were fresh. The harpacticoid copepod *Cletocamptus dietersi* is a common and widespread salt-tolerant species known from near coastal waters around Australia and was collected only at site 1 in this study. Many other 'freshwater' species were collected and tolerant of mildly saline waters, but most were not restricted to site 1 or were found only in some of the other sites. Examples include the copepod *Apocyclops dengizicus* from site 2, two of the *Berosus* beetles (*B. australiae* from 4 sites and *B. pulchellus* from site

1 only), the non-biting midge *Procladius paludicola* (sites 2 and 4) and the dragonfly *Diplacodes bipunctata*. It is likely that most species present would be able to tolerate mild salinity for short periods.

Sites 5 and 6 were located under a dense canopy of *Melaleuca*. Site 6 had 100% cover of leaf litter and, while areal cover of litter at site 5 was lower than at sites 3 and 4, this included more dead branches, sticks and logs. This and the dense canopy cover providing shade explains presence of some species just at these sites. For example, the mosquito *Anopheles bancrofti* was only found at site 5 and its larvae prefer 'deeply shaded freshwaters' (Liehne, 1991). Another mosquito, *Uranotaenia albescens* also has larvae that prefer 'shaded shallow margins of freshwater pools amongst vegetation or debris' (Liehne, 1991), which explains its presence only at sites 5 and 6. Another species found only at site 5 was the water scorpion *Ranatra diminuta* which is usually found amongst decaying twigs which act as a camouflage for this stick-like ambush predator. Syrphid (hover fly) larvae were found only at site 6 (the very shallow site consisting of litter filled pools) and these prefer organic stagnant waters. Some other species known only from these sites are associated with spring habitats. These include *Chrissia* ostracods (site 6) and 'ostracod gen. nov. 357' (site 5), both also found in Kimberley organic mound springs. The cladoceran *Karualona karua* (site 5) has also primarily been collected from springs in WA, including Kimberley organic mound springs and springs in the Pilbara. Another cladoceran *Kurzia longirostris* (site 5) is also known primarily from springs (including Kimberley organic mound springs) or highly vegetated swamps. For reasons unknown site 5 was the only site to have testate protozoa.

Species collected only from one of the other three sites are not such habitat specialists.

Site classification

Figure 5 shows cluster analyses of the plankton and benthic invertebrate samples. For the plankton samples, this shows that site 1 (the brackish site) differed in composition from all other sites. It also shows that site 6 (the very shallow north-west site under the *Melaleuca* canopy) differed from remaining sites and that site 2 (on the east side of the western bund) differed from the remaining deeper sites.

For benthic samples, the analysis again placed site 1 away from the other sites, but clustered the two sites under dense *Melaleuca* canopy (sites 5 and 6) together, separate to the three open water sites.

These analyses indicate that there is some patterning in the invertebrate fauna across the larger Nimalarragan wetland and that maintaining the current diversity of the wetland's invertebrate fauna would require maintaining this habitat diversity.

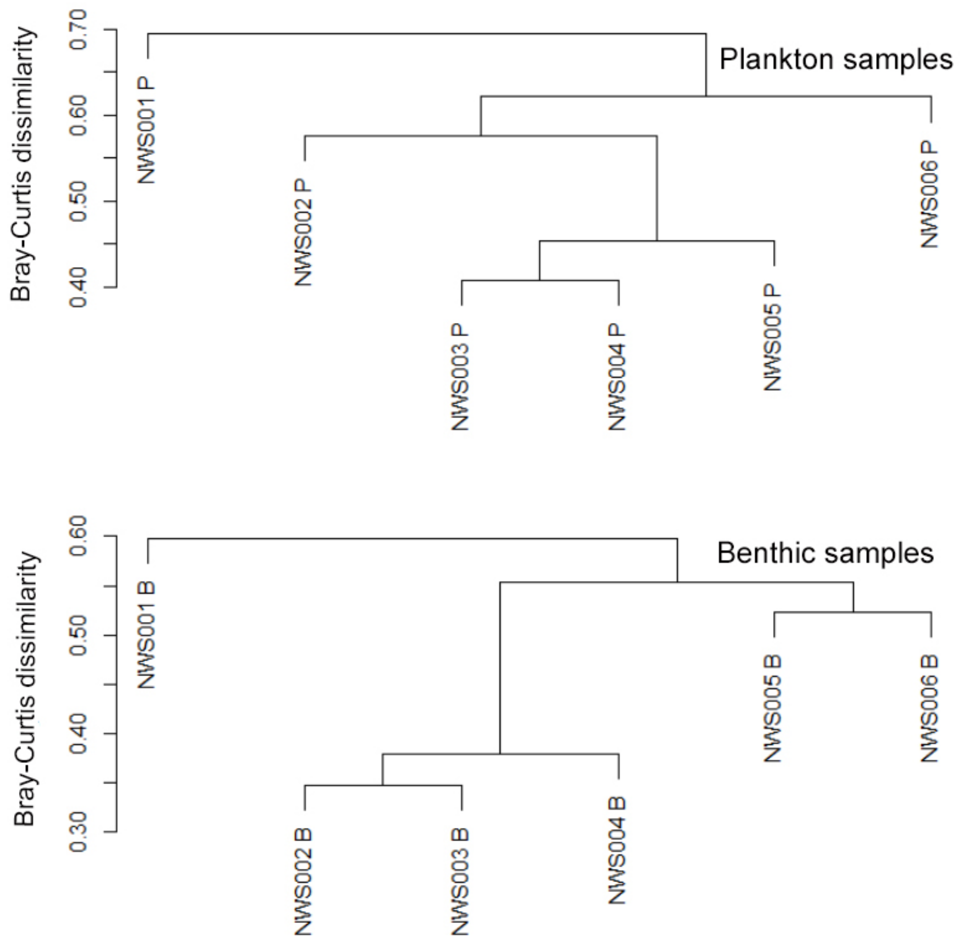

Figure 5. Dendrograms resulting from cluster analyses of the plankton samples (top) and benthic samples (bottom).

3.3.2 Significant species and records

A few of the species present at Nimalarragan have rarely been collected in Western Australia. However, the paucity of published studies of aquatic invertebrates in the Kimberley and of publications with species lists elsewhere in northern Australia hinders assessment of the conservation significance of some of these records. The Atlas of Living Australia (ALA) and the Global Biodiversity Information Facility (GBIF) have been used to find additional records. At present, published studies of aquatic invertebrates from the Kimberley with species level identifications are rare, with most data coming from a few wetlands surveyed by DBCA in 2009 (e.g. Department of Environment and Conservation *et al.*, 2009), our surveys of springs and some work on the Ord River as part of water allocation planning research (e.g. Storey, 2002).

Freshwater protozoa are not well surveyed in Australia, although have been included in most DBCA aquatic invertebrate surveys. Several of these (*Centropyxis platystoma*, *Centropyxis aerophila Netzelia tuberculata* and *Netzelia corona*) have rarely been reported in Western Australia but these are otherwise very widespread in Australia and likely cosmopolitan.

As mentioned above, the rotifer *Lecane plesia* (from the brackish site 1) has rarely been recorded in Australia, with just one other record in the Pilbara (also a brackish site).

There are very few records of the water flea *Diaphanosoma australiensis*; these being two collections on Cape York (Qld) including the type locality (Korovchinsky, 1981), a record of *Diaphanosoma* aff. *australiensis* from the southern Carnarvon Basin (Halse *et al.*, 2000) and now records from sites 2 to 6 at Nimalarragan.

The undescribed water mite *Arrenurus* sp. WA29, collected from all six sites at Nimalarragan, is otherwise known only from north-western Australian groundwater fed wetlands: at Walyarta (Quinlan *et al.*, 2016), plus Big Spring (west Kimberley) and Bamboo Spring (Victoria-Bonaparte) (Pinder *et al.*, 2019).

The ostracod "Strandesia/Chlamydotheca sp. 357" was collected from site 5 only and has otherwise only been collected from Long Spring (on the Victoria-Bonaparte coast) by Halse *et al*. (1996) and groundwater fed wetlands in the Little Sandy Desert (Pinder & Quinlan, 2013). This undescribed species of uncertain generic identity thus appears to be associated with groundwater fed wetlands in the north and inland of WA.

The *Stenocypris* ostracod collected from site 2 does not match other *Stenocypris* specimens in the DBCA collection or other described species known from Australia and may be a new species thus far known only from Nimalarragan.

Another species of ostracod appears 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 these specimens are an undescribed species. It is probably the same species as specimens from several of the Victoria-Bonaparte springs sampled in 2017 (Pinder *et al.*, 2019) and appears to be the same as specimens named '*Herpetocypris* sp. 652' from Big Spring (west Kimberley) and Black Spring (central Kimberley) collected in 1999 (DBCA unpublished data).

The ostracod *Cypris* sp. is one of very few records of this genus in Australia. There is one record on ALA from near Lake Eyre and two species were described from New South Wales and Queensland. Specimens from Edge Swamp on the Victoria-Bonaparte Coast were identified as *Cypris subglobulosa* but this identification should be viewed with caution[2]. *Cypris* was also recently collected from 'around Broome'[3].

The beetle *Hydroglyphus trifasciatus* has only recently been documented in north-western Australia, with records at Walyarta springs (Quinlan *et al.*, 2016), Big Springs and Bunda Bunda Springs in the west Kimberley (Pinder *et al.*, 2019) and Lake Eda on the Roebuck Plains (Kern *et al.*, 2009). The type locality is also a spring (Howard Springs in the NT) so this could be a species showing a preference for northern Australian springs.

Another beetle, *Spercheus platycephalus* is widespread across the northern Northern Territory and eastern Australia but has rarely been recorded in Western Australia. There is an ALA record from around Wyndham and two records from large wetlands in the Pilbara (Pinder *et*

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[2] Stuart Halse, Bennelongia Environmental Consultants

[3] Stuart Halse, Bennelongia Environmental Consultants

al., 2010). It was collected from all sites except site 1 (assuming the larval *Spercheus* were also this species).

Uranotaenia albescens is a rarely collected mosquito, with just 3 records on Atlas of Living Australia (Northern Queensland and Darwin). Larvae of this species were collected only from sites 5 and 6 (the sites under *Melaleuca* canopy) and is probably the same as the *Uranotaenia* sp. collected at Bunda Bunda spring (west Kimberley) and two Victoria-Bonaparte coast springs by Pinder *et al.* (2019). Larvae prefer shaded shallow margins of freshwater pools amongst vegetation or debris (Liehne, 1991) which explains its presence only at these two sites.

Finally, the surface-dwelling water bug *Microvelia* (*Picaultia*) *douglasi* occurs across far northern Australia but there are few records. This species was collected from sites 3 and 5 at Nimalarragan and at Big Springs further up the Dampier Peninsula coast by Pinder *et al.* (2019).

3.3.3 Biogeography

The aquatic invertebrate fauna of Nimalarragan wetland includes at least 27 species that are widely distributed across northern Australia, with a few extending into central Australia or part way down the east and/or west coasts. However, some of these are known from only a few locations and some have few or no previous records in the Kimberley region. A few of these probably extend into Indonesia or the wider Oceania region. A few are known only from north-western Australia at present, though may have distributions that extend into at least the northern Territory. These are the two *Arrenurus* water mites, four ostracods and possibly a non-biting midge (Pentaneurini sp. P1) (see 'Significant species and records' above). A few species have very wide Australian distributions. At least 44 additional species occur more widely than Oceania region. Some of the oligochaetes and cladocerans are pan-tropical and the protozoans and rotifers are cosmopolitan, as are some of the oligochaetes.

The idea that many species are widespread does need to be tempered by the increasing understanding that there is significant genetic diversity, indicating existence of 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. Recent work on ostracods is also showing much greater species diversity, partly through genetic analyses, than previously thought (Martens et al. 2013; Halse & Martens, 2019).The remaining taxa could not be identified to species level so their biogeographic affinities are not known.

A few species appear to be characteristic of springs and occurred both at the Nimalarragan wetland and in some of the organic mound springs sampled by Pinder *et al*. (2019). However, this was a small subset of the spring specialists collected in the Kimberley organic mound springs. This subset may have been underestimated by not sampling the small ponds and seepages further east into the *Melaleuca* woodland, which are more analogous to the habitats within the organic mound springs. Unfortunately, these were only discovered on the day of departure from Broome. We recommend that these habitats be sampled to better document the spring associated species.

4 Implications for management

Nimalarragan wetland supports an aquatic invertebrate community consisting primarily of species that are widespread across northern Australia, but possibly with a few species with more north-west distributions. At this stage the wetland does not appear to support invertebrate communities with as great a conservation significance as the organic mound springs such as Bunda Bunda. However, the number of species characteristic of the mound spring's habitats may have been underestimated at Nimalarragan by not sampling the groundwater seepage areas within the *Melaleuca* thickets. While most species have wide distributions, this does not detract from the fact that it is a wetland that remains in very good condition with no disturbances of major consequence and probably has a community composition not replicated in other types of wetlands in the Kimberley.

When visited, the wetland was deep enough to extend around the bunds, showing that the bunds are not required for the wetland to consist of substantial areas of surface water. The bunds may help to retain a small area of surface water as the wetland dries and thus extend the hydroperiod (time with water presence) but this is unlikely to have significantly affected the composition of the wetland's invertebrate communities, and it appears (from satellite imagery) that the whole open area of the wetland does dry at times. The shallow pools and seepages within the upstream *Melaleuca* thicket are likely to act as drought refuges for elements of the invertebrate fauna during these drier times.

Nutrient (N and P) concentrations may be elevated but not enough to cause significant impact and may decline over time if cattle are kept out of the wetland area and surrounds.

5 References

Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. ANZECC & ARMCANZ, Canberra.

Kern S., Pinder A. & Nowicki A. (2009). *Resource Condition Report for Significant Western Australian Wetland: Lake Eda.* Department of Environment and Conservation, Perth.

Department of Parks and Wildlife (2016). *Yawuru Birragun Conservation Park Joint Management Plan 2016*. Department of Parks and Wildlife, Perth.

Halse S.A. & Martens K. (2019). Four new genera and five new species of "*Heterocypris*" from Western Australia (Crustacea, Ostracoda, Cyprinotinae). *European Journal of Taxonomy*. https://doi.org/10.5852/ejt.2019.493

Halse S.A., Shiel R.J. & Pearson G.B. (1996). Waterbirds and aquatic invertebrates of swamps on the Victoria Bonaparte mudflat, northern Western Australia. *Journal of the Royal Society of Western Australia* **79**, 217–224

Halse S.A., Shiel R.J., Storey A.W., Edward D.H.D., Lansbury I., Cale D.J., *et al.* (2000). Aquatic invertebrates and waterbirds of wetlands and rivers of the southern Carnarvon

Basin, Western Australia. *Records of the Western Australian Museum* **Supplement 61**, 217–265

Karanovic I. (2012). *Recent freshwater ostracods of the world: Crustacea, Ostracoda, Podocopida*. Springer, Berlin ; New York.

Korovchinsky N.M. (1981). Taxonomic and Faunistic Revision of Australian Diaphanosoma (Cladocera : Sididae. *Australian Journal of Marine and Freshwater Research* **32**, 813–831

Liehne P.F.S. (1991). *An Atlas of the Mosquitoes of Western Australia*. Health Department of Western Australia, Perth.

Lyons M.N., English J., Collins M. & Department of Biodiversity, Conservation and Attractions (2019). Vegetation and Flora. In: *Biodiversity Survey, Mapping, Delineation and Assessment of Selected Organic Mound Springs of the Kimberley Region*. Department of Biodiversity, Conservation and Attractions.

Martens K., Halse S. & Schön I. (2013). On the Bennelongia barangaroo lineage (Crustacea, Ostracoda) in Western Australia, with the description of seven new species. *European Journal of Taxonomy* **0**, 1–59. https://doi.org/10.5852/ejt.2013.66

Martin P., Martinsson S., Wuillot J. & Erséus C. (2018). Integrative species delimitation and phylogeny of the branchiate worm *Branchiodrilus* (Clitellata, Naididae). *Zoologica Scripta* **47**, 727–742. https://doi.org/10.1111/zsc.12316

Mathews D., Semeniuk V. & Semenuik C.A. (2011). Freshwater seepage along the coast of the western Dampier Peninsula,Kimberley region, Western Australia. *Journal of the Royal Society of Western Australia* **94**, 207–212

Myers F.J. (1936). Three New Brackish Water and One New Marine Species of Rotatoria. *Transactions of the American Microscopical Society* **55**, 428. https://doi.org/10.2307/3222524

Pinder A., Halse S.A., McRae J.M. & Shiel R.J. (2005). Occurrence of aquatic invertebrates of the Wheatbelt region of Western Australia in relation to salinity. *Hydrobiologia* **543**, 1–24

Pinder A.M., Halse S.A., Shiel R.J. & McRae J.M. (2010). An arid zone awash with diversity: patterns in the distribution of aquatic invertebrates in the Pilbara region of Western Australia. *Records of the Western Australian Museum* **Supplement 78**, 205–246

Pinder A.M., Lyons M.N., Collins M., Lewis L., Quinlan K., Shiel R.J., *et al.* (2017). *Wetland Biodiversity Patterning Along the Middle to Upper Fortescue Valley (Pilbara Region: Western Australia) to Inform Conservation Planning*. Department of Biodiversity, Conservation and Attractions, Perth , Western Australia.

Pinder A.M., Quinlan K., Shiel R.J. & Department of Biodiversity, Conservation and Attractions (2019). Aquatic invertebrates. In: *Biodiversity Survey, Mapping, Delineation and Assessment of Selected Organic Mound Springs of the Kimberley Region*. Department of Biodiversity, Conservation and Attractions.

Quinlan K., Pinder A.M. & Lewis L. (2016). *Aquatic Fauna Survey at Mandora Marsh (Walyarta) in September 2015*. Department of Parks and Wildlife, Perth.

R Development Core Team (2018). *R: A Language and Environment for Statistical Computing, V 3.5.1*. R Foundation for Statistical Computing, Vienna, Austria.

Storey A.W. (2002). *Lower Ord River Aquatic Invertebrate Habitat Study. Final Report.* The University of Western Australia, Perth.

Appendices

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Inorganic Chemistry Section

Report of Examination

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Attention: Adrian Pinder

Report on: 6 samples received on 22/05/2018

LAB ID	Material	Client ID and Description
17S4618 / 001	water	Site 1
17S4618 / 002	water	Site 2
17S4618 / 003	water	Site 3
17S4618 / 004	water	Site 4
17S4618 / 005	water	Site 5
17S4618 / 006	water	Site 6

LAB ID			001	002	003	004
Client ID			Site 1	Site 2	Site 3	Site 4
Sampled			08/05/2018	09/05/2018	09/05/2018	09/05/2018
Analyte	**Method**	**Unit**				
Alkalinity as CaCO3	iALK1WATI	mg/L	120	123	125	141
Bicarbonate	iALK1WATI	mg/L	138	149	152	172
Calcium	iMET1WCICP	mg/L	98.7	27.4	28.8	33.0
Carbonate	iALK1WATI	mg/L	4	<1	<1	<1
Chloride	iCO1WCDA	mg/L	3960	479	485	550
Chlorophyll a	WL177	mg/L	0.021	0.017	0.035	0.018
Chlorophyll b	WL177	mg/L	0.003	0.002	0.003	<0.001
Chlorophyll c	WL177	mg/L	0.004	0.002	0.004	0.001
Chlorophyll Volume	WL177	mL	500	750	750	1000
Colour, TCU	iCOL1WACO	TCU	38	180	230	250
Electrical Conductivity	iEC1WZSE	mS/m	1170	168	169	190
Magnesium	iMET1WCICP	mg/L	154	32.9	34.6	39.7
Nitrogen, total soluble	iNP1WDFIA	mg/L	1.6	0.81	0.92	0.93
Nitrogen, total	iNP1WTFIA	mg/L	2.3	1.2	1.2	1.9
Phaeophytin a	WL177	mg/L	0.013	0.009	0.013	0.010
Phosphorus, total	iPP1WTFIA	mg/L	0.028	0.069	0.089	0.15
Phosphorus, total soluble	iPP1WDFIA	mg/L	0.016	0.023	0.041	0.048
Potassium	iMET1WCICP	mg/L	77.5	6.5	6.7	7.9
Sodium	iMET1WCICP	mg/L	2140	253	255	290
Sulphate	iANIO1WAIC	mg/L	161	8.8	9.2	10.8
Total dissolved solids(grav)	iSOL1WDGR	mg/L	6500	920	980	1100
Turbidity	iTURB1WCZZ	NTU	0.6	3.7	4.0	4.4

LAB ID			005	006
Client ID			Site 5	Site 6
Sampled			10/05/2018	10/05/2018
Analyte	**Method**	**Unit**		
Alkalinity as CaCO3	iALK1WATI	mg/L	115	263
Bicarbonate	iALK1WATI	mg/L	141	320
Calcium	iMET1WCICP	mg/L	23.5	57.8
Carbonate	iALK1WATI	mg/L	<1	<1
Chloride	iCO1WCDA	mg/L	452	617
Colour, TCU	iCOL1WACO	TCU	270	210
Electrical Conductivity	iEC1WZSE	mS/m	153	227
Magnesium	iMET1WCICP	mg/L	29.3	53.1
Nitrogen, total	iNP1WTFIA	mg/L	3.4	
Phosphorus, total	iPP1WTFIA	mg/L	0.30	
Potassium	iMET1WCICP	mg/L	6.3	12.6
Sodium	iMET1WCICP	mg/L	238	335
Sulphate	iANIO1WAIC	mg/L	5.6	16.2
Total dissolved solids(grav)	iSOL1WDGR	mg/L	870	1300
Turbidity	iTURB1WCZZ	NTU	7.2	1.6

Method	Method Description
iALK1WATI	Alkalinity (as CaCO3) and constituents by acid titration.
iANIO1WAIC	Anions in water by Ion Chromatography.
iCO1WCDA	Colourimetric analysis by DA (Discrete Autoanalyser).
iCOL1WACO	Colour by spectrometry.
iEC1WZSE	Electrical conductivity in water compensated to 25C.
iMET1WCICP	Total dissolved metals by ICPAES.
iNP1WDFIA	Total Soluble Nitrogen by persulphate digestion FIA.
iNP1WTFIA	Total Nitrogen by persulphate digestion and analysis by FIA.
iPP1WDFIA	Total Soluble Phosphorus by persulphate digestion and FIA.
iPP1WTFIA	Total Phosphorus by persulphate digestion and FIA.
iSOL1WDGR	Total dissolved solids (TDS) by gravimetry, dried at 178 - 182 C.
iTURB1WCZZ	Turbidity of water by Nephelometer.
WL177	Chlorophyll a, b, c and Pheophytin a by Spectrometry

These results apply only to the sample(s) as received. Unless arrangements are made to the contrary, these samples will be disposed of after 30 days of the issue of this report.
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Alex Martin
Chemist
SSD Inorganic Chemistry
5-Jun-2018

HMay

Hanna May
Team Leader
SSD Inorganic Chemistry

			1		2		3		4		5		6	
Major group	Family (if known)	Lowest level of identification	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton
Protozoans	Arcellinidae	*Arcella discoides*										1		
		Arcella bathystoma										1		
	Centropyxidae	*Centropyxis aculeata*										1		
		Centropyxis ecornis										1		
		Centropyxis platystoma										1		
		Centropyxis cf. *aerophila*										1		
	Difflugiidae	*Difflugia gramen*										1		
	Lesquereusidae	*Netzelia tuberculata*								1		1		
		Netzelia corona										1		
Hydrozoans		Hydra sp.				1		1	1	1		1	1	
Turbellaria (Flatworms)		Turbellaria				1				1		1		
Nematoda(Roundworms)		Nematoda			1		1						1	
Rotifera		Bdelloidea						1		1		1		1
	Floscolariidae	*Ptygura sp.*								1				
	Testudinellidae	*Testudinella patina*				1		1		1		1		
		Testudinella insinuata								1				
	Brachionidae	*Brachionus angularis*								1		1		1
		Brachionus quadridentatus				1		1		1		1		
		Brachionus quadridentatus minor						1		1		1		
		Platyias quadricornis								1				
	lepadellidae	*Colurella adriatica*										1		
		Lepadella oblonga		1						1		1		1
		Lepadella patella												1
		Lepadella rhomboides						1		1				1
	Euchlanidae	*Euchlanis dilatata*						1						1
		Tripleuchlanis plicata						1						
	Lecanidae	*Lecane bulla*				1		1		1		1		1
		Lecane clara								1				
		Lecane grandis										1		
		Lecane hamata												1
		Lecane luna						1				1		
		Lecane ungulata		1										1
		Lecane plesia		1										
		Lecane sp. A						1						1
		Lecane sp. B												1
	Mytilinidae	*Mytilina ventralis macracantha*		1				1				1		1
		Lophocharis oxysternon										1		
	Cephalodellidae	*Cephalodella forficula*								1				1
	Notommatidae	*Notommata tripus*												1
	Proalidae	*Proales* sp.						1						
Gastropoda(Snails))	Planorbidae	*Gyraulus* sp.	1	1	1	1	1	1	1	1	1	1	1	1
	Assiminiaeidae	*Assiminaeidae*					1	1	1					
Clitellata (Aquatic earthworms)	Naididae	*Dero nivea*									1	1		
		Dero furcata	1				1		1				1	1
		Dero pectinata			1	1	1		1	1				
		Allonais ranauana		1	1	1		1	1	1				1
		Allonais inaequalis			1	1			1		1	1		
		Pristina longiseta										1	1	1
		Pristina leidyi				1								
Acarina (Water mites)	Hydrachnidae	*Hydrachna* sp.			1				1					
	Eylaidae	*Eylais* sp.	1	1					1					
	Unionicolidae	*Neumania* sp.	1		1		1		1		1	1	1	
	Pionidae	*Piona* sp.					1	1	1		1	1		
	Arrenuridae	*Arrenurus (Brevicaudaturus) multicornutus*									1	1		

			1		2		3		4		5		6	
Major group	Family (if known)	Lowest level of identification	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton
		Arrenurus (Micruracarus) sp. 29		1	1	1	1	1	1			1	1	
		Arrenuridae								1				
Acarina (Other mites)		Acarina												1
		Mesostigmata							1				1	
		Trombidioidea							1					
		Oribatida sp.							1					
	Eniochthoniidae	Eniochthoniidae sp.							1		1			
Cladocera (Water fleas)	Sidiidae	*Diaphanosoma australiensis*				1		1		1		1		1
		Latonopsis australis										1		
		Sarsilatona papuana										1		1
	Chydoridae	*Chydorus* cf. *sphaericus*		1										
		Dunhevedia crassa		1				1		1		1		1
		Kurzia longirostris										1		
		Karualona karua										1		
	Daphniidae	*Ceriodaphnia cornuta*				1		1		1		1		
		Ceriodaphnia spp. (not cornuta)						1		1		1		
		Simocephalus heilongjiangensis						1				1		
	Moinidae	*Moina* sp.	1											
Ostracoda (Seed shrimps)	Darwinulidae	*Vestalenula marmonieri*			1				1				1	
	Candonidae	Candonidae					1							
		Cypretta sp.			1		1		1			1	1	1
		Cyprinotus cingalensis	1	1										
		Strandesia/Chlamydotheca gen nov 357										1		
		Cypricercus sp.					1							
		Cypris sp.											1	1
		Stenocypris sp. 1			1									
		Chrissia sp.											1	
Copepoda	Cyclopidae	*Microcyclops varicans*									1			1
		Mesocyclops brooksi	1		1	1	1	1	1	1	1	1	1	1
		Apocyclops dengizicus			1									
Coleoptera (Beetles)	Dytiscidae	*Laccophilus sharpi*			1		1		1				1	
		Laccophilus clarki			1		1		1				1	
		Hydrovatus fasciatus					1		1	1				
		Hydrovatus rufoniger politus			1		1							
		Hyphydrus lyratus			1		1				1			
		Hydroglyphus daemeli											1	
		Hydroglyphus trifasciatus							1		1		1	1
		Hydroglyphus leai	1	1	1		1	1	1	1	1	1		
		Limbodessus compactus											1	
		Limbodessus sp.							1		1			1
		Megaporus ruficeps									1			
		Cybister tripunctatus temnenkii									1			
		Cybister sp.			1				1				1	
		Bidessini												
	Sperchidae	*Spercheus* sp.				1	1			1				
		Spercheus platycephalus							1		1		1	1
	Hydrophilidae	*Berosus australiae*	1		1	1			1				1	1
		Berosus aquilo	1	1										
		Berosus nicholasi	1	1										
		Berosus pulchellus	1											
		Berosus sp.			1		1			1				
		Regimbartia attenuata											1	
		Enochrus deserticola	1											
		Enochrus sp.			1									

			1		2		3		4		5		6	
Major group	Family (if known)	Lowest level of identification	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton
		Paracymus pygmaeus	1						1				1	1
		Hydrophilus sp.											1	1
		Coelostoma fabricii	1											
		Hydrophilidae												
		Scirtidae							1				1	1
		Limnichidae					1							
Diptera (Flies)	Chaoboridae	*Chaoboridae*									1			
	Culicidae	*Anopheles (Anopheles) bancroftii*										1		
		Anopheles hilli		1										
		Anopheles sp.	1										1	
		Culex (Culex) annulirostris	1	1	1	1	1	1	1	1	1	1		
		Culex sp.											1	
		Culex (Lophoceraomyia) sp.						1			1			
		Uranotaenia albescens									1		1	1
	Ceratopogonidae	*Culicoides* sp.					1		1					
		Nilobezzzia sp. NWS			1	1	1		1					
		Ceratopogonidae						1			1			
		Dasyheleinae	1	1			1	1			1		1	
		Ceratopogonidae type KMS1			1									
		Ceratopogonidae type KMS2	1		1									
		Ceratopogonidae type KMS8			1									
		Ceratopogonidae type KMS9	1											
	Scatopsidae								1					
	Tabanidae		1		1		1						1	1
	Stratiomyidae		1	1	1	1	1	1	1	1	1	1	1	1
	Syrphidae												1	
	Ephydridae							1	1	1				
	Muscidae		1					1						
	Chironomidae	*Procladius paludicola*			1				1					
		Pentaneurini P1			1		1	1	1	1	1	1	1	1
		Tanytarsus fuscithorax/semibarbitarsus	1	1	1	1								
		Chironomus aff. *alternans*			1	1	1	1	1	1	1	1	1	1
		Kiefferulus intertinctus			1		1	1	1		1			
		Polypedilum nubifer	1											
		Polypedilum nr. *convexum*	1	1	1	1	1	1	1	1	1	1	1	1
		Parachironomus 'K1'								1				
Ephemeroptera (Mayflies)	Baetidae	*Cloeon sp.*	1	1	1	1	1	1	1	1	1	1	1	1
Hemiptera (Water bugs)	Mesoveliidae	*Mesovelia vittigera*	1		1			1	1		1		1	
		Mesovelia sp.		1						1				1
	Hydrometridae	*Hydrometra* sp.									1	1	1	1
	Veliidae	*Microvelia (Picaultia) douglasi*						1			1			
		Microvelia sp.					1							
	Gerridae	*Limnogonus fossarum gilguy*			1		1							
		Limnogonus sp.						1	1					
		Gerridae	1							1	1	1	1	1
	Nepidae	*Ranatra diminuta*									1			
		Ranatra sp.			1		1	1	1	1		1		
	belostomatidae	*Diplonychus* sp.	1	1	1		1	1	1	1	1	1	1	1
	Corixidae	*Micronecta virgata*	1	1	1		1	1	1	1	1		1	1
		Micronecta paragoga			1		1		1					
	Naucoridae	*Naucoris subopacus*							1	1				
		Naucoris sp.					1							
	Notonectidae	*Anisops nodulatus*					1		1				1	1
		Anisops semitus	1	1					1					

Major group	Family (if known)	Lowest level of identification	1		2		3		4		5		6	
			benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton	benthic	plankton
		Anisops sp.	1		1			1		1	1	1		
		Paraplea brunni			1		1	1	1	1	1	1	1	
		Paraplea sp.				1								1
Lepidoptera (Moths)	Crambidae	*Elophila* sp.						1	1	1		1		
Zygoptera (Damselflies)	Coenagrionidae	*Ceriagrion aeruginosum*					1	1	1		1	1		
		Ischnura aurora aurora	1		1			1	1	1	1		1	1
		Ischnura heterosticta heterosticta	1		1		1		1	1				
		Ischnura sp.		1										
		Pseudagrion microcephalum			1				1					
Epiproctophora (Dragonflies)	Aeshnidae	*Anax papuensis*	1		1		1		1	1				
		Aeshnidae sp.				1		1						
	Libellulidae	*Crocothemis nigrifrons*							1					
		Diplacodes bipunctata	1	1							1		1	
		Orthetrum caledonicum	1		1		1		1					
		Tholymis tillarga			1		1		1					
		Zyxomma elgneri							1		1			
		Tramea sp.	1		1									
		Tramea stenoloba/loewii									1		1	
		Libellulidae sp.					1							
			39	27	51	25	47	49	62	49	42	59	46	48