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Aquatic invertebrates and waterbirds of wetlands and rivers of the southern Carnarvon Basin, Western Australia

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Abstract – Fifty-six sites, representing 53 wetlands, were surveyed in the southern Carnarvon Basin in 1994 and 1995 with the aim of documenting the waterbird and aquatic invertebrate fauna of the region. Most sites were surveyed in both winter and summer, although some contained water only one occasion. Altogether 57 waterbird species were recorded, with 29 292 waterbirds of 25 species on Lake MacLeod in October 1994. River pools were shown to be relatively important for waterbirds, while many freshwater claypans were little used.

At least 492 species of aquatic invertebrate were collected. The invertebrate fauna was characterized by the low frequency with which taxa occurred: a third of the species were collected at a single site on only one occasion. Patterns of occurrence were not strongly seasonal. Many undescribed species were found and many range extensions were recorded, reflecting lack of previous aquatic invertebrate work in the region. The level of regional endemicity could not be assessed adequately, although it is probably comparatively low. In terms of their invertebrate fauna, five types of wetlands were distinguished: river pools, rock pools and larger flowing streams; seeps, springs and smaller creeks; freshwater claypans; birridas; and Lake MacLeod. Environmental factors to which invertebrates appeared to respond were ratio of calcium/alkalinity, total dissolved solids, turbidity, colour, flow, longitude and nutrients, although some factors were inter-correlated.

Additional surveys should find extra species of waterbird and, more particularly, aquatic invertebrate using wetlands of the southern Carnarvon Basin. For many invertebrates, occurrences are too sparse for effective protection of species within a nature reserve system and other mechanisms will be required to ensure their conservation. Comparison of site classifications based on waterbird, aquatic invertebrate and plant data (Gibson *et al.*, 2000) showed patterns among sites identified using one element of the biota did not reflect patterns shown by other elements. This suggests that, until further work has identified an element that reflects the whole wetland community, as many biotic elements as possible should be surveyed.

INTRODUCTION

The southern Carnarvon Basin is located on the mid-west coast of Western Australia, in an area with arid or semi-arid climate. The region contains few nature reserves or national parks, although Shark Bay, in the centre of the region, is a World Heritage area (Anonymous 1995). In 1994, Environment Australia commissioned a comprehensive biological survey of the Basin, including its vegetation, mammals, birds, amphibians, terrestrial arthropods and aquatic fauna (Burbidge *et al.*, 2000).

Beginning with the extensive records of Tom Carter, many casual observations have been made of waterbirds in the southern Carnarvon Basin and a number of small surveys undertaken (Johnstone *et al.*, 2000). Despite waterbirds probably being the most studied faunal group in the Basin, these historical data reveal only broad patterns of waterbird occurrence and some of the more important wetlands for waterbirds. They do not allow easy comparison of different wetlands. For aquatic invertebrates, even broad patterns of

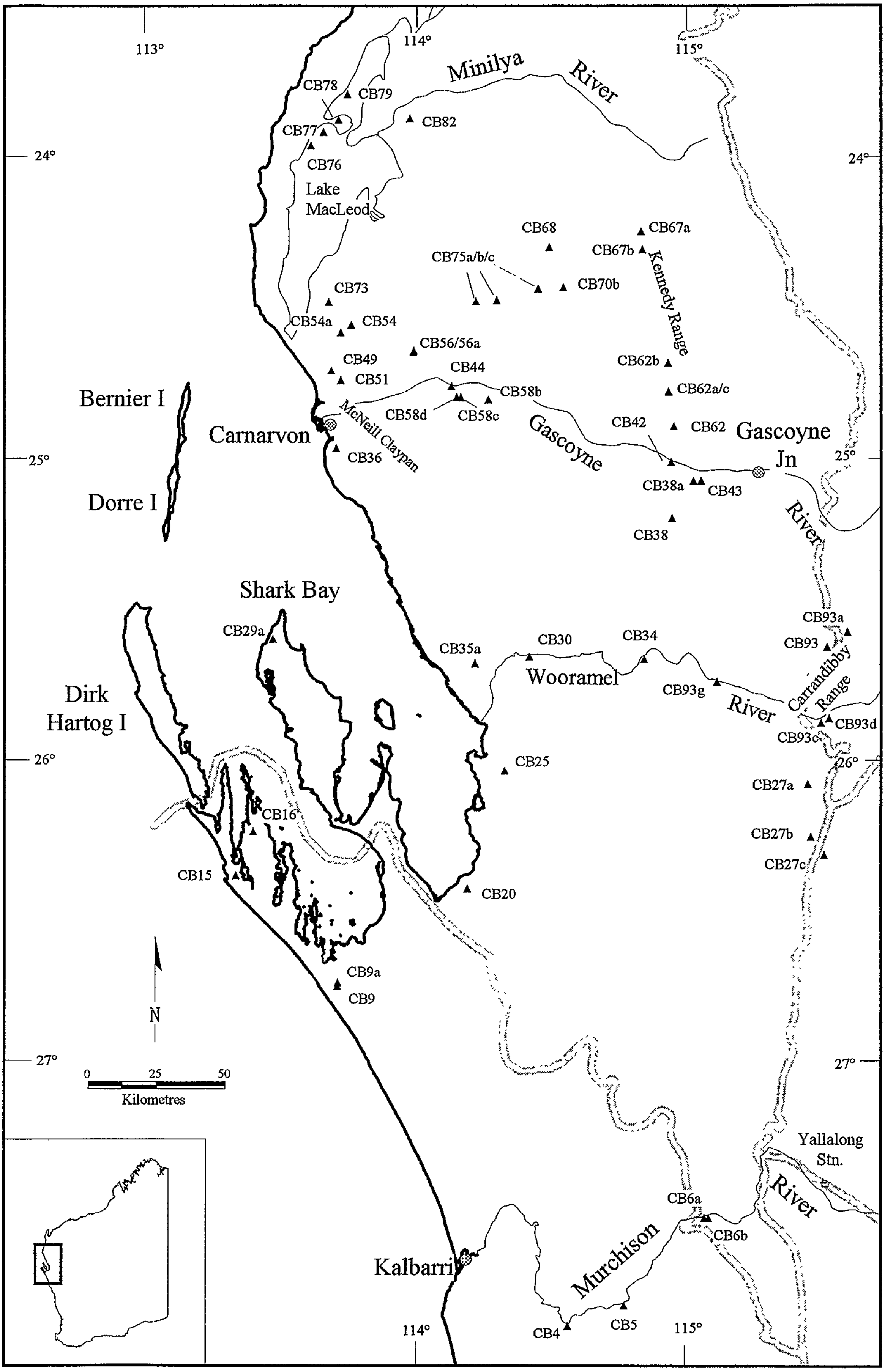

Figure 1 Map of the survey area and boundary of the southern Carnarvon Basin, showing the distribution of the aquatic sampling sites and places mentioned in text. See Appendix 1 for site codes.

occurrence are unknown because studies have been restricted to a few collections of particular groups for taxonomic purposes (e.g. Lansbury, 1969; De Deckker, 1978).

This lack of biological data is hampering assessment of conservation priorities. Other than parts of Shark Bay, only two wetlands in the southern Carnarvon Basin were identified as nationally significant in a recent review, namely Lake MacLeod and McNeil Claypan (Lane *et al.*, 1996) (Figure 1). Both are large claypans. Lake MacLeod receives marine groundwater, which upwells 20 km inland in sinkholes on the western side of the lake, as well as surface inflow via the Minilya River, smaller creeks and sheet flow from the Gascoyne River after very heavy rain. It has been shown to support very high numbers of waterbirds, especially migratory shorebirds (Smith and Johnstone, 1985; Jaensch and Vervest, 1990), as well as containing some of the few inland stands of mangroves in Western Australia. The values of McNeil Claypan are less well documented but it fills when the Gascoyne River floods and contains one of the more extensive *Muehlenbaeckia*/*Sesbania* shrublands in north-western Australia, as well as supporting a diversity of waterbirds, including freshwater crakes, rails and shorebirds (Lane *et al.*, 1996).

The southern Carnarvon Basin contains a much greater array of wetland types than are represented by Lake MacLeod and McNeil Claypan. The aims of this survey were (1) to inventory the waterbird and aquatic invertebrate fauna of the Basin, (2) to identify the major wetland types and faunal assemblages occurring in the region, (3) to relate the occurrences of these faunal assemblages to physical and chemical characteristics of waterbodies, and (4) to examine whether the biological community at each wetland may be characterized by surveying a single element of the biota. Fish, amphibians and tortoises were not included in the survey, although they occur commonly in the Basin.

Implications of the data collected, in terms of adequacy of existing nature reserves and formulation of a nature conservation strategy for the Carnarvon Basin, are dealt with by McKenzie *et al.* (2000).

STUDY AREA AND METHODS

Study Area

The area in which wetlands were surveyed extended from the Murchison River in the south to the Minilya River in the north and inland to Gascoyne Junction, covering all but the northern portion of the Carnarvon Basin (Figure 1). The physical environment is described by Wyrwoll *et al.* (2000). Essentially, the Basin contains low gradient alluvial plains that are traversed by the Murchison, Wooramel, Gascoyne and Minilya Rivers. The southernmost part of the Basin has a semi-arid climate with predominantly winter rainfall (Gentilli, 1972). North of Shark Bay, tropical systems influence rainfall patterns and result in significant summer precipitation in more inland areas, which are arid. Median annual rainfall is 379 mm at Kalbarri, 230 mm at Yallalong station, 206 mm at Carnarvon and 190 mm at Gascoyne Junction (data on rainfall preceding the sampling periods are given in Table 1 and Figure 2) (see Figure 1 for locations).

Table 1 Winter and summer rainfall (mm) associated with sampling periods in the southern Carnarvon Basin (see Table 2 for sampling dates). Long-term median values are shown in parentheses (data from Bureau of Meteorology).

	Winter 1994	Summer 1995	Winter 1995
Carnarvon	73 *(82)*	56 *(11)*	123 *(82)*
Gascoyne Junction	39 *(47)*	109 *(29)*	56 *(47)*
Kalbarri	186 *(204)*	2 *(5)*	173 *(204)*

Major rivers in the Basin flow intermittently, with significant dry intervals being more common in the north. Although flow patterns had not been studied long (8–25 years), data collected prior to 1982 suggested there was significant flow in the Murchison River nearly every year (flood events > 90 per cent of years) (Anonymous 1984). In contrast, flood events occurred on the Minilya River less than every second year. Between flood events, riverbeds dry and surface water recedes to a few pools.

Many sections of river floodplain support extensive networks of intermittently flooded claypans, especially on the Gascoyne River. Intermittently flooded interdunal claypans, often with well-defined lunettes, occur throughout the Basin, although they are less common in the south-east. There are also claypan-like pools on poorly defined watercourses that, it appears, often fill from local rain but form part of the regional drainage system only after exceptional rainfall events. Examples include Coollilee Pool (CB49) and Tirigie Claypan (CB56) in the northern part of the study area (Figure 1). Close to the coast, birridas (evaporite pans) occur in interdunal depressions, especially around Shark Bay. Most of the birridas contain gypsum and, although they may dry intermittently, anecdotal information suggests their water levels show subdued response to oceanic tides. Lake MacLeod, which was open to the sea during the Last Interglacial, is an example of a very large birrida.

Surface water is scarce in the Carnarvon Basin, except after major rainfall events. Permanently

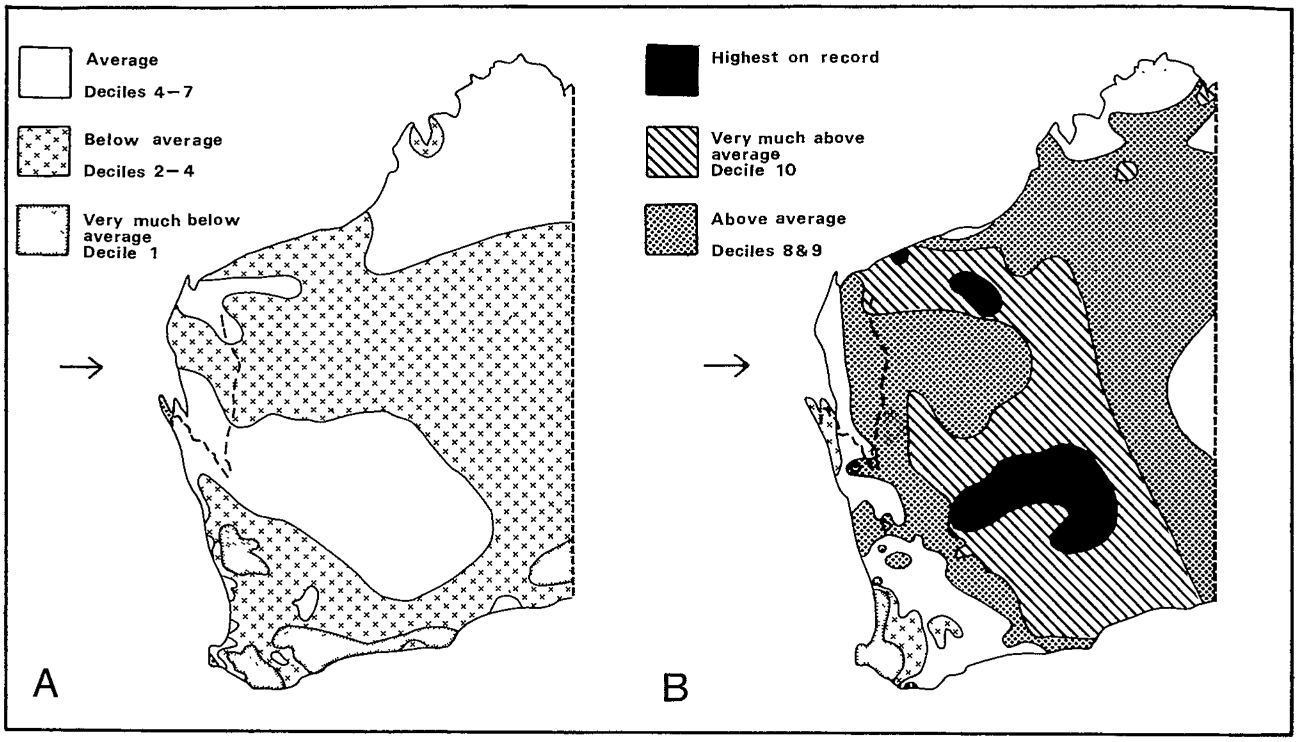

Figure 2 Rainfall deciles in Western Australia in winter 1994 and summer 1995. **A.** Winter 1994. **B.** Summer 1995. The arrow indicates the southern Carnarvon Basin. Data from Bureau of Meterology.

flowing water occurs only where there is groundwater discharge at seeps or springs, usually in the headwaters of small creeks associated with the Kennedy and Carrandibby Ranges in the eastern part of the study area. There are no naturally permanent freshwater swamps or claypans; the only sites with moderately deep permanent water are river pools, which are often formed by rocky amphitheatres. There are also a few uncapped artesian bores, which flow constantly, and have formed small artificial swamps. The bore feeding the swamp near Hamelin Station homestead (CB20), the example of this wetland type chosen for survey, was subsequently capped and the swamp has dried.

Site Selection and Sampling

A total of 56 sites were sampled across the study area, representing 53 wetlands. Lake MacLeod contained four sites (Figure 1). Fifty-three sites were sampled in winter, 37 in summer, and 36 in both winter and summer (Table 2, Appendix 1). Most of the sites were selected during reconnaissance in summer 1994 with the aims of (1) including representatives of all common wetland types in the region, (2) obtaining a geographic spread of wetlands, and (3) as far as possible, sampling wetlands that were in a natural condition. The swamp near Hamelin Station homestead (CB20) was included to examine conservation value of artificial wetlands.

Geographical coordinates of each site were determined using a handheld GPS. Most of the wetlands sampled were comparatively small claypans or swamps (< 5 ha), or were river pools, and the sampling area associated with the site effectively covered the whole wetland or river pool. When wetlands were large, the site constituted only a sampling point within the wetland. This was seen most clearly at Lake MacLeod, which has an area of 150,000 ha when fully flooded, and contained four sampling sites (CB76-79) (Figure 1).

On each visit to a site that contained water,

Table 2 Dates of reconnaissance and sampling of wetlands in the southern Carnarvon Basin. See Appendix 1 for explanation of site codes.

Sampling period	Season	No. of sites	Comments
24–30 April 1994	reconnaissance	–	Most sites north of Gascoyne River not visited
17–30 August 1994	winter	47	
11–13 October	winter	2	CB78, CB79 and aerial survey of Lake MacLeod
15–27 March 1995	summer	37	
25–27 July 1995	winter	4	CB27b, CB30, CB51, CB54a

information was collected about waterbirds, aquatic invertebrates and the wetland environment (mostly water chemistry). Vegetation data were collected separately (Gibson *et al.*, 2000). Binoculars or a telescope were used to identify waterbird species. Where available, waterbird lists from the reconnaissance, as well as two sampling trips, were included in analyses to provide as much information as possible about waterbird use of sites. An aerial survey was made of Lake MacLeod on 12 October 1994 to document waterbird use of the whole lake during a time when palaearctic shorebirds were likely to be present.

Two aquatic invertebrate samples were collected at each site using D-framed pondnets with 250 and 50 μm sized meshes. The 250 μm sample was collected by 50 m of vigorous sweeping in all identifiable microhabitats < 1 m deep at the site, including benthic sediment, submerged and emergent macrophytes, coarse organic material and open water, over a distance of up to 200 m. The 50 μm sample was collected with 50 m of less vigorous sweeping and included all habitats other than benthos. The 250 μm sample was preserved in 70% alcohol; the 50 μm sample was preserved in 1–2% formaldehyde. Samples were sorted in the laboratory under a dissecting microscope and representative specimens of each taxon were retained for identification. Most animals were identified to species or 'morphospecies' level but Nematoda were identified only to phylum and Polychaeta and some Crustacea with marine affinities were identified only to family. Protozoa were very much under-sampled, although they were identified when collected. Vouchers of most taxa have been retained at the Wildlife Research Centre (Department of Conservation and Land Management), Western Australian Museum or Murray-Darling Freshwater Research Centre. Names of Chironomidae follow Cranston (1994).

Maximum water depth at each site was estimated each sampling occasion and sites were assigned to a flow category (1, lentic; 2, seasonal river, not flowing when sampled; 3, spring-fed flowing or seeping water; 4, flowing river fed by catchment run-off). At each site, water samples and measurements were taken within the area sampled for invertebrates. Conductivity and pH were measured 15 cm below the water surface using TPS Models LC81 and LC80A meters; dissolved oxygen was measured near the surface and at the bottom of the water column with a WTW OXI96 meter and the two readings were averaged. Water samples were collected about 15 cm below the surface for subsequent measurement of total dissolved solids (TDS), ionic composition (including silica in summer), total soluble persulphate nitrogen and phosphorus, chlorophyll, colour and turbidity in the laboratory using standard techniques (APHA, 1989). Samples for nutrient analyses were usually passed through a 0.45 μm filter in the field and stored at ambient temperature unless water was very turbid, when they were frozen in the field without filtering and ultracentrifuged in the laboratory. Turbid samples for measurement of TDS were passed through a 0.2 μm filter in the laboratory (rather than the standard 0.45 μm) prior to evaporation to minimize contamination by fine particulate matter. At least 200 ml of water was passed through a glass fibre filter paper in the field to obtain a chlorophyll sample for analysis. $MgCO_3$ was added to the algal residue to stabilize chlorophyll, which was frozen until amount of chlorophyll present was determined in the laboratory (APHA, 1989).

Data on ionic composition were converted to milliequivalents L^{-1} and, to characterize water chemically, ratios of calcium to bicarbonate and carbonate (termed calcium/alkalinity), calcium and magnesium to chloride, and calcium to sulphate were calculated. In total, 14 environmental variables in winter, and 15 in summer, were used in analyses (Appendix 2).

Analyses

Waterbirds

Sites were grouped according to similarity of their waterbird fauna using the PATN analysis package (Belbin, 1993) and presence/absence waterbird data. Czekanowski's coefficient was used to measure degree of association between sites after species with a single occurrence and sites with a single species were removed from the dataset. Under-estimated association values (>0.9) were re-recalculated using the Shortest Path option in PATN and the 'Unweighted Pair-Group Mean Average' fusion method, with $\beta = -0.1$, was used to group sites (Sneath and Sokal, 1973). Waterbird species were classified into groups with similar patterns of occurrence using the Two-Step coefficient (Austin and Belbin, 1982) and UPGMA. The discreteness of wetland groups produced by the classifications were examined by ordination using 'Semi-Strong Hybrid Multidimensional Scaling' (Belbin, 1991).

Environmental variables

Sites were also grouped according to their environmental characteristics. This was done separately for sites sampled in winter and summer. All variables were range-standardized (each value of a variable was divided by the maximum value recorded for that variable) after those with strongly skewed distributions had been log-transformed. The Bray-Curtis association measure and UPGMA fusion method, with $\beta = -0.1$, were used after association measures >0.95 were recalculated.

Differences in environmental characteristics of wetland groups identified using aquatic invertebrate data were examined by one-way ANOVA, using the SAS statistical package (SAS Institute, 1989), after variables with skewed distributions were log-transformed. Student-Newman-Keuls tests were used to identify the groups contributing to significant overall variation in environmental variables.

Aquatic invertebrates

Sites were grouped on the basis of their invertebrate fauna using presence/absence data and the same methods as for waterbirds. Separate classifications were derived for winter and summer. Association measures >0.95 were recalculated. The discreteness of wetland groups produced by the classifications were examined by ordination using SSH. Maximum linear correlations between transformed environmental variables and vectors in ordination space were calculated using the PCC option in PATN after a varimax rotation of the ordination axes (Belbin, 1993). Significance of correlations was determined by Monte Carlo testing (1000 randomisations).

Site classifications based on invertebrates and on environmental variables were compared using a modified Rand statistic (Hubert and Arabie, 1985) (sites CB25 and CB62c were omitted from the winter comparison because of incomplete data). Site groupings based on winter and summer invertebrate datasets were also compared after datasets for each season were reduced to a common set of sites.

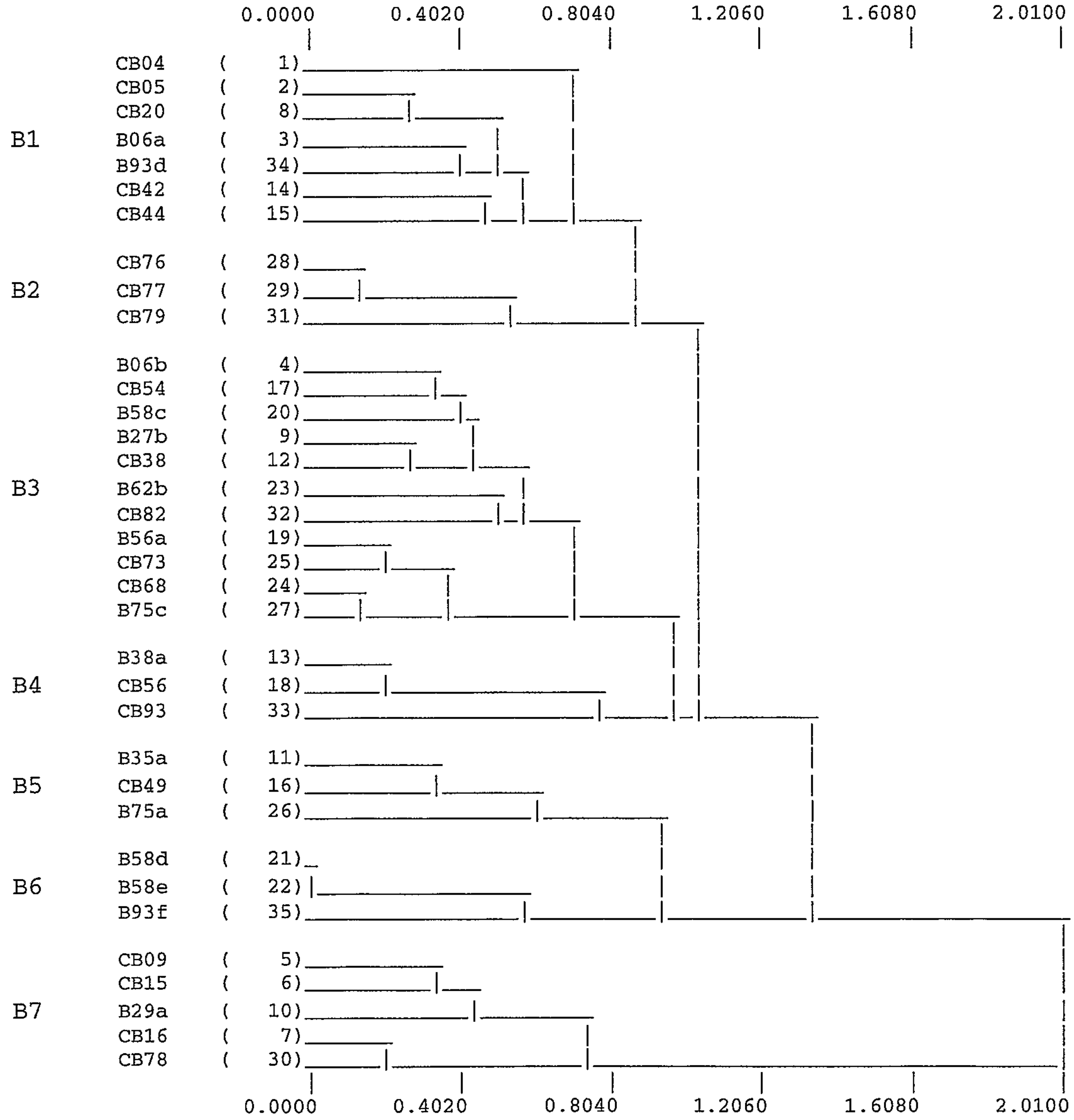

Figure 3 Classification of wetland sites in the southern Carnarvon Basin into seven groups (B1-7) based on waterbird use. See Appendix 1 for site codes.

RESULTS

Waterbirds

A total of 57 species of waterbird were recorded during surveys with the most commonly occurring being White-faced Heron (28 records of one or more birds at a site on a sampling date), Grey Teal (27), White-necked Heron (16), Pacific Black Duck (14), Black Swan (12), Australian Wood Duck (12), Hoary-headed Grebe (12) and Black-fronted Dotterel (12) (Appendix 3). All species recorded are widespread outside the study area (Blakers *et al.*, 1984).

Lake MacLeod (CB76-79) was clearly the wetland supporting greatest numbers of species and individuals during the surveys (29 292 birds of 25 species in October 1994, including birds counted during an aerial survey of the whole lake). Moderate numbers of birds were recorded on all visits to the bore swamp on Hamelin Station (CB20) (100 birds of 8 species in March 1994; 95 of 12 in August 1994). Lake Julia (CB62b) had 87 birds of 10 species in March 1994. Minilya Pool (CB82) and Winnemia Pool (CB42) were the river pools with most birds (87 birds of 10 species and 42 birds of 12 species, respectively, in August 1994). The birrida north of Big Lagoon (CB29a) supported 1285 shorebirds of 4 species in August 1994, making it the birrida with highest waterbird numbers. Waterbirds were not recorded at 11 sites and at another 10 sites only one species occurred. These 21 sites were not included in multivariate analysis (Appendix 3).

Based on waterbird usage, seven groups of sites were identified (Figure 3). Only sites in groups B1 and 2 supported many species, with average species richness of 10.9±1.3 and 18.3±4.9, respectively. B3 sites showed a considerable range in species richness, with 12 and 10 species, respectively, at CB62b and CB82 but a mean of only 3.9±0.5 at other sites. No site in groups B4-7 had more than four species (Appendix 3). In general terms, B1 sites were large river pools or vegetated swamps. B2 consisted of the three wetter Lake MacLeod sites, B3 sites were freshwater claypans, often with some emergent shrub or herbaceous vegetation, as well as the river pool site CB82. Groups B4-6 contained turbid freshwater claypans. B7 consisted of birridas and the driest Lake MacLeod site (CB78). Groups showed moderately clear separation in ordination space (Figure 4).

Seven groups of waterbirds were identified, based on their pattern of occurrence (Figure 5). Groups BI-III contained the more commonly occurring species. Species groups showed only loose relationships with site groupings but BI species occurred most consistently at river pools and vegetated swamps (B1 sites) and were absent from saline sites. Group BII species had the widest occurrence in the study area, occurring in all site groupings, although concentrated at sites of groups B1-3. Group BIII species occurred mostly at the more species-rich and deeper sites (B1 and 2). Group BIV consisted of the Banded Lapwing and Black-tailed Native-hen,

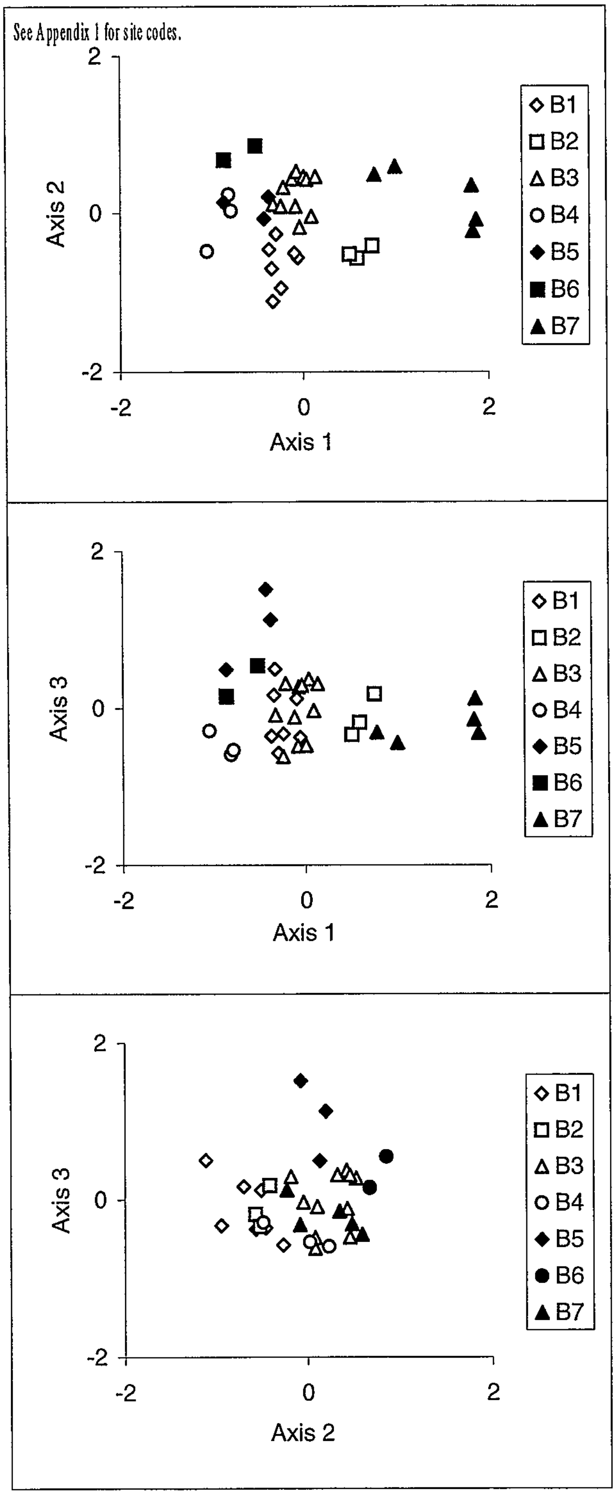

Figure 4 Ordination of wetland sites in the southern Carnarvon Basin based on waterbird use. Wetland groups from Figure 3 are superimposed on ordination (three dimensions, stress=0.08).

two relatively terrestrial waterbirds with limited occurrence in the study area. Groups BV and VI consisted of shorebirds, with BV species being restricted to saline Lake MacLeod and birrida sites (B2 and 7), whereas some BVI species were restricted to freshwater and others occurred in fresh as well as salt water and were present in most site groupings. Group BVII contained a mixture of species that occurred at Lake MacLeod; some were roosting in mangroves, others occurred on the water and some were aerial.

Aquatic invertebrate species richness

At least 492 species of aquatic invertebrate were collected during the surveys (Appendix 4 contains 518 taxa but probably some of these result from the same species being identified at different levels of taxonomic resolution). Fifty per cent of species were microinvertebrates, with many other species (e.g. nematodes, oligochaetes, watermites) also being very small. The major components of fauna richness were rotifers (14% of species), dipterans (14%, of which well over half were chironomids), cladocerans (14%), beetles (11%), ostracods (10%) and copepods (9%). The most frequently recorded taxa were the chironomid species complex *Procladius* spp. CBT1 (62% of samples), beetle *Eretes australis* (43%) and chironomid *Tanytarsus* sp. CBC3 (41%).

Of the 518 taxa in Appendix 4, 423 were collected during winter, 327 in summer and 232 were common to both seasons. The major cause of

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                                      B1    B2       B3     B4  B5  B6   B7
                                    CCCCCCC|CCC|CCCCCCCCCCC|CCC|CCC|CCC|CCCCC
                                    BBBBBBB|BBB|BBBBBBBBBBB|BBB|BBB|BBB|BBBBB
                                    0020944|777|05523685767|359|347|559|01217
                                    4506324|679|64878226385|863|595|883|95968
                                       ad       b cb b a  c a   a a def   a
                                           |   |           |   |   |   |
        Australasian Grebe          *****  |   |           |   |   |   |
        Australian Shelduck         ****   |   |           |   |   |   |
        Australian Wood Duck         **** *|   |*  ***     | **|   |   |
        Black-fronted Dotterel        *****|   |    *      |** |   |** |
BI      Pacific Black Duck          ****** |   |*       *  |  *|   |   |
        Eurasian Coot                **  **|   |     *     |   |   |   |
        Great Egret                 *  * **|   |           |   |   |   |
        Straw-necked Ibis              * * |   |      *    |   |   |   |
        Yellow-billed Spoonbill        * * |   |      *    |   |   |   |
                                    -------+---+-----------+---+---+---+-----
        Grey Teal                     *****|***|*******    |** |  *|   |
        White-faced Heron             **** |***|***********|   |   |   |    *
BII     Hoary-headed Grebe           ***  *|  *|   * **  **|   |   |   |
        Pink-eared Duck                *   |   | * ****    |   |   |   |
        White-necked Heron               * |   |**   ******|   |* *|***|
                                    -------+---+-----------+---+---+---+-----
        Australian Pelican              *  |** |      *    |   |   |  *|
        Darter                       *  ** |** |     *     |   |   |   |
BIII    Black Swan                   **  **|***|      *    |   |   |   |
        Little Pied Cormorant        **  * |***|           |   |   |   |
        Little Black Cormorant      *    **|***|           |   |   |   |
                                    -------+---+-----------+---+---+---+-----
BIV     Banded Lapwing                     |   |     *     |   |  *|   |
        Black-tailed Native Hen            |   |           |   |***|   |
                                    -------+---+-----------+---+---+---+-----
        Banded Stilt                       |  *|           |   |   |   |***
BV      Red-capped Plover                  |  *|           |   |   |   |*****
        Curlew Sandpiper                   |  *|           |   |   |   |  *
        Red-necked Stint                   |  *|           |   |   |   |  *
                                    -------+---+-----------+---+---+---+-----
        Common Greenshank                  |  *|     *     |   |   |   |   **
BVI     Red-kneed Dotterel                 |  *|     *     |   |*  |   |
        Common Sandpiper            *     *|  *|           |   |** |   |
        Red-necked Avocet             *    |  *|    *     *|   |   |   |
                                    -------+---+-----------+---+---+---+-----
        Black-winged Stilt            *    |* *|           |   |   |   |
        Little Egret                       |***|           |   |   |   |
        Pied Cormorant                     |***|           |   |   |   |
BVII    Silver Gull                        |* *|           |   |   |   | *
        Caspian Tern                       |** |           |   |   |   |
        Great Crested Grebe                |** |           |   |   |   |
        Gull-billed Tern                   |*  |           |   |   |   | *
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Figure 5 Two-way table of waterbird species groups and wetland site groups in the southern Carnarvon Basin. See Appendix 1 for site codes.

Table 3 Frequency of occurrence of aquatic invertebrate species from the southern Carnarvon Basin in 90 samples from winter 1994 and summer 1995.

No. of samples in which species occurred	No. of species
1	158
2–3	120
4–6	80
6–9	44
10–18	52
19–27	22
>27	10

differences in species lists between seasons appeared to be the high proportion of taxa collected infrequently. A third of taxa were recorded only once (although many individuals may have been collected on that occasion) and only 10 species occurred in more than 30% of samples (Table 3). Seasonal preferences were sometimes evident among more common taxa but they did not prevent collection in both seasons; for example, the rotifer *Keratella australis* had a strong preference for winter (13 out of 14 occurrences) but was recorded once in summer (Appendix 4). The shield shrimp *Triops australiensis australiensis* showed the opposite pattern, being found at eight of 37 sites in summer and only two of 53 sites in winter. More taxa exhibited preference for winter than summer.

Many new species were collected during the study, including four rotifers, one anostracan, 14 cladocerans (including an undescribed genus), 10 ostracods (including an undescribed genus), four copepods, one hemipteran and two beetles (Table 4). Three named species were recorded in Australia for the first time. The rotifers *Hexarthra brandorffi* and *Proales sigmoidea* were previously known from the foothills of the Andes in South America (Koste, 1978) and from Europe and Canada (De Smet, 1996), respectively, and the harpacticoid copepod *Robertsonia mourei* had been collected only from the Brazilian type locality (Nogueira, 1961). The oligochaete *Nais* sp. CB1 probably also represents a new record for Australia of a cosmopolitan species (A.M. Pinder, pers. comm.) and collections of the ostracod *Zonocypris* sp. nov. 466 represent the first time this predominantly African genus has been found in Australia. Identification of the cladocerans *Daphnia* sp. nov. (aff. *barbata*) and *D.* sp. nov. (aff. *gibba*) requires DNA-typing but both are similar to described African species (C. Wilson, pers. comm.).

Large range extensions within Australia were recorded for many species. At least 27 rotifers previously known from eastern Australia (e.g. Shiel and Koste, 1979) or the Northern Territory (Koste and Shiel, 1983) were recorded in Western Australia for the first time. Several other rotifer taxa that were strongly contracted in preservative remain identified to genus only and the number of range extensions may increase after they have been examined in more detail. About 20 cladoceran species from eastern Australia or the Northern Territory (Smirnov and Timms, 1983; Timms, 1988; Frey, 1991) were recorded from Western Australia for the first time. In many cases the range extensions have considerable conservation significance; for example, *Celsinotum hypsilophum* was previously

Table 4 Undescribed species of aquatic invertebrate collected to date only from wetlands of the southern Carnarvon Basin in 1994 and 1995.

Rotifera
Keratella sp. nov. (aff. *australis* group)
Asplanchna sp. nov. (aff. *sieboldi*)
Euchlanis sp. nov.
Lecane sp. nov.

Anostraca
Branchinella sp. nov. (aff. *lyrifera*)[1]

Cladocera
Alonine gen. nov.
Alona spp. nov. A–E
Biapertura sp. nov.
Rak sp. nov.
Macrothrix sp. nov.
Neothrix sp. nov. (aff. *superarmata*)
Ilyocryptus sp. nov.
Daphnia sp. nov. (aff. barbata)
Daphnia sp. nov. (aff. *gibba*)
Daphnia sp. nov. (aff. *projecta*)

Ostracoda
Paralimnocytherid gen.nov.[1]
Ampullacypris sp. nov. 469
?Ampullacypris sp. nov. 498
Bennelongia sp. nov. 414[1]
Cypericercus sp. nov. 415
Cypericercus sp. nov. 422
Cypericercus sp. nov. 444
Heterocypris sp. nov. 489
Mytilocypris sp. nov. 426
Zonocypris sp. nov. 466[2]

Calanoida
Calamoecia halsei[3]

Cyclopoida
Mesocyclops sp. nov.
Neocyclops petovskii[4]

Harpacticoida
Amondaria sp. nov.

Hemiptera
Plea sp. nov.

Coleoptera
Paroster sp. nov.
Tiporus sp. nov.

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[1] Common in Basin
[2] First record of genus in Australia
[3] Described by Bayly (1998)
[4] Described by De Laurentiis *et al.* (1997)

known only from the Paroo River region of New South Wales (Frey, 1991). Occurrence in the Carnarvon Basin of the calanoid copepod *Eudiaptomus lumholtzi*, common in northern Australia including the Kimberley (Timms and Morton, 1988), is a 1200 km southwards extension of the western range of the species. Similarly, records from the Carnarvon Basin extend the range of the anostracan *Branchinella probiscida* 2000 km south-westwards (see Geddes, 1981). Menke (1960) recorded the belostomatid hemipteran *Lethocerus distictifemur* as occurring only in eastern Australia and its collection in this study represents a large range extension.

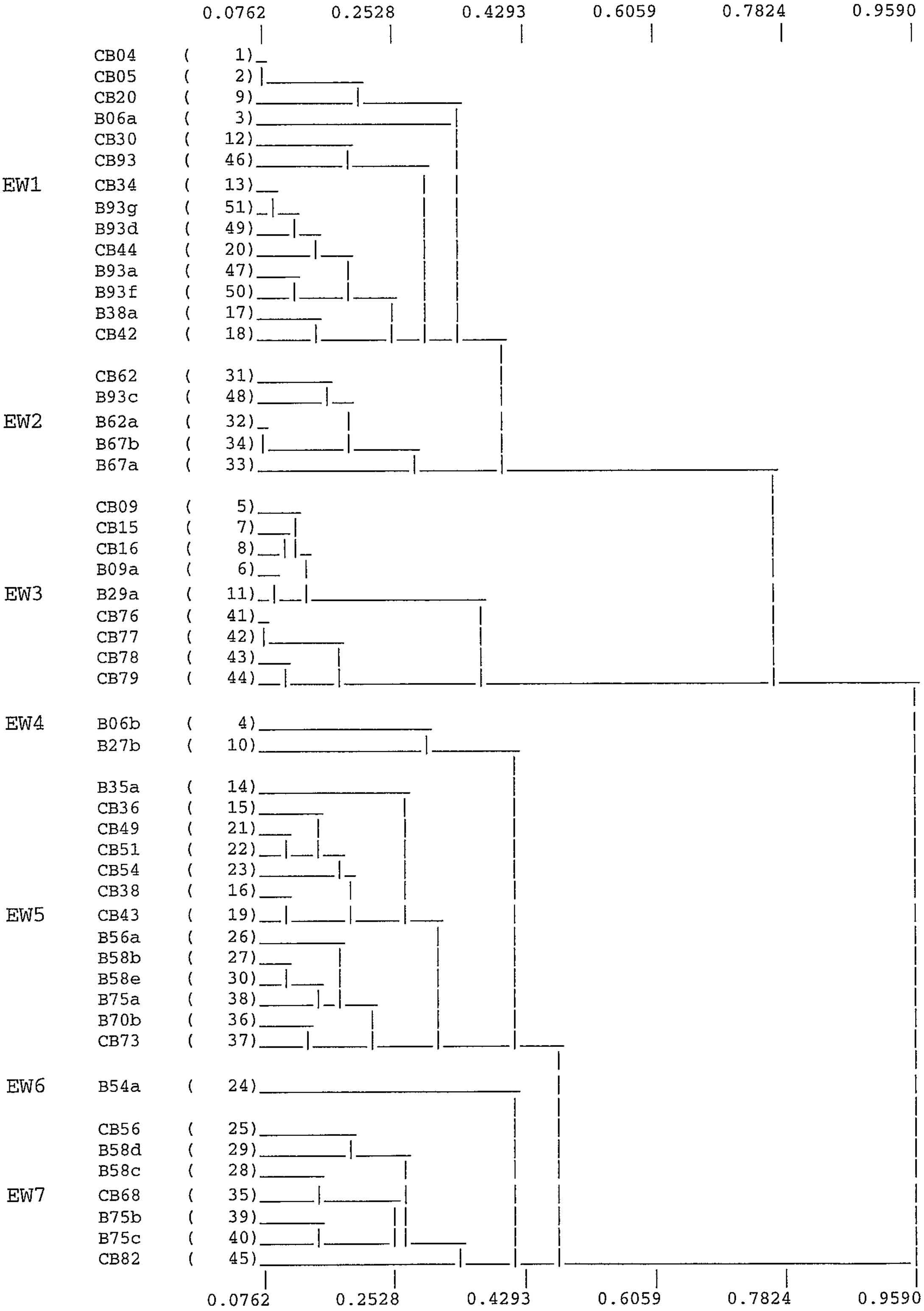

Figure 6 Classification of wetland sites in the southern Carnarvon Basin into seven groups (EW1-7) according to their environmental characteristics in winter (sites CB25 and CB62c were excluded). See Appendix 1 for site codes.

Male ostracods that morphologically appeared to be *Sarscypridopsis aculeata* were collected from Minilya Pool (CB82) both times it was sampled. If this identification is correct, it is the first time males of this common, cosmopolitan species have been recorded (see De Deckker, 1981).

Invertebrate communities and environmental variables

Winter

Based on their environmental characteristics in winter, seven groups of sites were identified (Figure 6). These were large river and rock pools (EW1), small creeks and seeps (EW2), saline sites with a marine connection (birridas and Lake MacLeod, EW3), two very fresh claypans in the south-eastern part of the surveyed area (CB06b, CB27b: EW4), highly turbid claypans with elevated TDS values (EW5), the single crab-hole swamp sampled (CB54a: EW6) and less turbid claypans (EW7).

Seven groups of wetland sites were also identified on the basis of their use by invertebrates in winter (Figure 7). IW1 sites were river pools, rock pools in river channels and the larger flowing streams and, on average, had the highest species richness (44.5±2.6 SE). Group IW2 sites were small flowing streams and seeps, which tended to be brackish (Table 5), and supported 28.8±4.0 species. The bore swamp at Hamelin Station homestead (CB20) also belonged to IW2. Group IW3 contained the more speciose claypan and swamp sites (38.5±3.4 species), which were less turbid and had less coloured water. Three 'river pools' (Minilya Pool CB82, Coollilee Pool CB49 and Boolan Pool CB73) were included in this group but none received through-flow during the survey and it is likely they were ecologically more similar to claypans than rivers. Sites in IW4 were more coloured, turbid claypans with high nutrient levels and intermediate numbers of species (27.8±2.4). One 'river pool' (Bulgra Pool CB70b) was in this group but physiognomically it resembled a claypan. IW5 sites were more coloured and turbid claypans with high nutrient levels and receding water levels, sometimes being close to dry. These claypans contained fewest species (18.2±1.9). Group IW6 sites were birridas and contained few species (11.0±1.5) while IW7 contained the four Lake MacLeod sites, which averaged 16.0±0.9 species. Sites in the latter two groups were saline with high ratios of calcium/alkalinity (Table 5).

Despite some superficial similarities in site classifications based on invertebrates and environmental variables, concordance between them was poor. Using seven groupings, only 26 of the 51 sites in the two classifications fell into the same groups and the Hubert/Arabie Rand statistic was 0.3435 (1.0 indicates identical classification, 0 indicates total dissimilarity).

Ordination of the wetland sites based on invertebrate data showed the same relationships between site groupings as the classification (Figure 8). Saline sites (IW6 and 7) were strongly separated from rivers and claypans. There was minimal overlap between the three groups of claypans (IW3-5) but the smaller streams and springs (IW2) did not separate clearly from larger river pools (IW1). Eight variables were significantly correlated with site positions in ordination space, including the ratio of calcium/alkalinity, TDS, turbidity and colour (Table 6, Figure 8).

Table 5 Mean values (±SE) of environmental variables in winter for the wetland groups identified by UPGMA cluster analysis based on winter invertebrate data. The significance values of one-way ANOVAs for each variable are shown. **** *P*<0.0001,*** *P*<0.001, NS *P*>0.05.

Variable	Wetland group							*P*
	IW1	IW 2	IW 3	IW 4	IW 5	IW 6	IW 7	
pH	8.6±0.2	8.0±0.4	8.1±0.2	7.8±0.1	8.3±0.3	8.2±0.2	8.0±0.4	NS
DO (% sat.)	112±6	134±23	97±6	97±4	109±12	115±9	132±10	NS
Colour (TCU)	11±2	12±4	315±152	879±265	4432±2490	8.2±3.8	8.5±1.4	****
Turbidity (NTU)	0.7±0.2	0.3±0.03	2587±1195	12620±5509	21196±7284	0.6±0.1	0.14±0.05	****
TDS (mg/L)	946±266	5950±1787	176±45	152±47	490±105	94200±22767	39920±2803	****
Ca/Alkalinity[a]	1.3±0.3	1.8±0.3	0.24±0.06	0.21±0.04	0.10±0.05	35±3	8.8±0.4.	****
Ca+Mg/Cl[a]	1.2±0.4	0.57±0.2	0.87±0.3	0.92±0.3	0.42±0.2	0.26±0.02	0.25±0.01	NS
Ca/SO_4[a]	3.4±1.6	0.38±0.1	3.0±1.3	2.7±0.9	2.6±1.6	0.56±0.06	0.45±0.05	NS
Nitrogen (mg/L)	0.67±0.17	0.64±0.1	1.4±0.4	2.3±0.5	2.2±0.5	2.1±0.3	0.54±0.11	****
Phosphorus (mg/L)	0.006±0.001	0.002±0.002	0.17±0.07	0.41±0.16	0.68±0.25	0.016±.002	0.005±0.002	****
Chlorophyll (mg/L)	0.017±0.008	0.009±0.003	0.05±0.02	0.03±0.02	0.008±0.005	0.008±0.003	0.011±0.009	NS
Latitude[b]	25.9±0.2	24.9±0.5	25.0±0.3	25.1±0.3	24.8±0.1	26.3±0.2	23.9±0.04	***
Longitude[b]	115.0±0.1	114.7±0.2	114.2±0.2	114.5±0.1	114.2±0.2	113.5±0.1	113.7±0.03	****
Flow[c]	2.3	3.2	1.1	1.0	1.0	1.0	1.0	–

[a] ratio of ionic compositions expressed as milliequivalents
[b] Decimal degrees
[c] Flow category (see text)

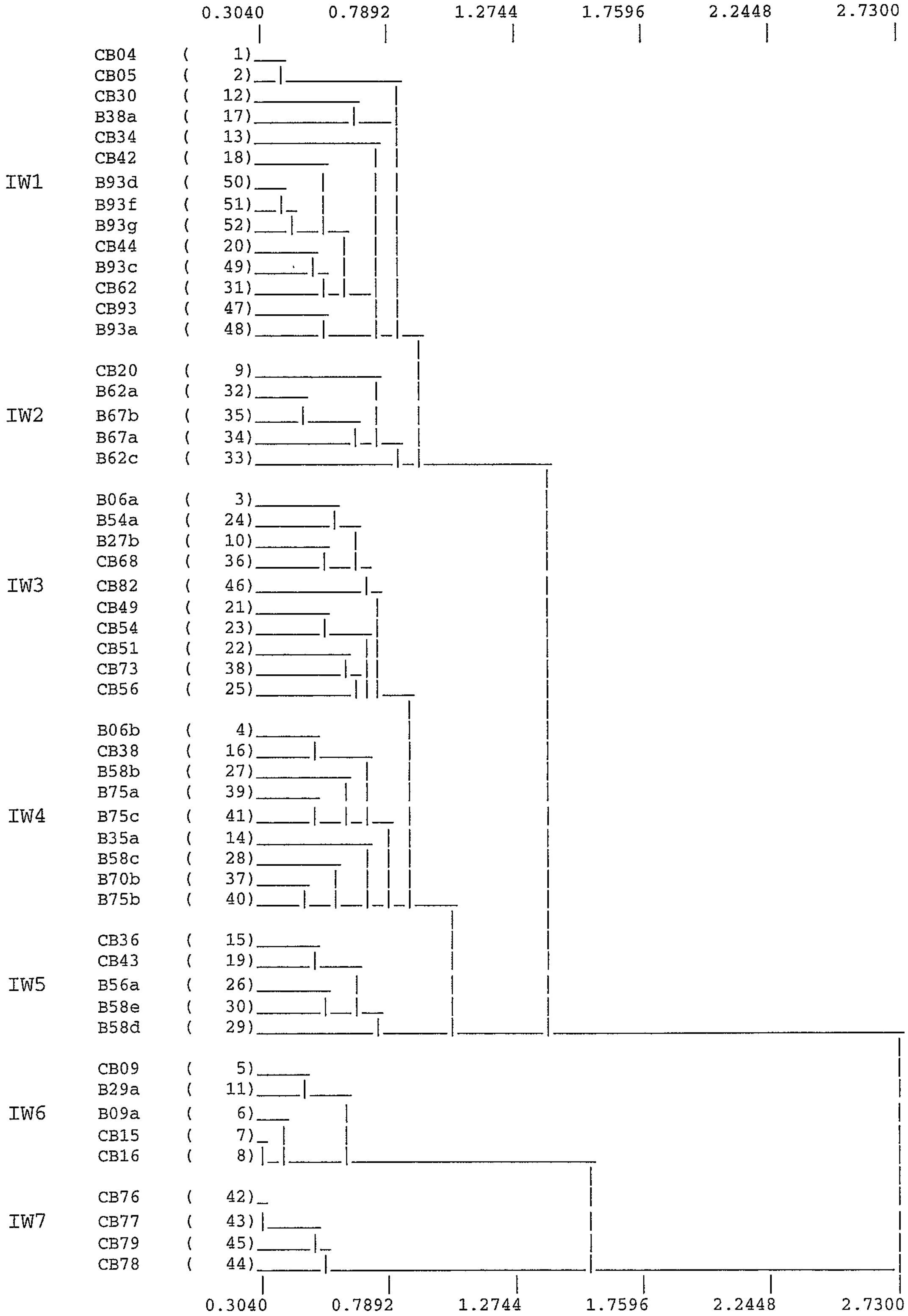

Figure 7 Classification of wetland sites in the southern Carnarvon Basin into seven groups (IW1-7) according to their invertebrate fauna in winter (site CB25 was excluded). See Appendix 1 for site codes.

Based on their pattern of occurrence in winter, sixteen groups of invertebrate species were identified. These included groups that were more or less restricted to each of site groups IW1-4 and 6-7. There were two groups of generalist species that occurred commonly in all but the saline sites. There was no species group restricted to IW5 sites (the depauperate drying-phase claypans) although some species showed a preference for the two turbid claypan groups (IW4 and 5).

Summer

Six groups of wetland sites were identified according to their environmental characteristics

Table 6 Significant correlations between environmental variables and the distribution of 51 wetland sites in ordinations based on the winter and summer invertebrate faunas of the sites. ***, $P<0.001$; **, $P<0.01$; *, $P<0.05$.

Variable	Winter ordination		Summer ordination	
	r	*P*	*r*	*P*
Calcium/alkalinity	0.9401	***	0.8347	***
TDS	0.8913	***	0.7796	***
Turbidity	0.8647	***	0.8724	***
Colour	0.8518	***	0.6198	**
Flow	0.7544	***	0.7624	***
Longitude	0.6745	***	0.7272	***
Phosphorus	0.6133	***	0.6797	***
Nitrogen	0.5129	**	0.6070	**
Latitude	0.4286	*	0.5405	**

in summer. The classification showed some differences from that based on winter environmental data, perhaps because it was a smaller dataset, but rivers, marine-influenced sites and claypans still constituted the major groupings (Figure 9). Concordance of the classifications based on summer environmental and invertebrate data (Figure 10) was equivocal, with 25 of 37 sites being placed in the same groups in both classifications and a Hubert/Arabie Rand statistic = 0.5255.

Six groups of wetland sites were identified on the basis of their invertebrate fauna in summer (Figure 10). Group IS1 sites were mostly claypans, with the exception of two sites on the lower Murchison River (Hardabut Pool CB04 and Bullock Pool CB05), and had moderate turbidity and colour, and high species richness (38.4±2.8). Group IS2 sites were claypans in the drying phase with high turbidity, high nutrient levels and moderate colour (Table 4). They had lower species richness (19.3±4.8). Group IS3 contained the bore swamp at Hamelin Station homestead (CB20), Birdrong Spring (CB67a) and two small flowing stream sites, which had slightly elevated TDS and averaged 30.2±3.2 species. Group IS4 contained river pools, rock pools and larger flowing stream sites and had high numbers of species (40.0±3.9). Group IS5 sites were saline birridas with very high ratios of calcium/alkalinity and few species (8.3±0.7); IS6 comprised the Lake MacLeod sites, which were also saline but had more species (15.3±2.9).

Fourteen groups of invertebrate species were identified, based on their pattern of occurrence at sites in summer. There were species groups restricted to all site groups except IS3 (seeps and streams), and one group of infrequently occurring species showed preference for this habitat. Several groups of generalist species occurred commonly at all but the saline sites.

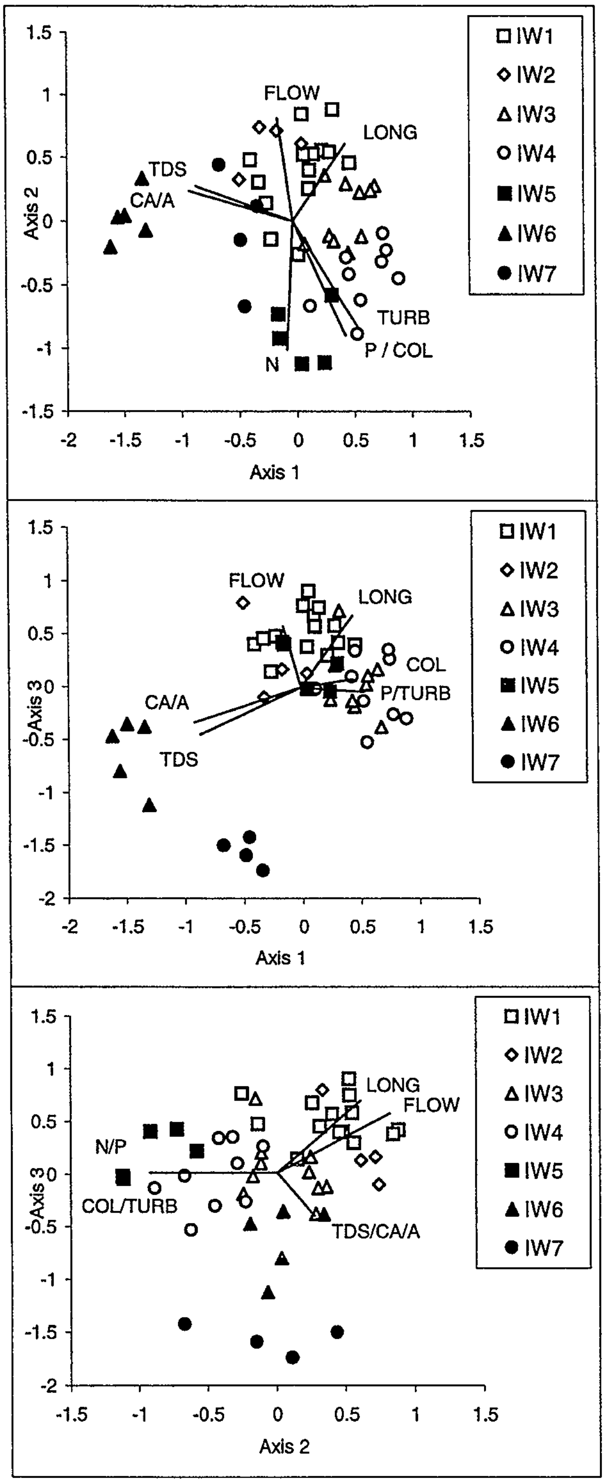

Figure 8 Ordination of wetland sites in the southern Carnarvon Basin based on their invertebrate fauna in winter, showing environmental gradients in the ordination space (three dimensions, stress=0.17).

Wetland types in the southern Carnarvon Basin and important environmental parameters

Wetland classifications derived from winter and summer invertebrate data for a common set of 34 sites showed a high degree of concordance at the five group level (Hubert/Arabie Rand

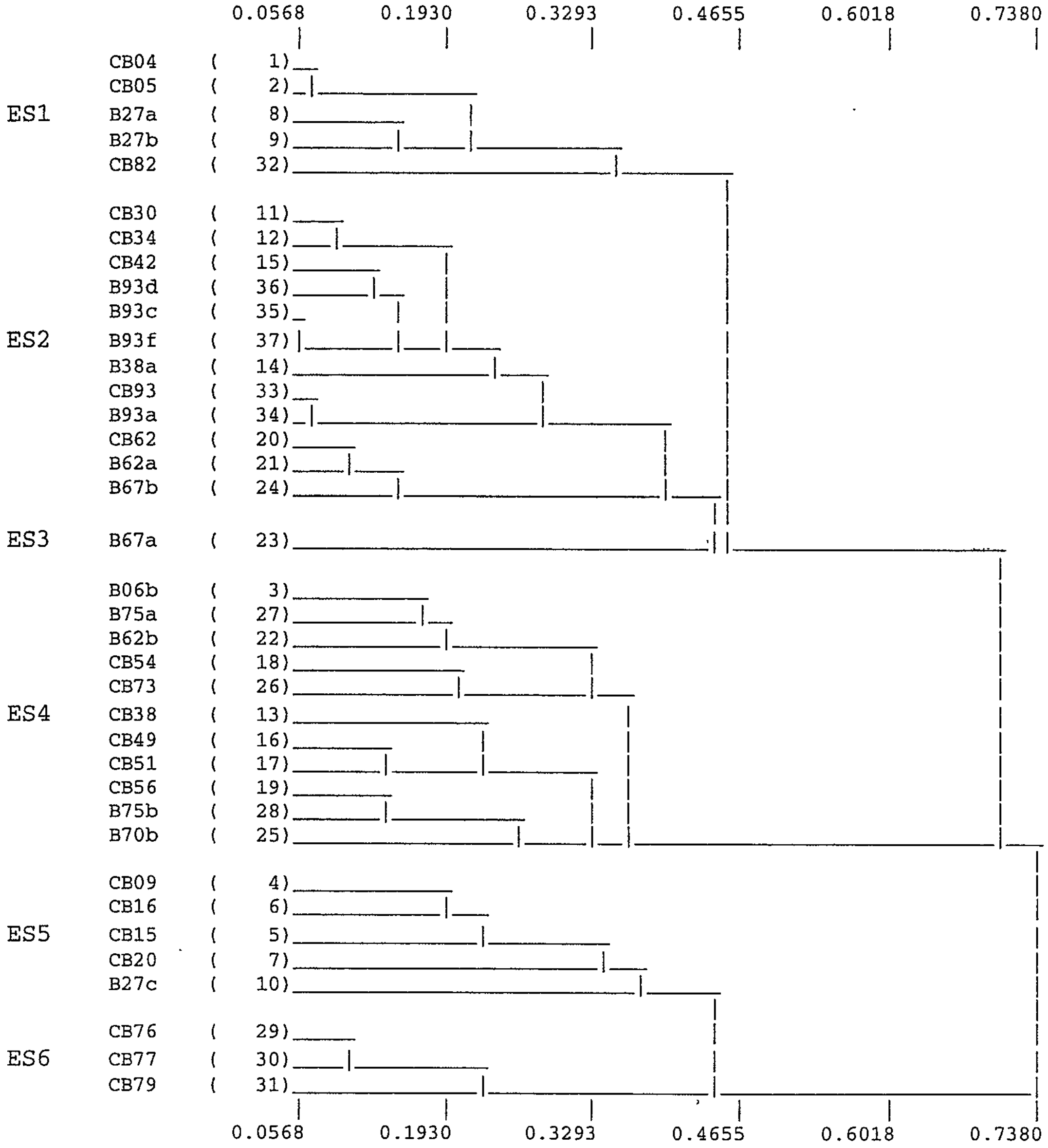

Figure 9 Classification of wetland sites in the southern Carnarvon Basin into six groups (ES1-6) based on their environmental characteristics in summer. See Appendix 1 for site codes.

statistic=0.7963), with only Hardabut and Bullock Pools (CB04 and CB05) on the lower Murchison River changing from river pool to claypan groups (see Figures 7 and 10). The Murchison River was in spate in summer and the main river channel could not be sampled. Backwaters and small pools associated with the river were sampled instead; these were likely to contain faunas with stronger claypan elements than the river channel and may have caused the changes in classification.

All classifications based on invertebrate data showed the existence of five major wetland groupings: (1) river pools, rock pools and larger flowing streams, (2) seeps, springs and small flowing streams, (3) claypans, (4) birridas, and (5) Lake MacLeod. There were slight differences between seasons in terms of environmental variables that were best related to invertebrate community composition but ratio of calcium/alkalinity, TDS, turbidity, colour, flow, longitude, phosphorus and nitrogen were significant both seasons (Table 6.). Several of these variables were inter-correlated (Table 7).

DISCUSSION

Climatic variation has considerable implications for any attempt to document the fauna of a region such as the southern Carnarvon Basin. Apart from obvious sampling difficulties if wetlands remain dry in low rainfall years, the fauna of many sites differs according to whether they are full or partially flooded. A Western Australian example of almost complete turnover of invertebrate fauna was provided by Lake Gregory, southern Kimberley, between 1989 and 1991, as a result of the lake flooding and salinity being dramatically reduced (Halse *et al.*, 1998b). The total aquatic invertebrate

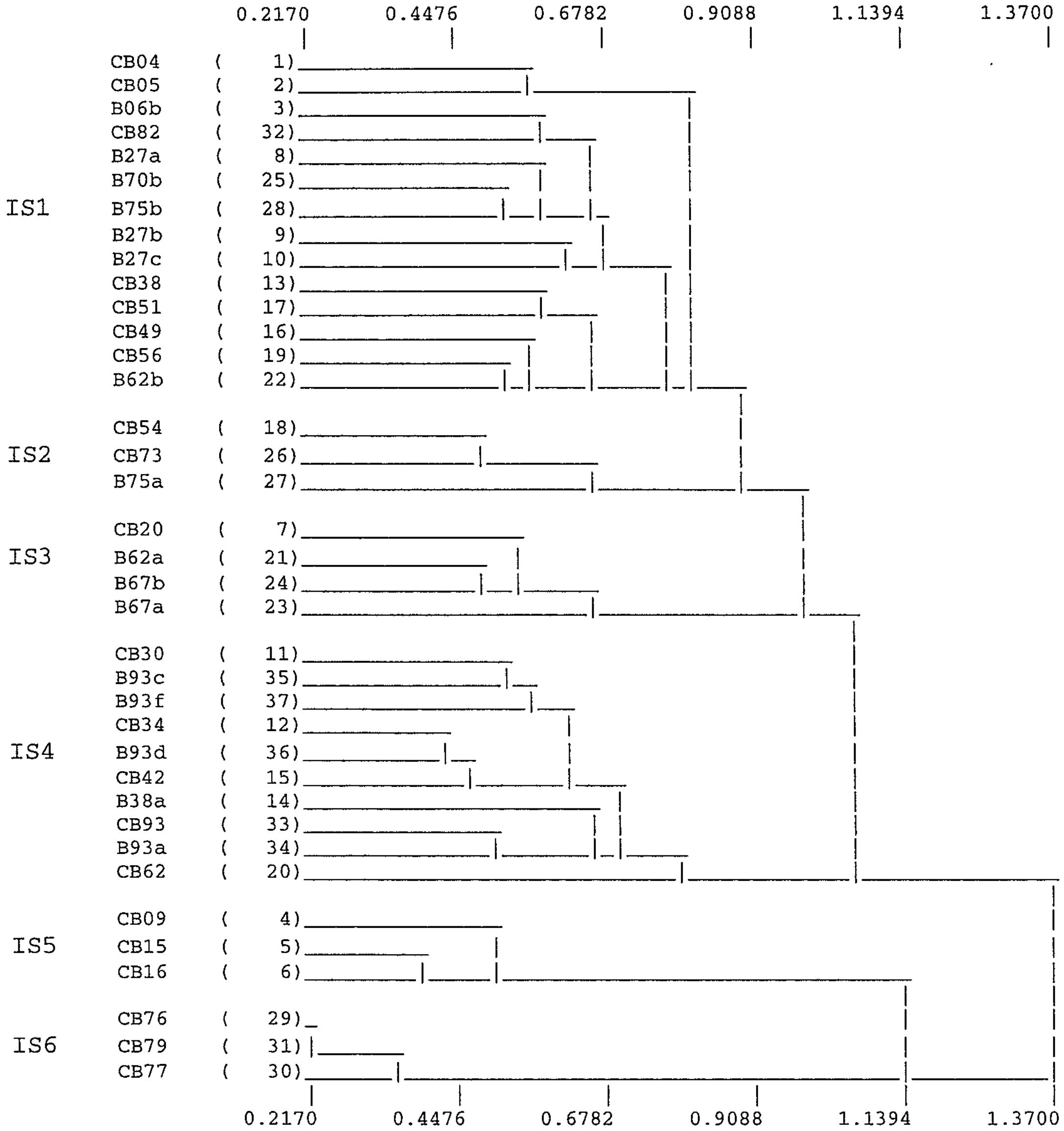

Figure 10 Classification of wetland sites in the southern Carnarvon Basin into six groups (IS1-6) according to their invertebrate fauna in summer. See Appendix 1 for site codes.

Table 7 Highly significant correlations ($P<0.001$) between environmental variables in winter and summer in southern Carnarvon Basin wetlands.

Variables	*r*	
	Winter	Summer
TDS and calcium/alkalinity	0.795	0.611
Colour and phosphorus	0.666	0.817
Colour and turbidity	0.561	0.758
Flow and longitude	0.534	–
Phosphorus and turbidity	0.477	0.624
TDS and longitude	–0.462	-0.497
Nitrogen and colour	0.452	0.640
Nitrogen and turbidity	–	0.575

fauna of an area such as the southern Carnarvon Basin is unlikely to be documented in one year (especially a dry year), nor can the conservation value of individual wetlands be assessed fully. Depending on rainfall patterns, the full value of a wetland may be expressed at intervals of many years or even decades (see Halse *et al.*, 1998a).

Waterbirds

Waterbird data collected during this survey reflected what was already known about broad distributional patterns in the southern Carnarvon Basin (Johnstone *et al.*, 2000). Data from individual sites highlighted the importance of pools in larger rivers, rather than freshwater claypans, as waterbird habitat. Timms (1997) found turbid freshwater claypans in northern New South Wales were also little used by waterbirds.

Two groups in the wetland classification contained most sites with high waterbird conservation value (B1, river pools and vegetated swamps; B2, Lake MacLeod), although B3 contained Lake Julia (CB62b) and Minilya Pool (CB82), which were among the richer sites in the Basin for waterbirds, and B7 contained the pan north of Big Lagoon (CB29a), which clearly had potential to support large numbers of migratory shorebirds. The survey reinforced the pre-eminent status of Lake MacLeod as waterbird habitat in the southern Carnarvon Basin (Smith and Johnstone, 1985; Lane *et al.*, 1996) but also showed that some species do not utilise the lake and rely on other habitats, especially river pools (Figure 5). Twenty-one sites were excluded from analyses because either no waterbird or only one species was recorded. There are many possible reasons for waterbirds not being recorded at a site and depauperate sites should not be treated as a natural grouping.

Although we analysed the waterbird data, results should be used cautiously. Sampling effort was low and variable, with a maximum of three surveys per site. Extra surveys would have increased the waterbird list at most sites: for example, two additional surveys at three sites produced an average of 2.7 extra species (Table 8). A further complication is that waterbird populations may have been unusually low, and thus waterbird use of sites unrepresentative, during the summer 1995 sampling period because of widespread, above-average inland rain (Figure 2). Rainfall in the Goldfields between January and March 1995 was the highest on record (Bureau of Meteorology, 1995). Thirteen sites, at which waterbirds were surveyed during summer both in the 1994 reconnaissance trip and in 1995, had almost three times more species in 1994 than 1995 (3.8±1.0 *vs* 1.3±0.4), when most of the summer surveying was done. This suggests that the phenomenon of waterbirds moving inland from coastal regions after rain (Bekle, 1983; Halse *et al.*, 1992) applies in the arid as well as the temperate zone.

Table 8 Numbers of waterbird species recorded at three sites in three sampling periods during the survey (summer 1994 to summer 1995) and in two subsequent surveys (winter 1995 and summer 1996). Numbers of species first seen in winter 1995 or summer 1996 are also shown. See Appendix 1 for explanation of site codes. ns, not surveyed.

	CB05	CB42	CB82
Summer 1994	6	2	ns
Winter 1994	7	12	10
Summer 1995	1	0	2
Winter 1995	5	6	6
Summer 1996	11	10	1
Extra species winter 1995	2	0	1
Extra species summer 1996	4	1	0
Total number of species	15	14	11

Aquatic invertebrates

Wetland classifications and environmental variables

As for waterbirds, some aspects of the aquatic invertebrate analysis should be used cautiously. The invertebrate surveys were not conducted during particularly wet years, although Carnarvon and eastern parts of the Basin received above-average rainfall in summer 1995 (Table 1, Figure 2), and some of the wetlands chosen during reconnaissance were dry during all three sampling periods. These included the drier type of 'crabhole' swamps, representatives of which were identified on Carbla and Minilya Stations. Site CB25 on Yaringa Station, the only saline claypan identified in the study area that did not have existing marine connections, was sampled but, because it was in the final stages of drying, contained a depauperate, unrepresentative fauna and was excluded from analyses.

Wetland classifications derived from invertebrate data gave consistent patterns across seasons with five major types of wetland site being recognized (1) river pools, rock pools and larger flowing streams, (2) seeps, springs and small flowing streams, (3) claypans, (4) birridas, and (5) Lake MacLeod. The claypan group could be further divided on the basis of turbidity and stage in the drying cycle (Figures 7 and 8). Less turbid claypans and those where water levels had not receded noticeably had higher species richness, although some species were more or less restricted to highly turbid and drying-phase claypans. Saline pans without current marine influence, such as CB25, may comprise a sixth, uncommon type of wetland.

Previous studies of community composition in wetlands of Western Australia have examined much smaller geographic areas and a restricted range of wetland types. Growns *et al.* (1992) and Davis *et al.* (1993) classified 40 shallow, permanent or seasonal lakes on the Swan Coastal Plain according to their invertebrate communities and found two small outlying groups, one of which was related to high salinity and the other to low pH. Groupings among the remaining wetlands appeared to be related to colour and nutrients. In a similar analysis of 23 shallow, permanent lakes on the south-western coast, Edward *et al.* (1994) found groupings based on invertebrate communities appeared to be related to salinity (although all salinities were <3000 mg L^{-1}) and nutrients. In a study of the macroinvertebrate communities of rivers across north-western Australia, based on family-level identifications, Kay *et al.* (1999) found variables measuring geographic position, salinity and river discharge were more important than turbidity, alkalinity and nutrients.

In this survey, wetland groups based on invertebrate communities were best correlated with ratio of calcium/alkalinity (not measured in other studies), salinity, turbidity, colour, flow (which separated rivers and springs from lentic wetlands), geographic position, phosphorus and nitrogen. Storey *et al.* (1993) suggested that environmental variables best related to wetland groupings vary according to the range of wetland types being studied, scale of the study and landscape setting. For example, environmental variables such as ratio of calcium/alkalinity will show far more variation if birridas, rivers and freshwater claypans are sampled than if only one wetland type is studied. In surveys of small areas, geographical coordinates are unlikely to be important. Similarly, turbidity will probably be more variable in lentic waterbodies than rivers, and show greater variation in north-western Australia, where soils often contain a high proportion of clay or loam, than on the Swan Coastal Plain, where they are sandy.

Inter-correlation among environmental variables in this survey creates doubt about the validity of some correlations between wetland groupings and environmental variables. The observed correlation between longitude and wetland groupings may have been at least partially the result of strong correlations with TDS, flow regime or distance from the coast (which was not measured), rather than reflecting large-scale zoogeographic pattern. Strong inter-correlations between nutrients, turbidity and colour may obscure the relative influence of these variables on community composition.

Biogeography

Analysis of biogeographical patterns in the southern Carnarvon Basin data is made difficult by the fact that distributions of most aquatic invertebrates are poorly known. About 50 species previously thought to be restricted to the eastern half of Australia were recorded in this survey and species that currently appear endemic to the Basin may be recorded elsewhere when surveys are conducted in other little studied regions of Australia. Inability to identify some faunal groups to species level further obscures biogeographical patterns, as well as preventing assessment of the conservation status of the unidentified animals. Despite being a major component of the fauna of Australian wetlands (e.g. Geddes *et al.*, 1981; Davis *et al.*, 1993), about 40% of ostracods collected were either undescribed or could not be confidently identified to species level. None of the ceratopogonid dipteran larvae could be identified to species.

Most of the undescribed species collected in the southern Carnarvon Basin are probably widespread (Table 4). Lack of survey in Western Australia means that many widespread species have been recorded rarely. For example, for 50 years the only known Australian locality of the harpacticoid *Cletocamptus confluens* was Shark Bay (Lang 1948), until it was found throughout Western Australia in the 1990s (Halse *et al.*, 1996; this study; Halse, unpubl. data). However, some species belonging to groups for which there has been comparatively high collecting effort should probably be treated as endemic to the Basin until there is evidence to the contrary. These include the calanoid copepod *Calamoecia halsei* (Bayly, 1998), several ostracods and the anostracan *Branchinella* sp. nov. (aff. *lyrifera*).

Gibson *et al.* (2000) found that, while most of the wetland flora in the southern Carnarvon Basin was typical of arid areas, significant numbers of south-western and tropical species occurred at the northern and southern limits, respectively, of their ranges. The same is true for aquatic invertebrates and the southern Carnarvon Basin appears to represent a zone where Bassian and Torresian biotic elements meet (see Serventy and Whittell, 1967). Examples of Torresian species that have extended their range southwards are the copepod *Eudiaptomus lumholtzi* (see Timms and Morton, 1988) and beetles *Berosus dallasae* and *Hydroglyphus leai* (see Watts, 1978, 1987). Examples of Bassian species extending north are the copepod *Calamoecia tasmanica subattenuata* (see Maly *et al.*, 1997) and ostracods *Mytilocypris mytiloides* and *Australocypris insularis* (see De Deckker, 1978). Nevertheless, most aquatic invertebrates in the Basin either have Eyrean affinities or occur throughout Australia. Groups such as anostracans and notostracans are typical of the former (Geddes, 1981; Williams, 1968); many corixid hemipterans are examples of the latter (Wroblewski, 1972; Knowles, 1974).

Until now, only the chironomid *Archaeochlus*, which occurs in small temporary streams on granite outcrops in south-western Australia and is also known from the Drakensberg Escarpment and Namibia in southern Africa, was recognized as a Gondwanan relic in arid parts of Western Australia (Edward, 1986; Cranston *et al.*, 1987). The occurrence of aquatic invertebrates, hitherto known only from South America, in the southern Carnarvon Basin raises the possibility that Gondwanan relics may occur quite commonly in arid areas. It seems unlikely that the copepod *Robertsonia mourei*, which occurs in Lake MacLeod, could have been transported by migratory shorebirds (Procter *et al.*, 1967) because there is no established flyway between South America and Western Australia. The rotifer *Hexarthra brandorffi* seems even more unlikely to have been translocated and almost certainly represents a relictual species. Similarly, the undescribed *Daphnia* sp. nov. (aff. *barbata*) and *D.* sp. nov. (aff. *gibba*) have strong

African affinities and may be Gondwanan (C. Wilson, pers. comm.). Past studies of Gondwanan relics in Western Australia have focussed on the wetter south-west (Edward, 1989; Cranston and Edward, 1992; Horwitz, 1997) and the significance of arid areas as habitat may have been underestimated, particularly for species with a resistant stage in their life history.

Wetland community patterns

Waterbirds and aquatic invertebrates in south-western Australia appear to respond to the same environmental variables, such as salinity and nutrient levels (see Davis *et. al.*, 1993; Halse *et al.*, 1993; Storey *et al.*, 1993), yet wetlands supporting the largest numbers of waterbird species frequently differ from those with most invertebrates. For example, in a recent survey on the Swan Coastal Plain none of the five wetlands with highest invertebrate richness (Davis *et. al.*, 1993) were among the 20 wetlands with highest waterbird richness or most breeding waterbird species (Storey *et al.*, 1993).

The same pattern applied in the southern Carnarvon Basin. Although there was some superficial agreement between classifications of sites based on waterbirds and aquatic invertebrates, site-by-site comparisons suggested that the processes underlying formation of waterbird and invertebrate assemblages were different. Information about community composition of waterbirds at a wetland could not be inferred reliably from data on invertebrates or *vice versa* (cf. Figures 3 and 7). Plant communities provided even less information about the biota: the same plant community occurred at marine sites CB09 and CB77, brackish river site CB38a and freshwater coastal pan CB36 (Figure 2 in Gibson *et al.*, 2000), despite these sites supporting three waterbird and four invertebrate communities (Figures 3 and 7). The Carnarvon Basin results mirror those of Yen (1987), who found terrestrial beetles, mammals and vegetation each provided only limited information about the composition of the other two biotic elements at sites in Victoria.

Lack of concordance between classifications based on different taxonomic elements means that inventory of each element is required to identify distribution patterns and important habitats before strategies can be prepared for the conservation and protection of that element. Wetlands with low conservation value for plants may be important for invertebrates or waterbirds.

Rare species and their conservation

A third of aquatic invertebrate taxa were collected only once during this survey (Table 3). The phenomenon was even more pronounced in the flora, with 55 % of species occurring at only one wetland (Gibson *et al.*, 2000). The most obvious implication for both invertebrates and plants is that the number of species recorded in the Basin will grow as survey effort is increased.

Infrequent occurrence may be the result of aquatic invertebrates occurring in a narrow range of wetland types or conditions, being present for a short time in the flooding cycle, or having poor colonizing ability and locally restricted distributions. Maly *et al.* (1997) argued that poor dispersal, rather than narrow ecological tolerances, shaped the distribution of most calanoid copepods in Australia. However, many of the species with a single occurrence in the Basin were insects (see Appendix 4) with strong powers of flight. Differences between communities of drying-phase (IW5 in winter and IS2 in summer) and other claypans suggested that temporal succession may have contributed to sporadic collection of some species but it seems unlikely to have been the factor underlying all rare occurrences. Gibson *et al.* (2000) suggested the southern Carnarvon Basin naturally contains many rare plant species and the same seems true for aquatic invertebrate species, although the reasons for rarity are not understood.

Rarity or infrequent occurrence of aquatic invertebrates and other species poses problems for their conservation, particularly when it is unclear whether they are restricted to very few wetlands or occur very infrequently at many sites. Given the high proportion of 'rare' species with poorly understood and unpredictable distributions, it is unlikely that all species can be conserved in a regional nature reserve system. The realistic objective for the reserve system should be protection of examples of all wetland types in the southern Carnarvon Basin and their typical invertebrate communities. Other mechanisms, designed to ensure careful management of wetlands on different land tenures, will be a necessary adjunct to nature reserves for conservation of some rarer, or infrequently occurring, species.

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Appendix 1

Wetland sites sampled in the southern Carnarvon Basin, 1994-95. * sampled August 1994, ‡ October 1994, # July 1995 (winter), † March 1995 (summer).

Site no	Name	Latitude	Longitude	Tenure	Type
CB04*†	Hardabut Pool	27°53'11"S	114°34'04"E	Mt View	Billabong
CB05*†	Bullock Pool	27°49'04"S	114°46'31"E	Riverside	River pool
CB06a*†	Un-named swamp	27°31'26"S	115°04'20"E	Coolcalalaya	Ephemeral swamp
CB06b*†	Un-named claypan	27°31'29"S	115°05'14"E	Coolcalalaya	Ephemeral pan
CB09*†	Un-named birrida	26°45'13"S	113°42'34"E	Tamala	Birrida
CB09a*	Un-named birrida	26°44'31"S	113°42'37"E	Tamala	Birrida
CB15*†	Un-named birrida	26°23'05"S	113°20'08"E	Carrarang	Birrida
CB16*†	Un-named birrida	26°14'20"S	113°23'56"E	Carrarang	Birrida
CB20*†	Hamelin Pool	26°25'40"S	114°11'33"E	Hamelin	Permanent swamp
CB25*	Un-named claypan	26°02'07"S	114°19'50"E	Yaringa	Ephemeral pan
CB27a †	Nr Wardawarra Pool	26°04'49"S	115°27'10"E	Yalardy	River pool
CB27b#†	Un-named swamp	26°15'22"S	115°27'49"E	Talisker	Ephemeral swamp
CB27c†	Un-named swamp	26°18'54"S	115°30'50"E	Talisker	Ephemeral swamp
CB29a*	Pan N of Big Lagoon	25°36'01"S	113°28'10"E	Marine Park	Birrida
CB30#†	Nr Namararra Well	25°39'30"S	114°25'20"E	Wooramel	River pool
CB34*†	Mundilya Pool	25°39'54"S	114°50'54"E	Meedo	River pool
CB35a*	Un-named canegrass pan	25°40'52"S	114°13'14"E	Wooramel	Ephemeral canegrass pan
CB36*	Ephemeral marsh	24°57'51"S	113°42'16"E	Brickhouse	Ephemeral coastal marsh pan
CB38*†	Chagra Well claypan	25°11'47"S	114°57'02"E	Jimba Jimba	Ephemeral pan
CB38a*†	Salt Gully	25°04'17"S	115°01'48"E	Jimba Jimba	River pool
CB42*†	Winnemia Pool	25°00'32"S	114°56'52"E	Jimba Jimba	River pool
CB43*	Un-named claypan	25°04'17"S	115°03'30"E	Jimba Jimba	Ephemeral pan
CB44*	Rocky Pool	25°45'23"S	114°08'08"E	Brickhouse	River pool
CB49*†	Coollilee Pool	24°42'21"S	113°41'10"E	Boolathana	River pool
CB51#†	Un-named canegrass pan	24'44'21"S	113°43'14"E	Boolathana	Ephemeral canegrass pan
CB54*†	Nr Cardabia Swamp	24°33'10"S	113°45'35"E	Boolathana	Canegrass swamp
CB54a#	Cardabia Swamp	24°34'44"S	113°43'13E	Boolathana	Crabhole swamp
CB56*†	Tirigie Claypan	24°38'34"S	113°59'29"E	Boolathana	Ephemeral pan
CB56a*	Un-named pan	24°38'19"S	113°59'35"E	Boolathana	Ephemeral pan
CB58b*	Un-named claypan	24°48'08"S	114°16'15"S	Doorawarrah	Ephemeral pan
CB58c*	Un-named bluebush swamp	24°47'44"S	114°10'05"E	Doorawarrah	Ephemeral bluebush swamp
CB58d*	Un-named canegrass pan	24°47'37"S	114°09'14"E	Brickhouse	Ephemeral canegrass pan
CB58e*	Un-named claypan	24°47'35"S	114°09'14"E	Brickhouse	Ephemeral pan
CB62*†	Mooka Ruin springs	24°53'26"S	114°57'29"E	Mooka	River pool
CB62a*†	Un-named creek	24°46'28"S	114°56'17"E	Mooka	River pool
CB62b †	Lake Julia	24°40'46"S	114°56'11"E	Mooka	Ephemeral swamp
CB62c*†	Un-named spring	24°46'31"S	114°56'20"E	Mooka	Hillside seep
CB67a*†	Birdrong Spring	24°14'40"S	114°52'11"E	Mardathuna	Hillside seep
CB67b*†	Scooped Hole	24°18'07"S	114°50'28"E	Mardathuna	River pool
CB68*	Un-named swamp	24°17'46"S	114°29'47"E	Hill Springs	Ephemeral swamp
CB70b*†	Bulgra Pool	24°25'41"S	114°32'54"E	Mardathuna	River pool
CB73*†	Boolan Pool	24°28'38"S	113°40'36"E	Boolathana	River pool
CB75a*†	Cattle Camp Pan	24°28'25"S	114°13'27"E	Cooralya	Ephemeral pan
CB75b*†	Bluebush Bore Swamp	24°28'19"S	114°18'08"E	Cooralya	Bluebush swamp
CB75c*	Dwyers Pan	24°26'00"S	114°27'18"E	Mardathuna	Ephemeral pan
CB76*†	Lake McLeod	23°57'39"S	113°36'40"E	Gnaraloo/Dampier Salt	Birrida
CB77*†	Lake McLeod	23°54'53"S	113°39'23"E	Gnaraloo/Dampier Salt	Birrida
CB78‡	Lake McLeod	23°52'19"S	113°42'43"E	Gnaraloo/Dampier Salt	Marine pan
CB79‡†	Lake McLeod (Blue Holes)	23°47'16"S	113°44'44"E	Gnaraloo/Dampier salt	Marine pan
CB82*†	Minilya Pool	23°52'04"S	113°58'44"E	Minilya	River pool
CB93*†	Cardilya Pool	25°37'34"S	115°31'28"E	Carey Downs	River pool
CB93a*†	Bidgelang Pool	25°34'32"S	115°36'01"E	Carey Downs	River pool
CB93c*†	Callytharra Spring	25°52.59"S	115°30.14"E	Carey Downs	River pool
CB93d*†	Nunnery Pool	25°51'45"S	115°31'53"E	Carey Downs	River pool
CB93f*†	Boothawalla Pool	25°47'31"S	115°17'26"E	Carey Downs	River pool
CB93g*	Meedo Pool	25°44'29"S	115°06'59"E	Gilroyd	River pool

Appendix 2

Values of environmental variables collected in the southern Carnarvon Basin in winter and summer. See text for description of variables.

Site	Season	pH	DO (% sat.)	Colour (TCU)	Turbidity (NTU)	TDS (mg/L)	Ca/Alkalinity	Ca+Mg/Cl	Ca/SO4	Total N (mg/L)	Total P (mg/L)	Chlorophyll (mg/L)	SiO_2	Latitude[a]	Longitude[a]	Flow[b]
CB04	summer	7.7	85	63	310	300	0.507	0.891	1.833	0.68	0.08	0.005	9.6	27.886	114.568	2
CB04	winter	8.2	98	14	0.24	3600	1.035	0.265	0.582	0.39	0.01	0.002		27.886	114.568	2
CB05	summer	6.2	83	77	280	260	0.468	0.926	1.917	0.75	0.06	0.007	11	27.818	114.775	2
CB05	winter	8	110	8	2	1100	1.097	0.286	0.675	0.41	0	0.007		27.818	114.775	2
CB06a	winter	8.3	120	14	0.76	23	0.196	0.669	4.793	0.44	0.01	0.006		27.524	115.072	1
CB06b	summer	7.5	68	1200	62000	1100	0.060	0.377	0.872				76	27.525	115.087	1
CB06b	winter	7.4	108	1100	17000	84	0.217	0.203	1.917	3.4	0.01	0.005		27.525	115.087	1
CB09	summer	7.3	52	50	15	52000	13.740	0.228	0.415	0.53	0.04	0.024	6.7	26.753	113.709	1
CB09	winter	7.8	106	3	0.91	180000	25.618	0.186	0.370	2.1	0.01	0.004		26.753	113.709	1
CB09a	winter	8.6	126	23	0.85	85000	34.043	0.269	0.543	3.2	0.02	0.002		26.742	113.710	1
CB15	summer	7.8	77	39	5.1	140000	18.994	0.197	0.411	1.6	0.02	0.147	3	26.385	113.336	1
CB15	winter	8	85	3	0.45	57000	34.043	0.286	0.657	2.1	0.01	0.015		26.385	113.336	1
CB16	summer	7.7	71	200	20	270000	6.596	0.195	0.186	1.2	0.005	0	7.4	26.239	113.399	1
CB16	winter	8.1	119	5	0.5	55000	44.907	0.282	0.719	1	0.02	0.002		26.239	113.399	1
CB20	summer	7.6	40	36	3.6	6300	2.537	0.258	0.513	0.24	0.005	0.004	9.6	26.428	114.193	2
CB20	winter	8.2	167	3	0.35	6000	2.585	0.264	0.568	0.35	0.01	0.001		26.428	114.193	2
CB25	winter		83			290000		0.159						26.035	114.331	1
CB27a	summer	8	77	56	250	310	0.351	1.266	3.082	0.87	0.09	0.014	6.9	26.08	115.453	2
CB27b	summer	6.7	75	60	300	150	0.303	1.171	2.397	0.67	0.07	0.015	1.9	26.256	115.464	1
CB27b	winter	7.38	92	34	440	45	0.127	0.323	0.799	1.7	0.11	0.25		26.256	115.464	1
CB27c	summer	7.5	78	51	26	1700	4.154	0.334	1.046	4.2	0.04	0.092	1.3	26.315	115.514	1
CB29a	winter	8.6	139	7	0.5	94000	38.521	0.267	0.530	2.2	0.02	0.017		25.600	113.470	1
CB30	summer	8.6	110	17	3.5	150	0.780	2.325	2.820	0.21	0.01	0.003	8	25.658	114.422	4
CB30	winter	8.91	102	24	1.1	140	0.811	2.611	4.622	0.54	0.01	0.11		25.658	114.422	2
CB34	summer	8.1	95	15	1.5	260	0.939	1.604	2.242	0.31	0.01	0.004	9	25.665	114.848	4
CB34	winter	9.4	137	7	0.38	230	0.656	0.452	1.551	0.69	0.01	0.014		25.665	114.848	2
CB35a	winter	7.8	68	55	37000	480	0.101	0.123	2.397	0.84	0.24			25.681	114.221	1
CB36	winter	8	88	400	9100	630	0.075	0.040	0.399	1.1	0.67	0.027		24.964	113.705	1
CB38	summer	7.5	81	120	6700	370	0.076	0.426	0.240	1.2	0.43		9.2	25.196	114.951	1
CB38	winter	8.2	105	400	10000	190	0.060	0.177	0.141	1.6	0.58			25.196	114.951	1
CB38a	summer	8.6	88	8	5.8	1400	7.293	0.982	0.923	0.41	0.01	0.02	4.3	25.071	115.030	2
CB38a	winter	9.1	115	6	1.8	690	5.324	0.802	0.971	0.28	0.01	0.001		25.071	115.030	2
CB42	summer	8.1	96	12	5.1	660	1.153	0.730	1.289	0.17	0.005	0.003	7.8	25.009	114.948	2
CB42	winter	8.6	74	5	0.35	1700	2.387	0.434	0.767	0.45	0	0.002		25.009	114.948	2
CB43	winter	8.5	95	180	36000	550	0.021	0.061	0.799	1.5	0.39	0		25.072	115.058	1
CB44	winter	8.6	130	7	0.27	360	0.622	0.804	2.896	0.58	0	0.001		25.756	114.136	2
CB49	summer	6.9	87	110	1200	460	0.190	0.776	1.525	0.82	0.21	0.036	16	24.706	113.686	1
CB49	winter	8.2	98	88	4100	230	0.119	0.233	0.737	1.3	0.48	0.008		24.706	113.686	1
CB51	summer	6.5	91	110	2400	710	0.086	0.426	0.599	0.62	0.35		7.4	24.739	113.721	1
CB51	winter	8.44	104	70	5300	410	0.055	0.268	0.533	1.5	0.33	0.078		24.739	113.721	1
CB54	summer	8.2	40	91	50000	930	0.076	0.079	0.409	5	0.96		2.8	24.553	113.760	1
CB54	winter	8.2	95	1400	12000	260	0.046	0.138	0.369	1.8	0.05	0.008		24.553	113.760	1
CB54a	winter	6.59	53	35	410	110	0.254	2.228	14.380	0.81	0.03	0.015		24.579	113.720	1
CB56	summer	7.8	85	91	4500	550	0.300	2.672	5.592	1.7	0.17	0.05	20	24.643	113.992	1
CB56	winter	8.5	121	260	820	56	0.380	0.436	2.996	0.43	0.06	0.02		24.643	113.992	1
CB56a	winter	7.4	100	12000	38000	500	0.299	1.338	8.788	3.9	0.84	0		24.639	113.993	1
CB58b	winter	8	101	1900	43000	250	0.069	0.276	2.397	3.1	0.52	0		24.802	114.271	1
CB58c	winter	8.1	95	48	380	68	0.312	2.869	9.587	0.77	0.03	0.003		24.796	114.168	1
CB58d	winter	9.3	156	780	880	91	0.053	0.339	1.198	1.9	0.01	0.015		24.794	114.154	1
CB58e	winter	8.2	104	8800	22000	680	0.056	0.304	1.798	2.4	1.5	0		24.793	114.154	1
CB62	summer	8.3	150	120	17	11000	2.176	0.477	0.412	2.8	0.01	0.006	25	24.891	114.958	4
CB62	winter	7.6	74	6	0.45	2000	1.150	0.513	0.472	0.51	0.01	0		24.891	114.958	4
CB62a	summer	8.2	124	76	2.9	11000	0.733	0.396	0.257	0.99	0.01	0.007	64	24.774	114.938	4
CB62a	winter	8.8	158	23	0.34	10000	1.120	0.387	0.194	0.68	0	0.006		24.774	114.938	4

Site	Season	pH	DO (% sat.)	Colour (TCU)	Turbidity (NTU)	TDS (mg/L)	Ca/Alkalinity	Ca+Mg/Cl	Ca/SO4	Total N (mg/L)	Total P (mg/L)	Chlorophyll (mg/L)	SiO_2	Latitude[a]	Longitude[a]	Flow[b]
CB62b	summer	7.6	70	490	3100	400	0.145	1.013	1.198	3.7	0.01		22	24.68	114.936	1
CB67a	summer	6.4	10	13	21	1200	1.796	1.047	0.474	0.47	0.21	0.034	15	24.244	114.870	3
CB67a	winter	6.9	68	8	0.21	1300	1.921	1.029	0.499	0.91	0	0.012		24.244	114.870	3
CB67b	summer	8.6	138	24	0.7	7200	1.211	0.534	0.234	0.43	0.01	0.005	16	24.302	114.841	4
CB67b	winter	8.2	145	12	0.34	6500	1.473	0.607	0.288	0.64	0	0.016		24.302	114.841	4
CB68	winter	8.1	110	140	400	43	0.435	2.933	1.332	0.53	0.02	0.009		24.296	114.497	1
CB70b	summer	9.4	120	80	250	300	1.217	0.894	1.667	2.2	0.06	0.14	24	24.428	114.548	1
CB70b	winter	7.8	101	1100	1400	74	0.294	1.278	2.397	5.5	0.64	0.134		24.428	114.548	1
CB73	summer	8.8	94	160	960	3000	0.238	0.145	0.723	7	1.1	0.042	15	24.477	113.677	1
CB73	winter	8.5	97	1000	2300	240	0.071	0.507	1.370	4.5	0.56	0.113		24.477	113.677	1
CB75a	summer	7.5	72	810	30000	1200	0.069	0.857	0.799	6	5.1		20	24.474	114.224	1
CB75a	winter	8.2	110	2300	2700	91	0.124	0.954	1.198	2.1	1.5	0.047		24.474	114.224	1
CB75b	summer	8	121	160	1500	730	0.254	4.686	9.587	1	0.15	0.076	39	24.472	114.302	1
CB75b	winter	7.5	84	550	1400	76	0.315	1.886	3.595	1.5	0.06	0.012		24.472	114.302	1
CB75c	winter	7.2	104	460	700	53	0.434	0.551	0.599	1.5	0.07	0.011		24.433	114.455	1
CB76	summer	7.9	152	13	3.6	53000	9.465	0.223	0.382	0.55	0.01	0.005	20	23.961	113.611	1
CB76	winter	8.2	147	9	0.26	46000	9.032	0.219	0.404	0.51	0.01	0.002		23.961	113.611	1
CB77	summer	7.8	164	14	4.8	41000	7.811	0.242	0.386	0.24	0.005	0.01	3.9	23.915	113.656	1
CB77	winter	8.9	145	5	0.21	40000	8.318	0.237	0.402	0.31	0	0.02		23.915	113.656	1
CB78	winter	7.4	133	8	0.05	32460	7.402	0.268	0.608	0.85	0.005			23.872	113.712	1
CB79	summer	7.2	84	17	0.6	40000	5.419	0.242	0.416	0.28	0.005	0	3.2	23.788	113.746	1
CB79	winter	7.3	105	12	0.05	41220	7.088	0.267	0.375	0.48	0.005			23.788	113.746	1
CB82	summer	6.9	74	21	540	140	0.741	5.356	2.846	0.41	0.06	0.017	6.3	23.868	113.979	2
CB82	winter	8.8	84	110	100	340	0.676	0.977	2.538	0.56	0.02	0.026		23.868	113.979	2
CB93	summer	8	109	28	0.7	80	0.456	4.112	7.190	0.41	0.01	0.009	6.9	25.626	115.524	2
CB93	winter	8.8	102	24	1.7	180	0.692	5.289	23.967	2.8	0.01	0.04		25.626	115.524	2
CB93a	summer	8.4	108	23	1.4	120	0.609	2.395	6.591	0.44	0.01	0.006	11	25.576	115.600	2
CB93a	winter	7.7	106	13	0.28	64	0.537	1.210	4.793	0.55	0	0.002		25.576	115.600	2
CB93c	summer	7.6	99	15	6.9	590	1.522	1.023	1.065	0.18	0.005	0.014	6.2	25.877	115.502	4
CB93c	winter	8.4	108	7	0.25	1700	1.416	0.590	0.799	0.23	0	0.001		25.877	115.502	4
CB93d	summer	8.1	99	11	16	310	1.416	1.414	1.031	0.24	0.005	0.014	6.6	25.863	115.531	2
CB93d	winter	8.7	142	7	0.25	580	1.332	1.103	1.174	0.48	0	0.001		25.863	115.531	2
CB93f	summer	8.3	89	14	3.4	680	1.712	1.033	1.027	0.28	0.005	0.009	6	25.792	115.291	4
CB93f	winter	8.4	108	17	0.25	420	0.832	1.179	3.414	0.78	0.01	0.026		25.792	115.291	2
CB93g	winter	9.5	161	10	0.31	480	0.949	1.022	1.580	0.72	0.01	0.03		25.741	115.116	2

[a] decimal degrees

[b] flow category

Appendix 3

Waterbirds recorded at wetlands in the southern Carnarvon Basin 1994-95. See Appendix 1 for wetland site names.

Species	CB04	CB05	CB06a	CB06b	CB09	CB09a	CB15	CB16	CB20	CB25	CB27a	CB27b	CB27c	CB29a	CB30	CB34	CB35a	CB36	CB38	CB38a	CB42	CB43	CB44	CB49	CB51	CB54	CB54a
Black Swan		4							11												2		1				
Australian Shelduck	4	4	1						17																		
Australian Wood Duck		4	1	20					2			4							7				4				
Pacific Black Duck	1	8	6	3					56												1						
Australasian Shoveler									1																		
Grey Teal			17	10					34			7							18	5	11		2		4	9	
Pink-eared Duck			2									4							3							3	
Hardhead	3																										
Unidentified duck																											
Australasian Grebe	1	3	6						3																		
Hoary-headed Grebe		1	3						5			7											2				
Great Crested Grebe																											
Unidentified grebe		9							8																		
Darter		2																			1						
Little Pied Cormorant		2							1												2						
Pied Cormorant																											
Little Black Cormorant	2																				1		8				
Unidentified cormorant																											
Australian Pelican																											
White-faced Heron			2	9					2			1						1	6		3					2	
Little Egret																											
White-necked Heron				1													2				3					1	
Great Egret	1		1																		2		1				
Unidentified egret																											
Striated Heron																											
Nankeen Night Heron																											
Straw-necked Ibis			6																		9						
Royal Spoonbill																											
Yellow-billed Spoonbill			1																		1						
White-bellied Sea-eagle																											
Buff-banded Rail									1																		
Baillon's Crake									6																		
Dusky Moorhen				1																							
Black-tailed Native-hen																	9							1			
Eurasian Coot		50							74												6		8				
Bar-tailed Godwit																											
Whimbrel																											
Marsh Sandpiper																											
Common Greenshank								1																			
Terek Sandpiper																											
Common Sandpiper	1																1						1	1			
Grey-tailed Tattler																											
Ruddy Turnstone																											
Great Knot																											
Red-necked Stint														7													
Sharp-tailed Sandpiper																											
Curlew Sandpiper														15													
Pied Oystercatcher																											
Black-winged Stilt									6																		
Banded Stilt					80		8							1250													
Red-necked Avocet									1										1								
Pacific Golden Plover																											
Grey Plover																											
Red-capped Plover					3		13	1		4				13													
Greater Sand Plover																											
Black-fronted Dotterel			2						7							1			1	3	2		2				
Red-kneed Dotterel																	10										
Banded Lapwing																											
Unidentified wader																											
Silver Gull							1																				
Gull-billed Tern							1																				
Caspian Tern																											
Unidentified Tern																											
No. of birds	13	87	48	44	83	0	23	2	235	4	0	23	0	1285	0	1	22	1	36	8	44	0	29	2	4	15	0
No. of species	7	10	12	6	2	0	4	2	17	1	0	5	0	4	0	1	4	1	6	2	13	0	9	2	1	4	0

CB56	CB56a	CB58b	CB58c	CB58d	CB58e	CB62	CB62a	CB62b	CB62c	CB67a	CB67b	CB68	CB70b	CB73	CB75a	CB75b	CB75c	CB76	CB77	CB78	CB79	CBLM	CB82	CB93	CB93a	CB93c	CB93d	CB93f	CB93g	No.of birds
																		16	3		12	853	1							903
																														26
6								17																5			3			73
														2								12		1			2			92
																														1
5			3					22							2			1605	63		228	1044	42		2		2			3135
								2															17							31
																														3
																														0
																											2			15
								20				4					6				1		2							51
																		1	2											3
								10														2								29
								1										3	3			8					2			20
																		3	11		4	16								39
																		4	44		2	257								307
																		60	71		4	207								353
																						22								22
																		70	2			368	2				1	1	1	445
	1	1	1					6				2		1		1	2	3	2	2	2	16	7				1			74
																		16	16		10									42
	1			1	1	2		3				1		1	1		1						1			1		2		23
																						5								10
																						34								34
																						2								2
																														0
																							1							16
																							1							1
																							6							8
																			1											1
																														1
																														6
																														1
															2															12
								5														20								163
																					6									6
																						10								10
																					5									5
								5												40	55	3								104
																					2									2
																					1									5
																					4									4
																					24									24
																					1									1
																					85									92
																					4									4
																					27									42
																						3								3
																		53			38	151								248
																					70	8084								9492
																	1				5	297								305
																					1									1
																					31									31
																				8	150									192
																					10									10
1				1	1																						3			24
								1													3									14
								2							2															4
																						17781								17781
																		42			2	43								88
																		2				7								10
																		2	1			47								50
																		10												10
12	2	1	4	2	2	2	0	94	0	0	0	7	0	4	7	1	10	1890	219	50	787	29292	80	6	2	1	16	3	1	34504
3	2	1	2	2	2	1	0	12	0	0	0	3	0	3	4	1	4	15	12	3	28	25	10	2	1	1	8	2	1	

Appendix 4

Aquatic invertebrates collected during winter 1994 or 1995 and summer 1995 in the southern Carnarvon Basin. See Appendix 1 for wetland site names.

	CB04s	CB04w	CB05s	CB05w	CB06aw	CB06bs	CB06bw	CB09s	CB09w	CB09aw	CB15s	CB15w	CB16s	CB16w	CB20s	CB20w	CB25w	CB27as	CB27bs	CB27bw	CB27cs	CB29aw	CB30s	CB30w	CB34s	CB34w	CB35aw	CB36w	CB38s	CB38w	CB38as	CB38aw	CB42s	CB42w	CB43w	CB44w	CB49s	CB49w	CB51s
PROTISTA																																							
LOBOSEA																																							
ARCELLINIDA																																							
Arcellidae																																							
Arcella sp.																																							
Centropyxidae																																							
Centropyxis sp.																				1																			
Difflugiidae																																							
Difflugia corona Wallich																																							
Diflugia aff. *gramen* Penard																				1																			
Difflugia sp. A																				1																			
Lesquereusidae																																							
Netzelia sp.																																							
NEMATODA																																							
Nematoda sp.				1			1															1													1				
ROTIFERA																																							
DIGONONTA																																							
Digononta sp.																																		1					
BDELLOIDEA																																							
Philodinidae																																							
Philodina sp.																																							
MONOGONONTA																																							
Conochilidae																																							
Conochilus dossuarius Hudson																		1																					
Conochilus hippocrepis (Schrank)																									1														
Conochilus natans (Seligo)																																							
Conochilus sp.																			1																				
Trochosphaeridae																																							
Horaella brehmi Donner																																							
Filiniidae																																							
Filinia australiensis Koste																				1																			
Filinia longiseta (Ehrenberg)																			1	1				1															
Filinia longiseta limnetica (Zacharias)					1																																		
Hexarthridae																																							
Hexarthra brandorffi Koste																															1								
Hexarthra fennica (Levander)												1		1								1										1							
Hexarthra mira (Hudson)	1		1			1	1											1	1				1		1				1	1									
Testudinellidae																																							
Testudinella patina (Hermann)				1	1		1																		1						1								
Flosclariidae																																							
Lacinularia sp.																									1														
Sinantherina procera (Thorpe)																				1																			
PLOIMIDA																																							
Brachionidae																																							
Brachionus angularis Gosse						1															1			1	1						1								
Brachionus bidentatus Anderson																																							
Brachionus calyciflorus Pallas																								1		1													
Brachionus dichotomus Shephard																										1	1												
Brachionus dimidiatus (Bryce)																																							
Brachionus falcatus Zacharias																									1														
Brachionus keikoa Koste																																							
Brachionus lyratus Shephard						1																																	
Brachionus nilsoni Ahlstrom			1												1																		1						
Brachionus aff. *novaezealandiae* (Morris)				1																																			
Brachionus aff. *pinneenaus* Koste & Shiel						1																																	
Brachionus plicatilis (Muller)												1				1																							
Brachionus quadridentatus Hermann	1		1		1																																2		

CB51w	CB54s	CB54w	CB54aw	CB56s	CB56w	CB56aw	CB58bw	CB58cw	CB58dw	CB58ew	CB62s	CB62w	CB62as	CB62aw	CB62bs	CB62cw	CB67as	CB67aw	CB67bs	CB67bw	CB68w	CB70bs	CB70bw	CB73s	CB73w	CB75as	CB75aw	CB75bs	CB75bw	CB75cw	CB76s	CB76w	CB77s	CB77w	CB78w	CB79s	CB79w	CB82s	CB82w	CB93s	CB93w	CB93as	CB93aw	CB93cs	CB93cw	CB93ds	CB93dw	CB93fs	CB93fw	CB93gw	Total
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Brachionus quadridentatus rhenanus (Lauterborn)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brachionus rubens Ehrenberg	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brachionus urceolaris (Mueller)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Keratella australis (Berzins)	.	.	1	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Keratella sp. nov. (aff. *australis* grp)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	1	.	.	1	.	.	.	.
Keratella procurva (Thorpe)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Keratella quadrata (Muller)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Keratella slacki (Berzins)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Keratella tropica (Apstein)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.
Keratella sp. A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plationus patulus (Muller)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Platyias quadricornis Ehrenberg	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
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Asplanchna brightwelli (Gosse)	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Asplanchna sieboldi (Leydig)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.
Asplanchna sp. nov. (aff. *sieboldi*)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
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Cephalodella gibba (Ehrenberg)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eosphora aff. *anthadis* Harring & Myers	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eosphora najas Ehrenberg	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Notomamta aff. *copeus* (Ehrenberg)	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Notomamta aff. *tripus* Ehrenberg	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Polyarthra dolichoptera Idelson	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.
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Trichocercidae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trichocerca pusilla Jennings	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Trichocerca similis grandis (Hauer)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
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Dicranophoridae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dicranophorus epicharis Harring & Myers	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
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Lecane thalera (Harring & Myers)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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GASTROPODA																																							
NEOTAENIOGLOSSA																																							
Truncattidae																																							
Truncatella aff. *guerinii* Villa & Villa	1		1							1	1	1																											
Bithyniidae																																							
Gabbia sp. A		1																																					
Gabbia sp. B																																							
Marginellidae																																							
Marginellidae sp.																																							
OPISTHOBRANCHIA																																							
Scaphandridae																																							
Acteocina sp.																																							
Diaphanidae																																							
?Diaphanidae sp.																																							
BASOMMATOPHORA																																							
Planorbidae																																							
?*Glytophysa* sp.						1																																	
Gyraulus sp.	1																																	1		1			
Isidorella newcombi (Adams & Angas)																																					1		
Isidorella sp. B					1																						1										1		1
?*Leichardtia* sp.																												1										1	
Lymnaeidae																																							
Austropeplea lessoni (Deshayes)																																		1		1			
ANNELIDA																																							
POLYCHAETA																																							
PHYLLODOCIDA																																							
Nereidae																																							
Nereidae sp.																																							
Polynoidae																																							
Polynoidae sp.																																							
CAPITELLIDA																																							
Capitellidae																																							
Capitellidae sp.																																							
ORBINIIDA																																							
Orbiniidae																																							
Orbiniidae sp.																																							
OLIGOCHAETA																																							
TUBIFICIDA																																							
Enchytraeidae																																							
Enchytraeidae sp.											1																												
Tubificidae																																							
Tubificidae sp.		1																																					
Naididae																																							
Allonais pectinata (Stepenson)																																							
Dero furcata (Muller)																																					1		
Dero nivea Aiyer																																							
Dero sp.																																					1		
Nais sp. CB1																																				1			
Nais sp.																																							
Pristinella jenkinae (Stephenson)																																							
Pristina longiseta Ehrenberg																										1													
Pristina sp.																																							
OPISTHOPORA																																							
Opisthopora sp.																																							
HIRUDINAE																																							
Hirudinae sp. H1																																							
ARTHROPODA																																							
ARACHNIDA																																							
HYDRACARINA																																							
Hydracarina sp.																							1																
Hydrachnidae																																							
Hydrachna approximata Halik																		1														1					1		
Hydrachna sp.																																							

CB51w	CB54s	CB54w	CB54aw	CB56s	CB56w	CB56aw	CB58bw	CB58cw	CB58dw	CB58ew	CB62s	CB62w	CB62as	CB62aw	CB62bs	CB62cw	CB67as	CB67aw	CB67bs	CB67bw	CB68w	CB70bs	CB70bw	CB73s	CB73w	CB75as	CB75aw	CB75bs	CB75bw	CB75cw	CB76s	CB76w	CB77s	CB77w	CB78w	CB79s	CB79w	CB82s	CB82w	CB93s	CB93w	CB93as	CB93aw	CB93cs	CB93cw	CB93ds	CB93dw	CB93fs	CB93fw	CB93gw	Total
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Sarsilatona aff. *papuana* (Daday)	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Alona rectangula novaezealandiae Sars	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Alona sp. nov. (aff. *A. diaphana vermiculata*)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Alona/Biapertura sp. A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Biapertura affinis s.l. (Leydig)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Biapertura aff. *longinqua* Smirnov	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Biapertura aff. *macrocopa* (Sars)	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	.	.	.	1	.	.	.	2	.	1	.	.	.
Biapertura rigidicaudis Smirnov	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.
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Celsinotum hypsilophum Frey	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chydorus eurynotus Sars	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	1	.	1	.	.	.
Dunhevedia crassa King	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ephemeroporus barroissi Richard	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Leydigia aff. *acanthocercoides* (Fischer)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Monospilus' diporus Smirnov & Timms	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Monospilus' aff. *diporus* Smirnov & Timms	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Monospilus' elongatus Smirnov & Timms	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Planicirclus alticarinatus Frey	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Macrothricidae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Macrothrix breviseta Smirnov	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Macrothrix aff. *hirsuticornis* Norman & Brady	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	1	.	.	.	.	1	.	.	.	.	.	1	.	.	.
Macrothrix aff. *spinosa* King	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Neothrix paucisetosa Smirnov	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Neothrix sp. nov. (aff. *superarmata*)	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.
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Moina aff. *australiensis* Sars	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	.	1	.	1	.	.	.	.	.	.	1	.	1	.	1
Moina aff. *flexuosa* Sars	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Moina micrura Kurz	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	1	.	.
Moina mongolica Daday	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Moina aff. *weismanni* Ishikawa	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Simocephalus victoriensis Smirnov & Timms	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Cyprideis australiensis Hartmann	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Limnocythere aff. *porphyretica* De Deckker	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
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Ampullacypris sp. nov. 469	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
?Ampullacypris sp. nov. 498	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Bennelongia australis (Brady)	1	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Candonocypris novaezelandiae (Baird)	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cypericercus salinus De Deckker	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	1	.	.	.	1	.	.
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Cypericercus sp. nov. 422	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Cyprinotus edwardi McKenzie	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Hemicypris megalops Sars sensu McKenzie	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Heterocypris sp. nov. 489	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Ilyodromus amplicolis De Deckker	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.

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Ilyodromus candonites De Deckker	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.
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Ilyodromus aff. *viridulus* (Brady)	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ilyodromus sp. nov. 255	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
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Mytilocypris sp. nov. 426	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
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Reticypris pinguis De Deckker	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Zonocypris sp. nov. 466	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Boeckella triarticulata (Thomson)	1	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	.	1	.	.	.	1	.	.	1	1	.	.	.	.	1	1	.
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Calamoecia ampulla (Carnarvon form) (Searle)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamoecia canberra Bayly	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.
Calamoecia clitellata Bayly	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamoecia sp. nov. (aff. *lucasi* Cue form)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Calamoecia tasmanica subattenuata (Fairbridge)	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Apocyclops dengizicus (Lepechkine)	.	.	.	.	.	.	.	.	1	.	.	1	.	1	1	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
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Ectocyclops rubrescens Brady	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Metacyclops arnaudi sensu Kiefer	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Neocyclops petovskii De Laurentiis *et al.*	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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	CB04s	CB04w	CB05s	CB05w	CB06aw	CB06bs	CB06bw	CB09s	CB09w	CB09aw	CB15s	CB15w	CB16s	CB16w	CB20s	CB20w	CB25w	CB27as	CB27bs	CB27bw	CB27cs	CB29aw	CB30s	CB30w	CB34s	CB34w	CB35aw	CB36w	CB38s	CB38w	CB38as	CB38aw	CB42s	CB42w	CB43w	CB44w	CB49s	CB49w	CB51s
Cletocamptus confluens (Schmeil)	.	.	.	.	.	.	.	1	.	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cletocamptus dietersi (Richard)	.	1	.	1	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Heterolaophonte oculata (Gurney)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Quinquelaophonte wellsi (Hamond)	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Agraptocorixa eurynome (Kirkaldy)	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Agraptocorixa hirtifrons (Hale)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
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Sigara mullaka Lansbury	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Lethocerus distinctifemur Menke	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Anisops calcaratus Hale	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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	CB04s	CB04w	CB05s	CB05w	CB06aw	CB06bs	CB06bw	CB09s	CB09w	CB09aw	CB15s	CB15w	CB16s	CB16w	CB20s	CB20w	CB25w	CB27as	CB27bs	CB27bw	CB27cs	CB29aw	CB30s	CB30w	CB34s	CB34w	CB35aw	CB36w	CB38s	CB38w	CB38as	CB38aw	CB42s	CB42w	CB43w	CB44w	CB49s	CB49w	CB51s
Anopheles sp.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.
Culex annulirostris Skuse		.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.		.	1	.	.	.
Culex australicus Dobrotworsky & Drummond	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.			.	.	.	.	.	.
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Chaoboridae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.
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Psychodidae sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Cricotopus sp. CBO9	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.
? *Limnophyes pullulus* (Skuse)	.	.	.		.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.		.	.	1		.	.			.	.	.	.	1	.
Nanocladius sp. CBO1	1		1	1	.	.	.		.	.	.	.		.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	1	1	.	1	.	.	.
Parakieffiella sp. CBO5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.		.	.
Parametriocnemus ? Ornaticornis Kieffer *sensu* Cranston	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.		.	.		.	.	.
?*Parametriocnemus* sp. CBO4			.	.	.	.		.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.		.	.	.	.	.
Rheocricotopus sp. CBO6	.	.	.	.	.	.		.		.				.	.	.	.	.	.	.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Orthocladiinae ?gen. ?sp. CBO2	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Orthocladiinae ?gen. ?sp. CBO8	.	.	.	.	.	.	.	.	.				.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ablabesmyia spp.^	1	.	.	.	1	1		.	.	.		.	.	.	.	.	.	1	.	1	.	.	1	.	1	.	.	.	.	.	1	1	1	1	.	1	.	.	.
Coelopynia pruinosa Freeman	.	.	1	.	.	.		.		.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1		1	1	.	1	.	.	.
Larsia ? albiceps (Johannsen)	1	1	.	1	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	1	1	1	.	.	.	.	1	.	1	.	.	.	.	.	.
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Paramerina sp. CBT7	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Procladius spp. CBT1!	1	1	1	1	1	1		.	.	.	.	.	.	.	1	1	.	1	.	1	.	.	.	.	1	1	1	.	.	.	1	1	1	1	.	1	1	.	.
Chironomus aff. *alternans* Walker	1	1	.	.	.			.	.	.	.	.	.	.	.	1	.	1	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chironomus tepperi Skuse	1	.	.		.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Cladopelma curtivalva Kieffer	.	.	.	1	.	1	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1		.	.	.	.	.	.	.	.	.	.	.	.
Cladotanytarsus sp. CBC27	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Cladotanytarsus sp. CBC2	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	1	.	.	.	.	.
Cryptochironomus griseidorsum Kieffer	.	.	.		1	1			.	.	.	.		.	.	.	.	.	1	1	.	.	1	.		.	.	.	.	.	.	1	.	.	1	1	1	.	.
Dicrotendipes sp. CBC13	.	.	.	1	1		.	.	.	.		.		.	.	1	.	.	.	.		.	1	.	1	.	.		.	.	.	1	1	.	.	1	1		.
Dicrotendipes jobetus Epler	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.		.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
? *Harnischia* sp. CBC21	.	.	.	.	.			.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	1	.	.	.	.
Kiefferulus intertinctus Skuse	.	.	.	.	.	.	.		.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	1	.	.	.	.	.
Paraborniella sp. CBC14	.	.	.		1	1	.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Parachironomus sp. CBC22	1	1	1			1	.	.	.	.	.	.	.	.	.	.	.		.	1	.	.	.	.	.		.	.	.	.	.	.	.	.	.	1	1	.	.
Paracladopelma sp. CBC15	.	.	.		1		.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1		.	.	.	.	.	.
Paratendipes sp. CBC24	.	.	.			.			.	.			.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.
Polypedilum watsoni Freeman	.	.	.	.	1		.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.
Polypedilum leei Freeman	.	.	.	1			.			.		.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	1		.	.
Polypedilum nubifer (Skuse)	1	.	.	.	1	.	.		.	.	.	.	.	.	1	1	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rheotanytarsus ? juliae Glover *sensu* Cranston		.	.		.	.	.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
? *Stictochironomus* sp. CBC26	.		.	.	.	.		.	.		.		.	.	.	.	.	.	.	.	.		.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tanytarsus barbitarsus Freeman	.	.	.	.	.	.	.	1	.	.	1	1	1	.	.	.	.	.	.	.	.		.	.	.			.	.	.	.	.				.	.	.	
Tanytarsus sp. CBC16	1			.	1	.	.	.		.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.		.
Tanytarsus sp. CBC3	.	1	.	.	.	1	.	.	.	.	.	.	.	.	1	1	.	1	1	1	.		1	1	1		.	.		.	1	1	1	1	.	1	.	.	.
Chironomini ?gen. ?sp. CBC9	.		.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Forcipomyinae sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.		.	.
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Palpomyinae sp.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1		.	1	.	.		.	.	.	.	.	.	.	1	.	.	.	.	.
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Ceratopogonidae sp. B	.	.	.	.		.	.		1	.	.		.	.	.	.	.	.	.			.		.	.	.	.	.	.	.	.	.	.	.	.	.	.		.
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Ceratopogonidae sp. E	.	.	.		.		.		.	.	.		.	.	.	1	.	.	.	.		.	.			.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ceratopogonidae sp.	1		.	.	.	1	.	1	.	.	.	.	1	.	1	.	.			.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	1
Stratiomydidae	.	.	.		.	.				.		.	.	.	.	.	.	.	.	.	.	.		.		.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Tabanidae			.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.
Tabanidae sp. A		.	.	.	.		.		.	.	.		.	.		.		.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

CB51w	CB54s	CB54w	CB54aw	CB56s	CB56w	CB56aw	CB58bw	CB58cw	CB58dw	CB58ew	CB62s	CB62w	CB62as	CB62aw	CB62bs	CB62cw	CB67as	CB67aw	CB67bs	CB67bw	CB68w	CB70bs	CB70bw	CB73s	CB73w	CB75as	CB75aw	CB75bs	CB75bw	CB75cw	CB76s	CB76w	CB77s	CB77w	CB78w	CB79s	CB79w	CB82s	CB82w	CB93s	CB93w	CB93as	CB93aw	CB93cs	CB93cw	CB93ds	CB93dw	CB93fs	CB93fw	CB93gw	Total
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Hydroglyphus leai (Guignot)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Hydrovatus opacus (Sharp)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hyphydrus elegans (Montrouzier)	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	1	.	.
Laccophilus sharpi Regimbart	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Necterosoma penicillatus (Clark)	.	.	.	.	.	.	.	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Platynectes decempunctatus (Fabricius)	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Rhantus suturalis W.S. MacLeay	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sternopriscus multimaculatus (Clark)	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	1	.	.	.	1	.	.	.	.	.	.	.	.
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	CB04s	CB04w	CB05s	CB05w	CB06aw	CB06bs	CB06bw	CB09s	CB09w	CB09aw	CB15s	CB15w	CB16s	CB16w	CB20s	CB20w	CB25w	CB27as	CB27bs	CB27bw	CB27cs	CB29aw	CB30s	CB30w	CB34s	CB34w	CB35aw	CB36w	CB38s	CB38w	CB38as	CB38aw	CB42s	CB42w	CB43w	CB44w	CB49s	CB49w	CB51s
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Berosus approximas Fairmaire	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Berosus dallasae Watts	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.
Berosus munitipennis Blackburn	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Berosus nutans (W. MacLeay)	1	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	1
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Enochrus deserticola (Blackburn)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Enochrus elongatus (W. MacLeay)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
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Hydrophilus brevispina Fairmaire	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Laccobius zietzi Blackburn	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Limnoxenus zealandicus (Broun)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paracymus pygmaeus (W. MacLeay)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paracymus spenceri (Blackburn)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.
Sternolophus immarginatus d'Orchymont	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Heterocerus delibipes (Blackburn)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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No of species	43	42	36	42	48	55	20	9	9	10	9	15	7	14	34	35	2	34	51	50	32	7	23	27	52	40	21	25	23	28	25	35	39	38	17	53	44	18	25

** *Dapnia projecta* and *D*. sp. nov. (aff. *pojecta*) were not separated

Bennelongia sp. nov. 414 consisted of a winter and a less common summer form

^ *Mesocyclops brooksi* (predominantly), *Mesocyclops australiensis* (Sars) and *Mesocyclops* sp. nov. were not separated

^ *Ablabesmyia* spp. consisted of *A. notabilis* Skuse and, sometimes, *A. hilli* Freeman

! *Procladius* spp. consisted of *P. paludicola* Skuse and, less frequently, a smaller species of *Procladius*

CB51w	CB54s	CB54w	CB54aw	CB56s	CB56w	CB56aw	CB58bw	CB58cw	CB58dw	CB58ew	CB62s	CB62w	CB62as	CB62aw	CB62bs	CB62cw	CB67as	CB67aw	CB67bs	CB67bw	CB68w	CB70bs	CB70bw	CB73s	CB73w	CB75as	CB75aw	CB75bs	CB75bw	CB75cw	CB76s	CB76w	CB77s	CB77w	CB78w	CB79s	CB79w	CB82s	CB82w	CB93s	CB93w	CB93as	CB93aw	CB93cs	CB93cw	CB93ds	CB93dw	CB93fs	CB93fw	CB93gw	Total
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