17. On the chemistry and biota of some saline lakes in Western Australia

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Introduction

Several limnological studies of Australian salt lakes have been made. Most relate to Victorian waters (reviewed by Williams 1978), but Bayly (1970) and De Deckker & Geddes (1980) have studied a number of (mostly) ephemeral salt lakes near the coast of south-eastern South Australia. Many similarities occur between lakes in these two regions, the only major differences being the presence of dense angiosperm beds (*Ruppia* and *Lepilaena*) and several invertebrates with marine affinities in some of the South Australian lakes.

The limnology of salt lakes in Western Australia is much less known, although there are much larger regions there within which salt lakes are present than in any other State. Indeed, there is an immense area near Kalgoorlie known as 'Salinaland' because of the abundance there of ephemeral saline lakes and dry salt pans (Jutson 1934; Gentilli 1979). Although limnological knowledge of Western Australian salt lakes is sparse, there is nevertheless enough to suggest both similarities to and differences from those in eastern Australia. Their chemical composition appears to be similar, as indicated by the work of Williams & Buckney (1976). These authors studied 24 standing waters in south-western Western Australia, all but two of which were saline (i.e. salinity >3‰). The pattern of ionic dominance recorded was remarkably constant and similar to that recorded for most salt lakes in eastern Australia. It was Na > Mg > Ca > K for the cations in all lakes, and Cl > HCO_3 > SO_4 in three lakes of moderate salinity (>12‰) and Cl > SO_4 > HCO_3 for the anions in the remainder. There are similarities in the fauna too; the cladoceran *Daphniopsis pusilla* and the halobiont copepods, *Calamoecia clitellata* and *C. salina*, are known to occur in both Western Australia and south-eastern Australia (Bayly & Edward 1969; Bayly 1979). But there also appear to be some faunal differences, principally the greater number of species in certain genera in Western Australia. Thus, six species of the halobiont anostracan *Parartemia* have been described from Western Australia, only two from eastern Australia (Linder 1941; Geddes, in press). A similar situation prevails for the gastropod *Coxiella*, for which Macpherson (1957) described several species from Western Australia; apparently just one occurs in mainland eastern Australia.

Most Western Australian species of *Parartemia* and *Coxiella* have been recorded from only one locality, and no ecological data on their habitats exist. It was to widen our knowledge of these (and other) halobionts in Western Australia that the present study was undertaken. A broader objective, of course, was to compare the fauna on both sides of the continent in the light of greater information. To these ends, this paper aims to list the biota of Western Australian salt lakes and discuss factors determining its occurrence.

Water bodies studied were those accessible from the highway between Kalgoorlie, Wiluna, Meekathara, Northam, Lake Grace, Esperance and Norseman, i.e. an area of some 800 by 500 km (Fig. 17.1). The study was undertaken in 1978 and in August, a month when water is most likely to occur in the many large, ephemeral basins in the area. Approximately 100 bodies of water were sampled. Fifty-four had salinities of 3‰ or more, and only

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these are considered in this paper. Their location is shown in Fig. 17.1 where they are numbered in order of increasing salinity. Most other localities were temporary roadside pools, small claypans of excavated dams. Only a few small creeks were seen, and these were mostly temporary; one of them (locality 11) was quite saline. Figure 17.2 illustrates a representative selection of the saline waters.

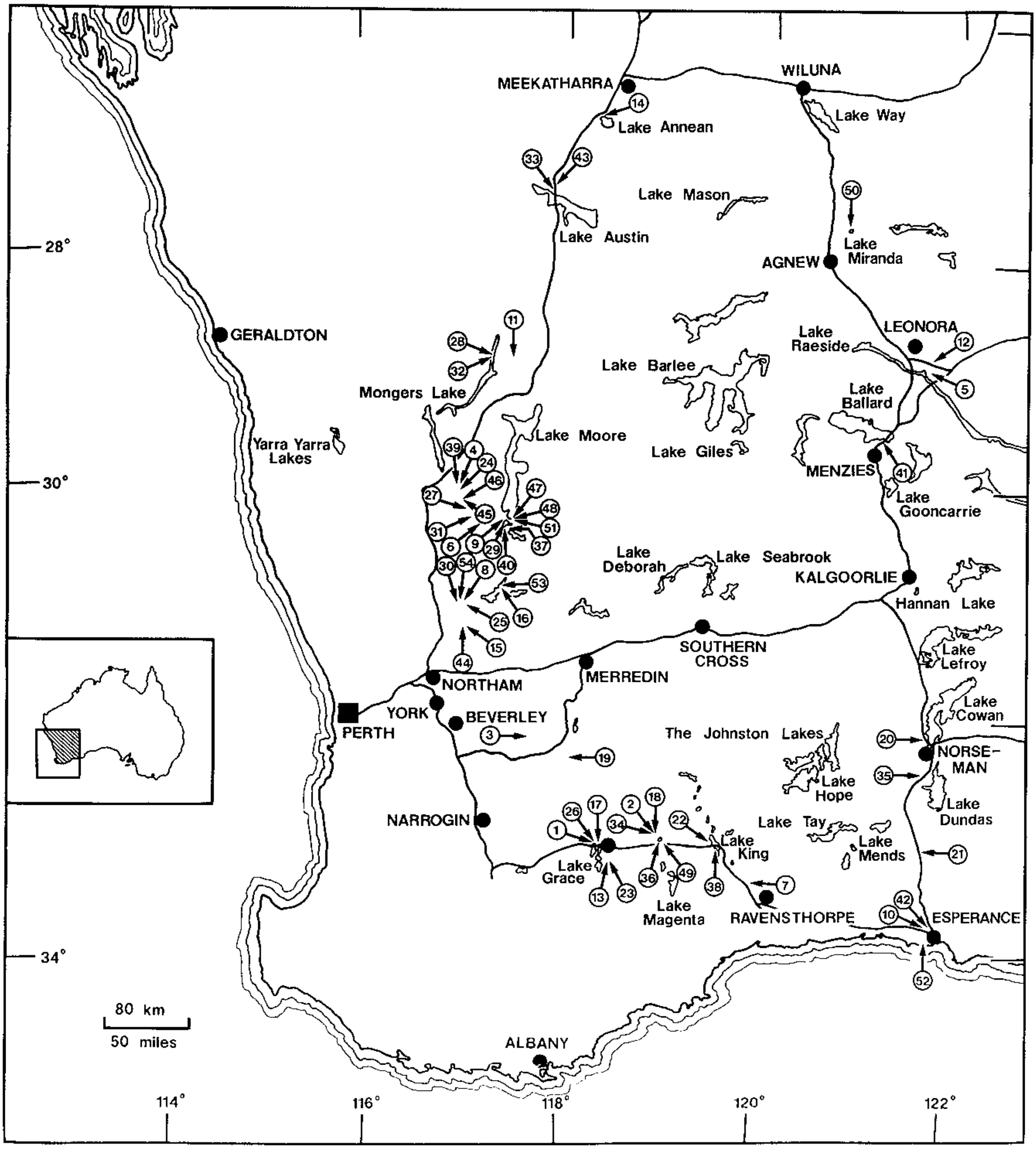


Fig. 17.1 Position of localities sampled. Localities are numbered 1 to 54 in order of increasing salinity. For further details see Appendix 17.1.

Appendix 17.1 lists all saline waters, indicates their precise position, and provides notes on approximate depth at time of sampling. Whether the locality was a playa or not is also indicated, and the localities are grouped into four geographical areas (I–IV) according to climate (see below).

Methods

At each locality a water sample was collected in a polyethylene bottle, pH was measured, and faunal collections were made with a hand net (400 μm mesh) and coarse and fine plankton nets (160 μm,

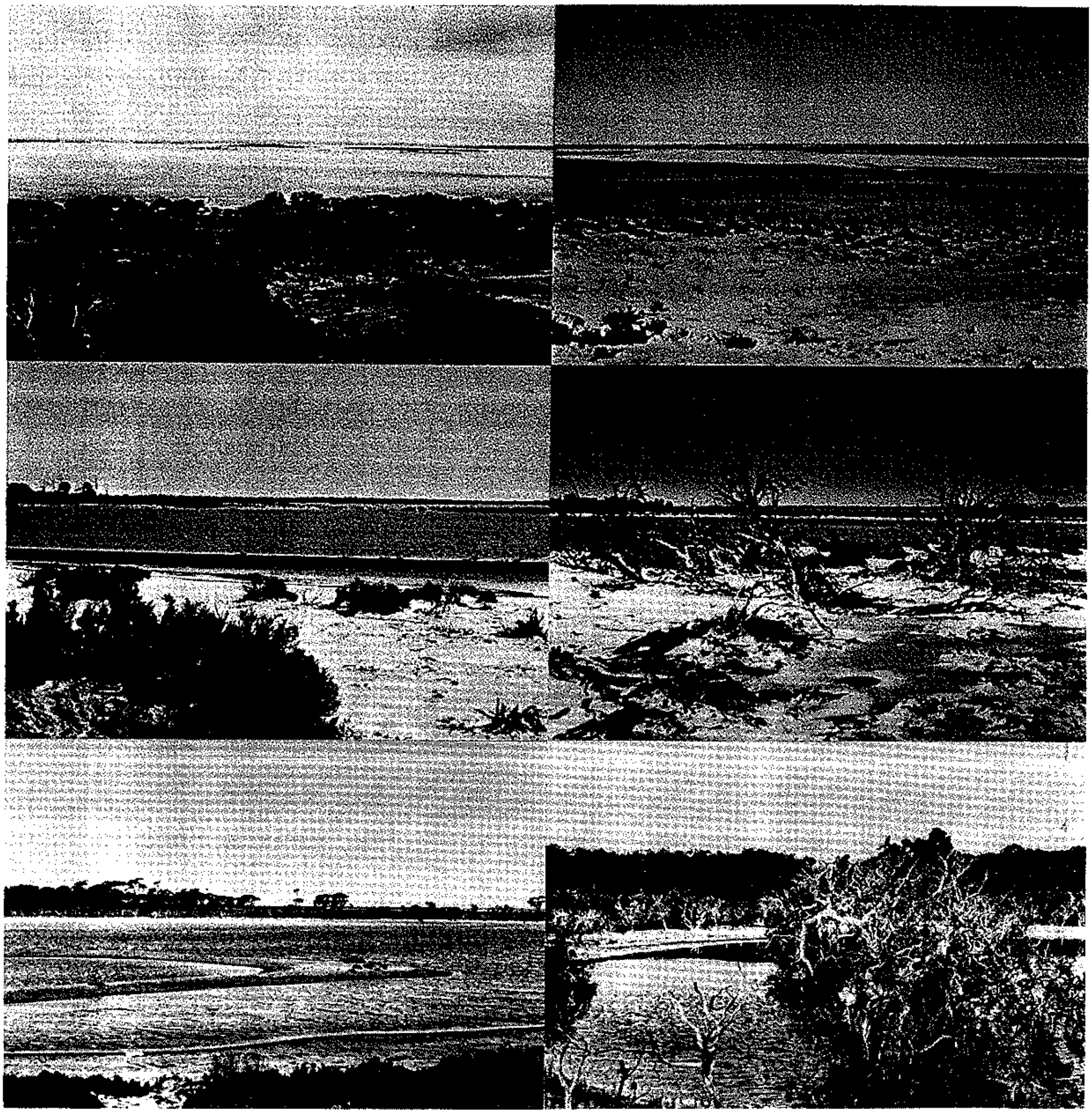


Fig. 17.2 Some representative localities. Top left, Lake Ballard (Loc. no. 41, area I); top right, Lake Austin (Loc. no. 43, area I); middle left, Lake de Courcey (Loc. no. 27, area II); middle right, remnant of Lake Moore (Loc. no. 51, area II); bottom left, lake near Lake Grace township (Loc. no. 23, area III); bottom right, Lake Warden (Loc. no. 42, area IV).

60 μm). Some sorting was done in the field and two samples were preserved, one in 70% ethyl alcohol, another in 4% formalin. The size and depth of localities, and the presence or absence of macrophytes were noted. At some localities macrophytes were collected.

Chemical analyses were completed (by MT) as soon as possible on return to the laboratory. Sodium and potassium were determined by flame photometry and calcium and magnesium by atomic absorption spectrophotometry. Chloride was determined by Mohr's method (APHA 1975), sulphate turbidimetrically (APHA 1975), and carbonate-bicarbonate alkalinity potentiometrically by titration to pH 4.5 with standard acid. Except for alkalinity, most ionic determinations were on samples diluted to concentrations within optimal analytical ranges. With few exceptions, analyses gave ionic balances within acceptable limits (±5% of total anionic concentration). Analyses were further checked by measuring conductivity, calculating total dissolved solids (T.D.S.) according to the equation of Williams (1966), and comparing that value to salinity expressed as the sum of the ions.

In the laboratory, faunal groups were separated and identified, the Anostraca by MCG, the Copepoda by DWM, the Ostracoda by PDD and some others by WDW. I. Lansbury (Hemiptera), B. D. Mitchell (Cladocera), R. Hamond (Harpacticoida) and M. Brock (aquatic macrophytes) gave taxonomic assistance. Several new species of crustaceans were encountered; they will be referred to in subsequent descriptions according to the designations given here.

Climatic and meteorological data were obtained from the Bureau of Meteorology, Perth, Western Australia, or from published rainfall statistics (Bureau of Meteorology 1977).

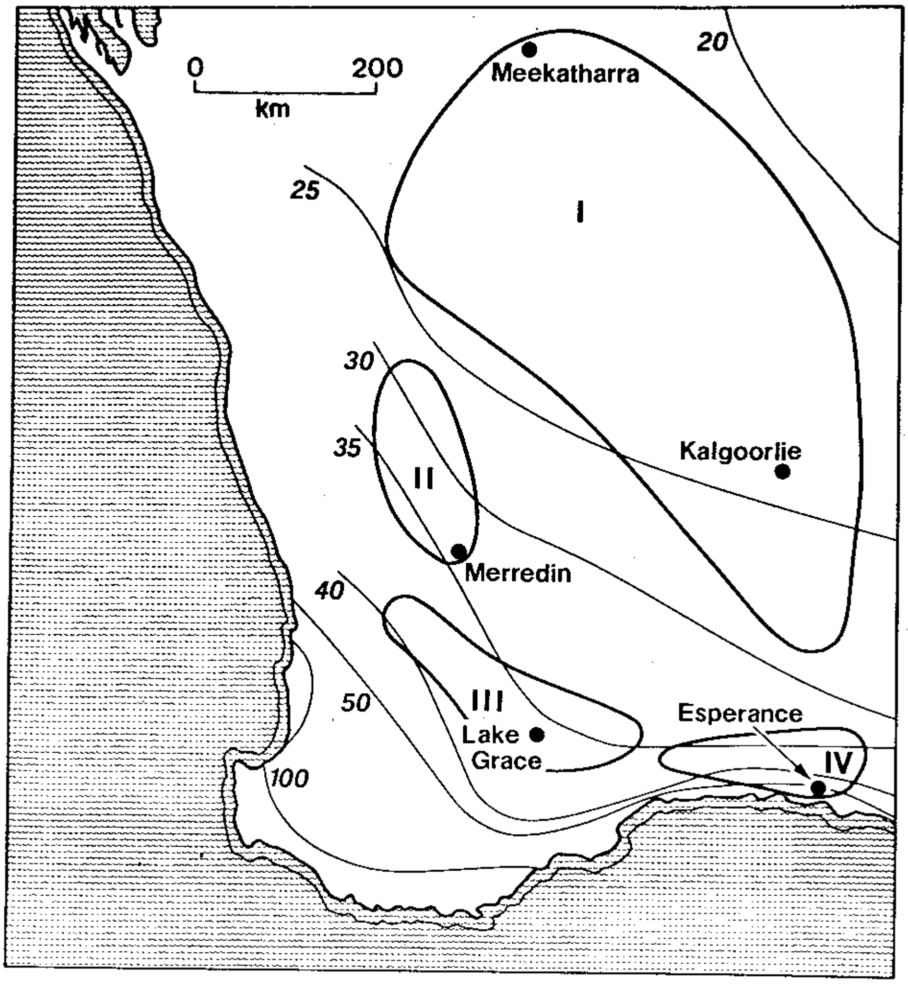


Fig. 17.3 Mean annual rainfall isohyets (cm) in survey area. Localities sampled fall within areas I to IV.

Results

Climatic features

Figure 17.3 shows mean annual rainfall isohyets in the area surveyed. Rainfall varies from 21 to 67 cm yr^{-1} in the area. Further climatic data are given in Figs. 17.4 and 17.5 which show mean monthly rainfall and monthly rainfall, monthly evaporation and monthly mean maximum and minimum temperatures for 1978, at four meteorological stations.

Figure 17.4 shows that as well as considerable variation in mean annual rainfall between stations there are differences in rainfall seasonality. At Meekatharra, rainfall is not strongly seasonal but peaks in March, while at the other three stations most rain generally falls in winter, viz. June, July and August. Evaporation is much greater at Meekatharra that at Merredin which in turn has much greater evaporation than Esperance. Temperatures generally fall from Meekatharra to Merredin to Lake Grace to Esperance with summer

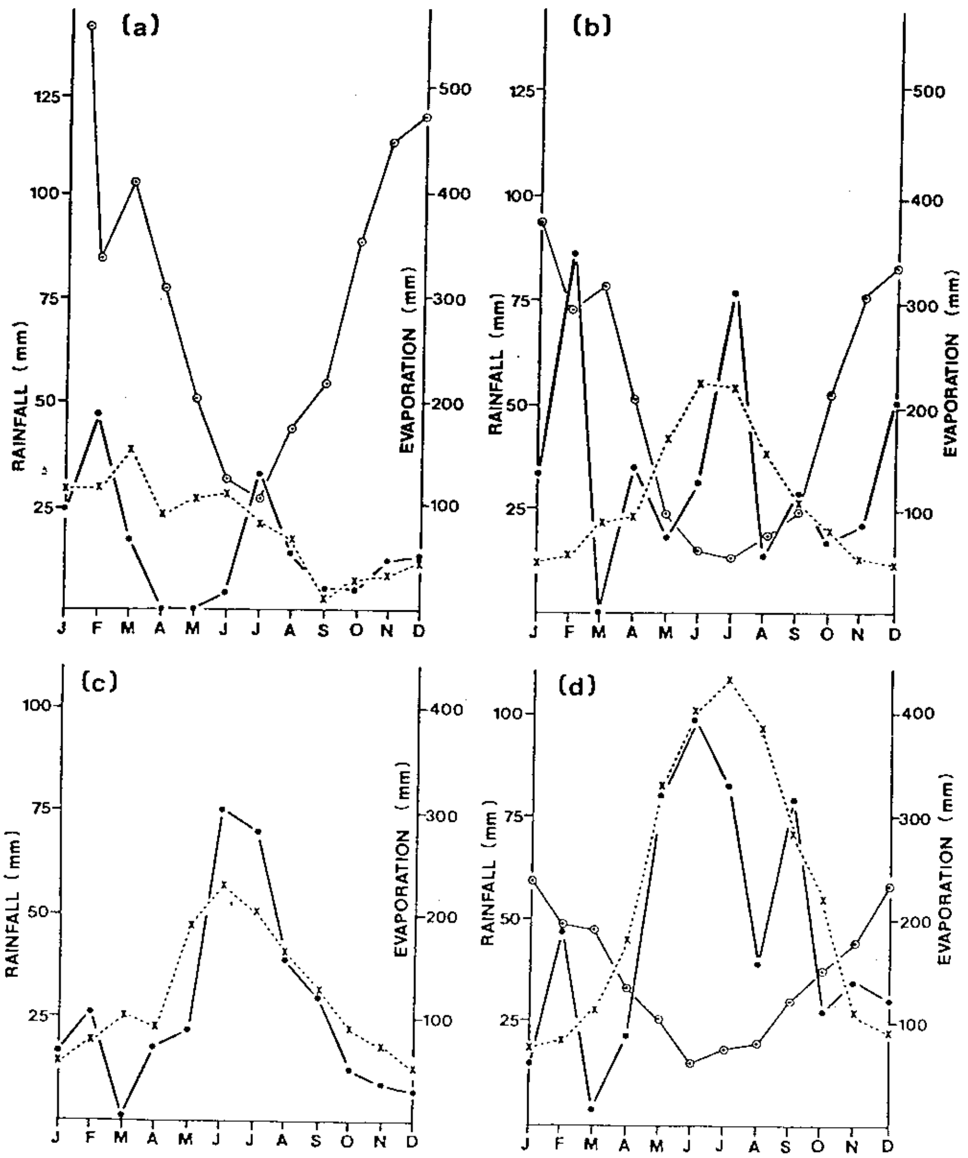


Fig. 17.4 Long term mean monthly rainfall (- - -), monthly rainfall for 1978 (—), and monthly evaporation for 1978 (—) for weather stations in (a) area I (Meekatharra), (b) area II (Merredin), (c) area III (Lake Grace) and (d) area IV (Esperance).

temperatures showing considerable differences (Fig. 17.5). Considering these climatic data and the position of the lakes sampled, the 54 localities can be grouped into four geographical areas (Fig. 17.3).

Area I – localities from Kalgoorlie to Meekatharra. Most are in an area where mean annual rainfall is less than 25 cm, most rain generally falling in the first half of the year. Summer temperatures are very high (monthly mean maxima to 39 °C), as is evaporation (370 cm yr^{-1}). Monthly evaporation always considerably exceeds precipitation so that lakes are probably short-lived.

Area II – localities north of Merredin. The majority of these localities receive a mean annual rainfall of 30–35 cm, with most rain arriving in the winter months although falls from summer-autumn storms may be significant. Summer temperatures are high (monthly mean maxima to 34 °C) as is evaporation (240 cm yr^{-1}). Monthly evaporation generally exceeds precipitation, but this may be reversed in June and July.

Area III – localities around Lake Grace. In this area mean annual rainfall is from 35 to 40 cm, and most rain falls in winter. Summer temperatures are moderately high (monthly mean maxima to 32 °C). It is presumed that evaporation is moderate although no data are available.

Area IV – localities around Esperance. In this area, mean annual rainfall is greater than 40 cm, is strongly seasonal, and falls in winter. The area is coastal, and summer temperatures are modeate (monthly mean maxima to 27 °C). Evaporation is also moderate (170 cm yr^{-1}), and precipitation often exceeds evaporation in May, June, July and August so that ephemeral lakes in this area would be relatively long-lived.

In 1978, annual rainfall was close to average in all four areas (Fig. 17.4). At Meekatharra and Merredin, heavy falls were recorded in February and July. Water presumably entered localities in areas I and II in July. At Lake Grace and Esperance, winter rains began in May and heavy falls were recorded in June and July. Water presumably entered localities in areas III and IV in May-June.

Chemical features

For each water body, Table 17.1 gives the ionic

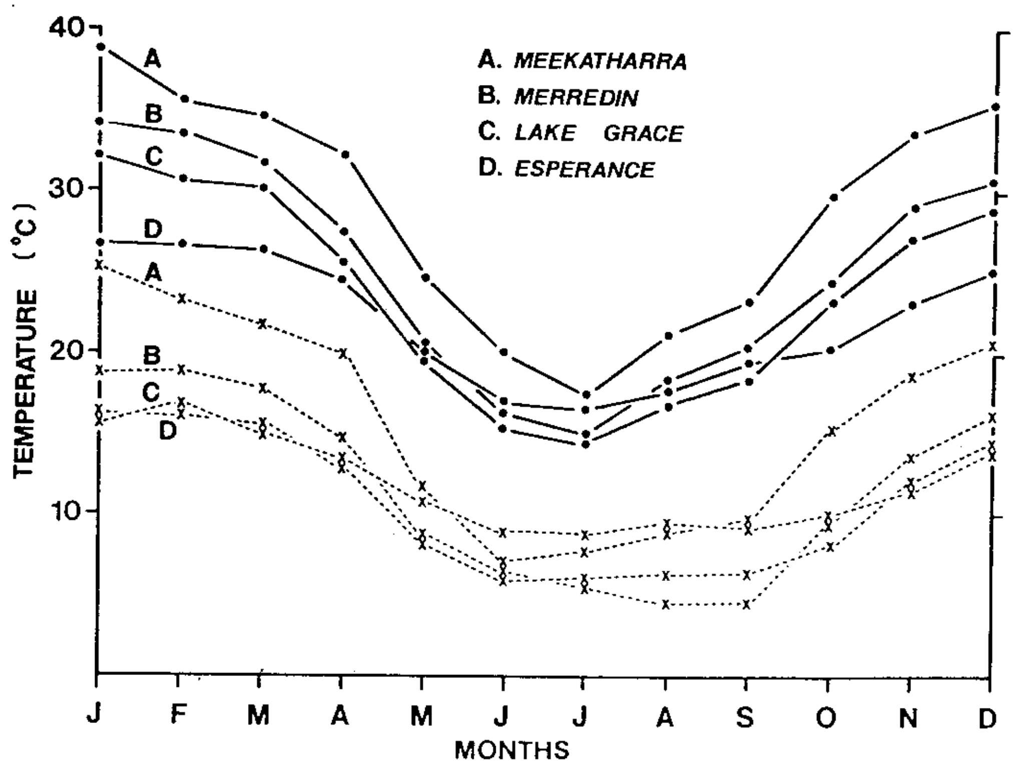


Fig. 17.5 Mean monthly maximum (—) and minimum (. . . . .) temperatures at Meekatharra, Merredin, Lake Grace and Esperance in 1978.

Table 17.1 Chemical features of some Western Australian salt waters. For geographical location see Fig. 17.1, and for further details Appendix 17.1

Index No.	Field pH	Salinity[a] (‰)	T.D.S.[b] (‰)	Value[c]	Na	K	Ca	Mg	Cl	SO_4	HCO_3
1	8.5	2.98	3.65	A	.931	.034	.025	.076	1.58	.185	.148
				B	82.9	1.8	2.5	12.8	87.6	7.6	4.8
2	8.2	3.57	4.16	A	1.10	.032	.046	.111	2.00	.183	.098
				B	79.6	1.4	3.8	15.2	91.1	6.3	2.6
3	8.2	4.42	4.69	A	1.37	.017	.085	.146	2.33	.344	.129
				B	78.1	0.6	5.5	15.7	87.7	9.5	2.8
4	8.6	4.82	3.73	A	.860	.050	.549	.159	1.57	1.57	.065
				B	47.2	1.6	34.6	16.5	56.7	41.9	1.4
5	8.9	6.69	5.28	A	1.42	.070	.507	.094	2.82	1.73	.038
				B	63.9	1.9	26.2	8.0	61.5	37.8	0.7
6	9.2	8.45	9.64	A	2.74	.070	.095	.273	4.64	.600	.032
				B	80.4	1.2	3.2	15.2	90.9	8.7	0.4
7	10.1	9.01	10.1	A	2.74	.074	.212	.160	4.86	.860	.106
				B	83.4	1.2	6.9	8.5	88.9	10.0	1.1
8	8.1	9.50	10.3	A	2.85	.060	.186	.307	5.21	.701	.179
				B	77.4	1.0	5.8	15.8	89.3	8.9	1.8
9	7.9	11.2	12.4	A	3.31	.160	.087	.338	6.06	1.23	.013
				B	79.9	2.3	2.4	15.4	86.2	13.7	1.1
10	9.5	14.6	16.1	A	4.92	.145	.108	.306	8.12	.802	.198
				B	86.2	1.5	2.2	10.1	92.0	6.7	1.3
11	8.6	15.9	16.8	A	4.76	.291	.216	.604	8.15	1.60	.279
				B	75.3	2.7	3.9	18.1	85.9	12.4	1.7
12	8.8	17.0	16.7	A	5.10	.215	.469	.349	8.01	2.85	.043
				B	79.3	2.0	8.4	10.3	79.0	20.7	0.3
13	9.4	20.0	22.4	A	7.10	.146	.075	.495	11.5	.472	.196
				B	86.5	1.0	1.0	11.5	95.2	3.9	0.9
14	8.8	21.3	20.9	A	6.28	.305	.417	.479	9.64	4.06	.072
				B	80.0	2.3	6.1	11.6	76.0	23.6	0.4
15	8.5	27.4	29.0	A	8.55	.307	1.02	.447	14.1	2.92	.073
				B	79.5	1.7	10.9	7.9	86.5	13.2	0.3
16	8.8	29.9	32.8	A	9.75	.228	.281	1.02	17.0	1.52	.143
				B	80.3	1.1	2.7	15.9	93.3	6.2	0.5
17	8.8	30.6	26.7	A	10.7	.140	.054	.718	17.7	1.08	.174
				B	87.7	0.7	0.5	11.1	95.2	4.3	0.5
18	9.5	32.5	38.6	A	10.8	.246	1.62	1.02	19.1	4.04	.048
				B	73.2	1.0	12.6	13.2	86.4	13.5	0.1
19	8.0	33.3	36.3	A	9.98	.140	.505	1.40	18.4	2.82	.067
				B	75.1	0.6	4.4	19.9	89.7	10.1	0.2
20	-	34.4	37.7	A	10.6	.096	.800	1.15	19.1	2.56	.061
				B	77.1	0.4	6.7	15.8	90.8	9.0	0.2
21	8.0	46.2	49.0	A	14.4	.307	.745	1.62	25.2	3.80	.181
				B	77.8	1.0	4.6	16.6	89.6	10.0	0.4
22	8.0	48.5	52.9	A	16.5	.465	.709	.665	27.1	2.94	.132
				B	87.5	1.5	4.3	6.7	92.3	7.4	0.3
23	8.8	48.5	54.4	A	17.4	.232	.109	1.06	28.2	1.16	.236
				B	88.5	0.7	0.6	10.2	96.6	2.9	0.5
24	8.9	52.4	57.1	A	16.2	.579	1.30	1.30	28.9	4.12	.039
				B	79.0	1.7	7.3	12.0	90.4	9.5	0.1
25	7.9	55.5	61.2	A	16.9	.438	.958	1.85	30.5	4.70	.158
				B	77.6	1.2	5.1	16.1	89.5	10.2	0.3
26	8.8	59.5	68.4	A	20.3	.229	.411	1.42	34.4	2.68	.084
				B	86.0	0.6	2.0	11.4	94.4	5.4	0.2
27	8.3	61.7	67.4	A	19.8	.457	.745	2.09	34.4	4.16	.047
				B	79.6	1.1	3.4	15.9	91.7	8.2	0.1

Table 17.1 (Cont.)

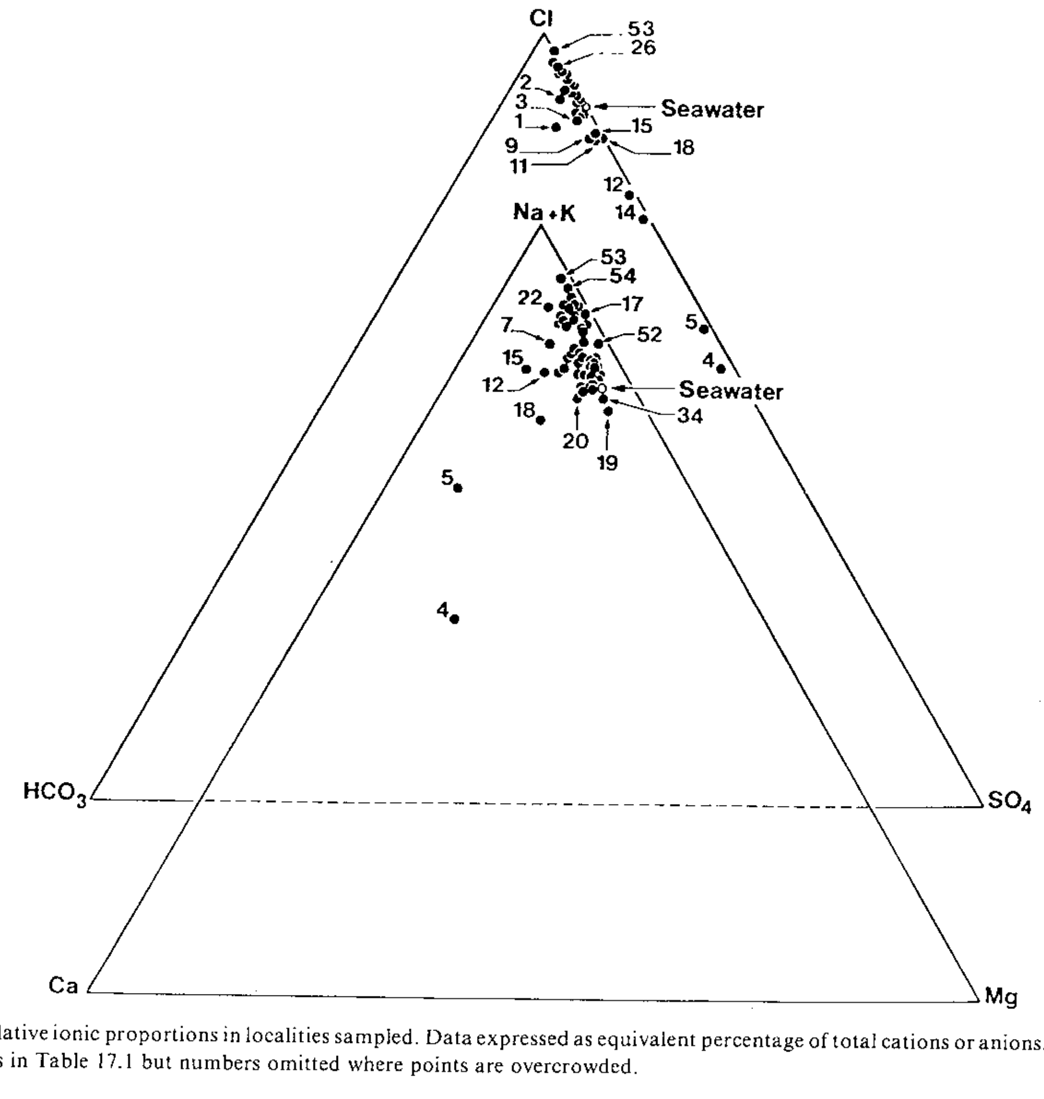
Index No.	Field pH	Salinity[a] (‰)	T.D.S.[b] (‰)	Value[c]	Na	K	Ca	Mg	Cl	SO_4	HCO_3
28	8.9	61.9	69.0	A	19.6	.594	.735	2.03	34.3	4.58	.085
				B	79.7	1.2	3.4	15.7	90.9	9.0	0.1
29	8.9	62.3	68.5	A	19.6	.551	1.38	1.53	34.2	5.04	.048
				B	80.3	1.3	6.5	11.9	90.1	9.8	0.1
30	8.0	64.4	71.1	A	20.0	.500	.982	2.15	35.2	5.52	.085
				B	78.4	1.2	4.4	16.0	89.5	10.4	0.1
31	8.4	70.3	78.3	A	22.1	.727	1.30	2.03	39.0	5.09	.090
				B	79.3	1.5	5.4	13.8	91.1	8.8	0.1
32	8.3	74.1	81.7	A	23.9	.641	.493	2.33	41.5	5.14	.096
				B	81.7	1.3	1.9	15.1	91.5	8.4	0.1
33	8.2	80.6	93.8	A	28.0	.430	.309	1.60	43.6	6.48	.079
				B	88.5	0.8	1.1	9.6	90.0	9.9	0.1
34	8.6	87.9	100	A	27.4	.516	1.15	3.50	49.3	6.00	.094
				B	76.8	0.9	3.7	18.6	91.7	8.2	0.1
35	6.3	88.5	105	A	30.6	.446	.641	1.62	52.1	3.10	.006
				B	88.3	0.8	2.1	8.8	95.9	4.1	0.0
36	7.8	91.4	107	A	31.0	.343	1.46	1.60	51.1	5.81	.100
				B	86.3	0.6	4.7	8.4	92.2	7.7	0.1
37	8.7	95.1	106	A	30.6	.903	1.41	2.78	52.5	6.87	.059
				B	80.5	1.4	4.3	13.8	91.1	8.8	0.1
38	7.5	99.6	113	A	32.4	.684	1.60	2.49	55.3	7.01	.076
				B	82.3	1.0	4.7	12.0	91.3	8.6	0.1
39	8.0	101.2	119	A	31.3	1.11	1.54	3.24	57.1	6.94	.034
				B	78.5	1.6	4.4	15.5	91.7	8.3	0.0
40	4.1	106.6	122	A	35.6	.872	1.30	2.66	59.2	6.92	0
				B	83.5	1.2	3.5	11.8	92.1	7.9	0.0
41	7.9	122.2	123	A	37.0	.880	1.36	2.83	64.5	5.62	.064
				B	83.1	1.2	3.5	12.1	93.9	6.0	0.1
42	7.6	120.2	139	A	41.4	.571	.667	2.13	69.5	5.76	.201
				B	89.0	0.7	1.6	8.7	93.3	6.6	0.1
43	7.8	112.0	138	A	39.5	1.00	1.43	3.38	68.4	8.26	.052
				B	82.1	1.2	3.4	13.3	91.8	8.2	0.0
44	8.4	122.6	142	A	41.6	.778	1.36	2.05	70.6	6.05	.127
				B	87.7	1.0	3.3	8.2	94.0	5.9	0.1
45	8.6	123.1	137	A	41.4	1.28	1.50	2.25	69.5	7.20	.067
				B	86.0	1.6	3.6	8.8	92.8	7.1	0.1
46	8.6	126.3	138	A	41.4	.829	.758	2.49	73.4	7.40	.070
				B	87.2	1.0	1.8	10.0	92.9	7.0	0.1
47	7.8	129.9	140	A	40.7	1.11	1.23	4.00	74.8	8.02	.041
				B	80.9	1.3	2.8	15.0	92.7	7.3	0.0
48	7.9	137.6	148	A	41.2	1.29	1.55	4.27	77.6	7.97	.076
				B	79.5	1.5	3.4	15.6	92.9	7.0	0.1
49	7.9	151.8	176	A	50.8	.555	1.74	3.04	88.3	7.35	.074
				B	86.2	0.6	3.4	9.8	94.2	5.8	0.0
50	–	153.9	138	A	49.9	2.28	.898	3.50	84.7	12.6	.071
				B	84.7	2.3	1.7	11.3	90.1	9.9	0.0
51	7.1	186.2	223	A	65.3	.805	1.14	3.08	108.0	8.07	.025
				B	89.6	0.6	1.8	8.0	94.8	5.2	0.0
52	7.6	192.6	221	A	63.2	1.03	.419	5.81	112.0	9.75	.319
				B	84.0	0.8	0.6	14.6	93.8	6.0	0.2
53	7.9	246.9	286	A	90.1	.704	1.32	2.94	146.1	5.72	.034
				B	92.3	0.4	1.6	5.7	97.2	2.8	0.0
54	3.0	262.5	305	A	93.6	.653	.768	3.80	157.0	6.72	0
				B	91.6	0.4	0.9	7.1	96.9	3.1	0.0

[a] Derived by addition of major ions.
[b] Derived by determination of conductivity.
[c] A, values as ‰; B, values as milliequivalent percentages.

composition, field pH value, and derived concentrations for salinity and T.D.S.

Salinities ranged from 2.98 to 262.5‰. Localities of salinity up to 154‰ are well-represented, but there were only four lakes with salinities greater than that value. Each of the four areas had localities which spanned a wide salinity range. T.D.S. values calculated from conductivity show good correlation with salinity. Bayly & Williams (1966) found that T.D.S. estimated from conductivity was about 1.1 times salinity determined as the sum of major ions. The few exceptions to that relationship, localities 4, 5, 12 and 32, generally have unusual ionic proportions as discussed below. Field pH was usually between 8 and 9, although some higher values were recorded (pH 9.4 at locality 13, 9.5 at 10 and 18, and 10.1 at locality 7). Localities 40 and 54 were remarkably acidic having pH values of 4.1 and 3.0 respectively.

The ionic proportions of the waters in all four groups were fairly similar (Fig. 17.6). For cations, dominance was Na > Mg > Ca > K in nearly all localities. Sodium values generally varied from 75 to 90% of cation equivalence. At high salinity (>100‰), Na equivalence was generally >85%, but high values were also present in even the least saline localities (82.9% in locality 1). Potassium was always the minor cation, varying from 0.4 to 2.7% equivalence. Magnesium was generally sub-dominant, varying from 6.7 to 18.6% equivalence. The



'ig. 17.6 Relative ionic proportions in localities sampled. Data expressed as equivalent percentage of total cations or anions. Localities umbered as in Table 17.1 but numbers omitted where points are overcrowded.

Table 17.2 Occurrence of biota in individual localities.
+: present and active; (+): present but inactive.

			ANOSTRACA										CLADOCERA			COPEPODA									
Locality index no.	Salinity (‰)	Area	*Branchinella affinis*	*B. simplex*	*Parartemia extracta*	*P. cylindrifera*	*P. serventyi*	*P. contracta*	*P. informis*	*P. longicaudata*	*P.* sp.nov. 1	*P.* sp.nov. 2	*Daphnia carinata*	*Moina* sp.	*Daphniopsis pusilla*	*Boeckella triarticulata*	*Calamoecia clitellata*	*C. salina*	*Microcyclops dengizicus*	*M. arnaudi*	*M. platypus*	*M.* sp.nov. 1	*M.* sp.nov. 2	*Mesochra* sp.nov.	*Attheyella* sp.
1	2.98	III				+									+				+						
2	3.57	III											+	+		+			+						
3	4.42	III											+	+		+				+		+			
4	4.76	II	+										+		+				+						
5	6.69	I																	+			+			
6	8.45	II													+				+						
7	9.01	IV													+										
8	9.50	II													+										
9	11.2	II													+										
10	14.6	IV													+		+								
11	15.9	I																	+						+
12	17.0	I																							
13	20.0	III				+									+		+						+	+	
14	21.3	I		+											+						+				
15	27.4	II			+																		+		
16	29.9	II							+												+				
17	30.6	III													+								+		
18	32.5	III													+								+	+	
19	33.3	III													+		+						+		
20	34.4	I					+																		
21	46.2	IV													+						+				
22	48.5	III													+			+							
23	48.5	III															+						+		
24	52.4	II																			+		+		
25	55.5	II																					+		
26	59.5	III								+								+							
27	61.7	II									+												+		
28	61.9	I																	+						
29	62.3	II									+														
30	64.4	II							+														+		
31	70.3	II									+														
32	74.1	I							+														+		
33	80.6	I							+												+				
34	87.9	III								+													+		
35	88.5	I										+													
36	91.4	III								+													+		

Table 17.2 (cont.)

OSTRACODA																						OTHER BIOTA							
Eucypris virens	*'Chlamydotheca' sp.*	*Cyprinotus edwardi*	*Heterocypris sp.*	*Sarscypridopsis aculeata*	*Australocypris robusta*	*A. insularis*	*A. sp.nov.*	*A. sp. (juveniles)*	*Mytilocypris minuta*	*M. mytiloides*	*M. sp. (juveniles)*	Mytilocypridini gen.nov.	*Platycypris baueri*	*Diacypris fodiens*	*D. whitei*	*D. compacta*	*D. sp.nov. 1*	*D. sp.nov. 2*	*Reticypris sp.nov. 1*	*R. sp.nov. 2*	*R. sp. (juveniles)*	*Eulimnadia sp.*	*Austrochiltonia subtenuis*	Insecta[a]	*Coxiella sp. or spp.*	Nematoda	*Ruppia sp.*[b]	*Lepilaena sp.*	Species richness[c]
				+		+							+			+								3					10
	+	+		+																				2					9
+	+		+	+																		+		2					12
	+	+	+															+				+		1			+		11
																													2
						+			+							+					+			2			+		8
		+		+						+			+			+							+	4					11
				+				+							+									2			+		8
			+	+																				1					4
						+	+						+						+					1	+		+		9
									+								+							6			+		11
																								1		+			2
						+							+		+	+												+	10
			+									+								+							+		7
						+									+												+		5
																			+										3
						+					+		+			+								1	+				8
						+							+		+	+								1			+	+	10
		+		+		+					+		+		+									3	+				13
						+									+														3
						+							+	+		+			+					2					9
						+							+		+	+					+								7
						+							+			+													5
															+														3
						+																		2	+				5
													+		+				+						+				6
					+										+												+		5
																													1
																								1					2
																								1					3
						+									+									1			+		5
							+								+												s		4
															+												s		3
						+							+			+													5
															+														2
								+							+										(+)				4

Table 17.2 (Cont.)

Locality index no.	Salinity (‰)	Area	ANOSTRACA *Branchinella affinis*	*B. simplex*	*Parartemia extracta*	*P. cylindrifera*	*P. serventyi*	*P. contracta*	*P. informis*	*P. longicaudata*	*P.* sp.nov. 1	*P.* sp.nov. 2	CLADOCERA *Daphnia carinata*	*Moina* sp.	*Daphniopsis pusilla*	COPEPODA *Boeckella triarticulata*	*Calamoecia clitellata*	*C. salina*	*Microcyclops dengizicus*	*M. arnaudi*	*M. platypus*	*M.* sp.nov. 1	*M.* sp.nov. 2	*Mesochra* sp.nov.	*Attheyella* sp.
37	95.1	II							+																
38	99.6	III								+													+		
39	101.2	II																					+		
40	106.6	II						+																	
41	112.2	I							+																
42	120.2	IV								+															
43	122.0	I																							
44	122.6	II																					+		
45	123.1	II																							
46	126.3	II																							
47	129.9	II																					+		
48	137.6	II									+														
49	151.8	III								+													+		
50	153.9	I																							
51	186.2	II							+																
52	192.6	IV								+															
53	245.9	II																							
54	262.5	II																							

[a] Numbers indicate number of different insect groups present.
[b] s = seeds only.
[c] Excluding seeds or inactive forms.

proportion of Mg was not related to salinity or proximity to the sea. Calcium was the most variable cationic component. In most lakes it varied from 0.5 to 6.9% equivalence, but in five lakes of low to moderate salinity (area I localities 5 and 12; area II locality 15; area III localities 4 and 18) levels were considerably higher and Ca often displaced Mg in ionic dominance. Among anions, dominance was always $Cl > SO_4 > HCO_3$. Chloride generally accounted for 87–97% of the anion equivalence and its dominance clearly increased with increasing salinity. The five localities mentioned above as having high Ca levels, plus locality 14 in area I, had high SO_4 levels – as high as 42% equivalence in the case of locality 4. These lakes presumably derived their unusual (for Australia) ionic proportions from local geological sources.

Biological features

The biota collected is listed in Table 17.2. Crustaceans were by far the dominant group, and were represented by twenty-one species of ostracods, ten of anostracans, ten of copepods, three of cladocer-

Table 17.2 (cont.)

Locality index no.	OSTRACODA																						OTHER BIOTA							
	Eucypris virens	*'Chlamydotheca'* sp.	*Cyprinotus edwardi*	*Heterocypris* sp.	*Sarscypridopsis aculeata*	*Australocypris robusta*	*A. insularis*	*A.* sp.nov.	*A.* sp. (juveniles)	*Mytilocypris minuta*	*M. mytiloides*	*M.* sp. (juveniles)	Mytilocypridini gen.nov.	*Platycypris baueri*	*Diacypris fodiens*	*D. whitei*	*D. compacta*	*D.* sp.nov. 1	*D.* sp.nov. 2	*Reticypris* sp.nov. 1	*R.* sp.nov. 2	*R.* sp. (juveniles)	*Eulimnadia* sp.	*Austrochiltonia subtenuis*	Insecta[a]	*Coxiella* sp. or spp.	Nematoda	*Ruppia* sp.[b]	*Lepilaena* sp.	Species richness[c]
37																+														2
38						+									+															4
39																+	+													3
40																														1
41																+														2
42																										(+)				1
43																														0
44							+																					s		2
45																														0
46																+														1
47																+														2
48									+							+										(+)				3
49																														2
50																										(+)				0
51																														1
52																														1
53																										(+)				0
54																														0

ans and one species of the Conchostraca and Amphipoda. The halobiont gastropod, *Coxiella*, was collected from ten localities and the aquatic macrophytes *Ruppia* and *Lepilaena* from fifteen. Nineteen of the less saline localities contained nsects. Nematodes were noted in one locality. The number of species per locality (species richness) was related to salinity although there was considerable variation between localities (Table 17.2). Considering only the dominant faunal group, the Crustacea, at salinities below 50‰ there were often six or more species, at salinities from 50 to 100‰ there were from one to five species, while at salinities above 100‰ there were three or fewer. Except in the most saline localities, where *Parartemia* occurred alone, usually more than half the species were ostracods.

From present and published data, several crustacean species can be regarded as freshwater forms with some tolerance to salinity, but most species collected are to be regarded as halobionts, viz., species found only in salt lakes. Table 17.3 provides a consolidated list of the crustacean fauna collected, and indicates the nature of its ecological affinities and endemicity.

Table 17.3 Ecological affinities and extent of western endemicity of crustacean fauna collected.

Ecological affinities with freshwater fauna	
Branchinella affinis	*Eucypris virens*
Daphnia carinata	*'Chlamydotheca'* sp.
Moina sp.	*Cyprinotus edwardi*
Boeckella triarticulata	*Eulimnadia* sp.
Microcyclops arnaudi	*Austrochiltonia subtenuis*
Of uncertain ecological affinity with freshwater fauna	
*Branchinella simplex**	*Heterocypris* sp.
Microcyclops sp. nov. 1	*Sarscypridopsis aculeata*
Ecological affinities with fauna of inland saline waters	
*Parartemia extracta**	*Mytilocypris minuta*
P. cylindrifera	*M. mytiloides*
*P. serventyi**	*Australocypris robusta*
*P. contracta**	*A. insularis*
*P. informis**	*A.* sp. nov.*
*P. longicaudata**	Mytilocypridini gen. nov.*
P. sp. nov. 1*	*Platycypris baueri*
P. sp. nov. 2*	*Diacypris fodiens*
Daphniopsis pusilla	*D. whitei*
Calamoecia clitellata	*D. compacta*
C. salina	*D.* sp. nov. 1
Microcyclops dengizicus	*D.* sp. nov. 2*
M. platypus	*Reticypris* sp. nov. 1
M. sp. nov. 2	*R.* sp. nov. 2*
Mesochra sp. nov.*	
Atthyella sp.	

* Possible endemics to Western Australia.

There was no relationship between basin size and fauna. Large playas had faunas similar to those of small lakes of similar salinity. Rather surprisingly, the depth and ephemerality of the localities also seemed not to affect the fauna. Lake Biddy (locality 2) was several metres deep and had not been dry for many years, yet the fauna was similar to that of locality 3, an ephemeral roadside pool. One locality where physical characteristics of the habitat did affect the fauna was locality 11, a semi-permanent saline stream; this was the only locality for *Diacypris* sp.nov. 1 and *Atthyella* sp., and one of only two localities at which *Mytilocypris minuta* was collected. Many insects also were collected from this stream. Generally, minor variations in ionic dominance seemed not to affect the distribution of the fauna. However, at locality 40, which had a very low pH (4.1), *Parartemia contracta* alone was collected. This locality was the only locality at which this species was collected.

The major factors affecting distribution appear to be salinity and geographic position. Table 17.4 shows the distribution of the major groups of halophiles and halobionts among the four areas shown in Fig. 17.3 and gives the salinity range for each taxon. Several species are distributed over all

Table 17.4 Distribution of major groups of halophiles and halobionts according to geographical area and salinity.

Taxon	Area				Salinity range (‰)
	I	II	III	IV	
Anostraca					
Parartemia informis	+	+			30–186
P. longicaudata			+	+	56–193
P. sp. nov. 1		+			62–134
P. extracta		+			27
P. cylindrifera			+		3.0–20
P. serventyi	+				34
P. contracta		+			107
P. sp. nov. 2	+				89
Cladocera					
Daphniopsis pusilla	+	+	+	+	3.0–49
Copepoda					
Calamoecia clitellata			+	+	15–49
C. salina			+		49–60
Microcyclops dengizicus	+	+	+	+	3.0–62
M. platypus	+	+			21–81
M. sp. nov. 2	+	+	+		20–152
Mesochra sp. nov.			+		20–33
Atheyella sp.	+				16
Ostracoda					
Australocypris robusta		+	+		62–100
A. sp. nov.	+			+	15–74
A. insularis	+	+	+	+	8.5–123
Mytilocypris mytiloides				+	9.0
M. minuta	+	+			8.5–16
Mytilocypridini gen. nov.	+				21
Platycypris baueri			+	+	3.0–88
Diacypris sp. nov. 1	+				16
D. sp. nov. 2		+			4.8
D. fodiens			+	+	46–100
D. whitei	+	+	+		9.5–138
D. compacta		+	+	+	3.0–101
Reticypris sp. nov. 1		+	+	+	15–60
R. sp. nov. 2	+				21
Gastropoda					
Coxiella sp. or spp.	+[a]	+	+	+	15–60[b]
Macrophytes					
Ruppia sp.	+	+	+	+	4.8–70[c]
Lepilaena sp.			+		20–32

[a] Empty shells collected from one locality.
[b] Range for active individuals only.
[c] Range for plants (not seeds) only.

four areas (*Daphniopsis pusilla*, species of *Microcyclops*, *Australocypris insularis*), but many have more limited distributions. Thus, all *Parartemia* species have restricted distributions; the *Calamoecia* species are found only in areas III and IV, as is *Platycypris baueri; Microcyclops platypus* is found only in areas I and II; and *Diacypris compacta* is absent from area I. It is interesting to note that of the 16 crustacean species recorded from area I, 7 are new. In area IV, only two of twelve crustacean species are new.

Each biological group is considered separately and in more detail below.

Anostraca

Anostracans were collected from 26 localities (Table 17.2) and included two species of the mainly freshwater genus *Branchinella* and eight of the halobiont genus *Parartemia*, including two new ones. More than one species of anostracan was never collected from any locality. Seven of the eight species of *Parartemia* are endemic to Western Australia. One, *P. cylindrifera*, has recently been collected in South Australia (De Deckker & Geddes 1980). The common eastern Australia species, *P. zietziana*, was not collected; it remains unrecorded from Western Australia.

Branchinella affinis, a mainly freshwater species, was collected once, at 4.76‰, as also was *B. simplex*, at 21.3‰. *Branchinella simplex* was previously known from only the type locality, for which there is no ecological information. *Parartemia cylindrifera* was collected twice, near Lake Grace in area III; both localities were only moderately saline (2.98 and 20.0‰). This is consistent with its occurrence in only moderately saline localities in South Australia (De Deckker & Geddes 1980). *Parartemia extracta* may also prefer waters of low or intermediate salinity: the only collection of that species was at 27.4‰. Three other species of *Parartemia* were collected only once: *P. contracta* from a salt lake (107‰) with the extremely low pH of 4.1; *P. serventyi* from a pool (34‰) adjacent to L. Cowan; and *Parartemia* sp.nov. 2 from a small lake (89‰) south of Norseman. The three other species were collected on several occasions and over wide salinity ranges (Table 17.4). All collections of *P. informis* were from areas I and II, while all collections of *P. longicaudata* were located between L. Grace and Esperance in areas III and IV. From these data, and that of Linder (1941) and Geddes (in press), it seems that the distributions of these two species do not overlap. *Parartemia* sp.nov. 1 was collected from four localities within a very limited part of area II – the maximum distance between localities was 60 km. Its area of distribution is within that of *P. informis*.

Cladocera

Daphnia was collected three times and *Moina* twice from salinities below 5.0‰. The *Daphnia* in localities 2 and 4 are characterized as a *D. carinata* variety unrecorded by Sars (1914) or Hebert (1977) (B. D. Mitchell, personal communication); they have no helmet but do have a long caudal spine. *Daphnia* in locality 3 were *D. carinata* var. *intermedia* Sars. The *Moina* were probably *M. flexuosa*. The halophilic cladoceran, *Daphniopsis pusilla*, was collected from 14 localities (Table 17.2) spread over all four geographic areas. The salinity range (2.98–46.2‰) is similar to that recorded for the species in eastern Australia (see Williams 1978) when it is considered that those values are for T.D.S. The present collections considerably extend the distribution of the species in Western Australia as recorded by Bayly & Edward (1969).

Copepoda

Three species of calanoid copepods, *Boeckella triarticulata*, *Calamoecia clitellata* and *C. salina*, were encountered. *Boekella triarticulata* was collected twice, at salinities of 3.57 and 4.42‰. This species is widely distributed in eastern Australia, Western Australia and New Zealand (Bayly 1964, 1979) in fresh and slightly saline waters (Bayly 1976). *Calamoecia* was collected from only six localities (Table 17.2), all in areas III and IV, between Narrogin and Esperance. *Calamoecia clitellata* or *C. salina* occur in almost all moderately saline lakes in eastern Australia (Bayly & Williams 1966; Geddes 1976; De Deckker & Geddes 1980), so their absence from areas I and II is noteworthy. *Calamoecia clitellata* occurred in four lakes with salinities form 14.6 to 52.4‰, while *C. salina* was in two more saline lakes, 48.5 and 59.5‰. This kind of distribution is similar to that found in eastern Australian salt lakes (Geddes 1976).

Several species of the cyclopoid *Microcyclops* were collected (Table 17.2). Of these, three are described species: *M. dengizicus, M. arnaudi* and *M. platypus* (described by Kiefer (1967) as *Metacyclops arnaudi platypus*), and two are species previously collected elsewhere by one of us (DWM) who is presently describing them. They are herein designated as *Microcyclops* sp.nov. 1 and *Microcyclops* sp.nov. 2. In his forthcoming revision of the Australian Cyclopidae, Morton will list these designations in the synonymies of the species. All of these species are known from eastern Australia with the exception of *M. platypus* which is not known to occur further east than Lake Eyre. *Microcyclops arnaudi* and *Microcyclops* sp.nov. 1 occurred once and twice respectively; these two co-occurred at a salinity of 4.42‰ and the latter was found with *M. dengizicus* at 6.69‰. The other three species occurred on several occasions. *Microcyclops dengizicus* generally occurred at salinities below 20‰ but one record is from 61.9‰. *Microcyclops platypus* was found in lakes of intermediate salinity (21.3–80.6‰) while *Microcyclops* sp.nov. 2 [which is the species incorrectly identified as *M. arnaudi* by Kiefer (1967) whose identification was followed by Bayly & Williams (1966) and Geddes (1976)] occurred in moderate and high salinities (20.0–151.8‰). This species seems to occur more consistently and at more elevated salinities in the present lakes than is usual in south-eastern Australian salt lakes. All three of the more frequently collected species appear to be widely distributed in the survey area (Table 17.4).

Only three collections of harpacticoid copepods were made (Table 17.2). Two of these were of a new species of *Mesochra* (D. Hamond, personal communication), a genus which contains the halobiont *M. baylyi* in south-eastern Australia. The third collection was of an unidentified species of *Attheyella* (D. Hamond, personal communication).

Ostracoda

Twenty species of ostracods from twelve genera in the freshwater family Cyprididae were collected, making this group the most diverse encountered. Five of the species and genera were restricted to low salinities: *Eucypris virens* and *'Chlamydotheca'* sp. only occurred in localities below 5‰ and, although *Cyprinotus edwardi, Heterocypris* sp. and *Sarscypridopsis aculeata* were each recorded once from above 20‰, most collections of them were from below 10‰ (Table 17.2). These species all belong to genera which commonly occur in temporary fresh waters. None of these genera except *'Chlamydotheca'* is endemic to Australia, and two species, *Sarscypridopsis aculeata* and *Eucypris virens* are cosmopolitan. All of the species have been recorded in South Australia (PDD, unpublished).

The remaining six genera are halophilic or halobiontic. *Mytilocypris, Australocypris* and a new genus are unusually large ostracods (3 mm or more long). Only rarely were individuals mature when collected. Two species of *Mytilocypris* were collected; M. *minuta* from two localities and *M. mytiloides* from one. All three localities were only moderately saline, which is consistent with previous findings in eastern Australia. The new genus was collected only once, from L. Annean, in area I at 21‰. The new genus almost certainly belongs to the tribe Mytilocypridini (no adults with soft parts were collected). Three species of *Australocypris* were collected; *A. robusta* and *A.* sp.nov. were each collected twice, while *A. insularis* was collected often. Each was collected from a wide range of salinities over a wide area (Table 17.4). This was especially true for *A. insularis* which was collected from 3–123‰ and from all four geographic areas. *Australocypris robusta* is known from eastern Australia while *A. insularis* and *A.* sp.nov. are presently considered endemic to Western Australia. It may be remarked, however, that *A. insularis* and *A. hypersalina* (widespread in eastern Australia) are morphologically similar.

Platycypris baueri was collected on 12 occasions over the salinity range 3–88‰. It was restricted to areas III and IV. This species occurs commonly in salt lakes in eastern Australia (Geddes 1976; De Deckker & Geddes 1980), and the present record is the first from Western Australia. It is interesting to note that this genus contains only one species which is widespread whereas other genera of salt lakes ostracods have many species of more restricted distribution.

Five species of *Diacypris* and two of *Reticypris* were collected. Up to three species of these small ostracods often co-occurred, in contrast to the situation for the large ostracods where co-occurrence was rare. The species *Diacypris* sp.nov. 1 and *D.* sp.nov. 2 were each collected only once and at low salinity (Table 17.2). The other three species were collected over wide salinity ranges (Table

17.4). *Diacypris fodiens* was collected only from localities in areas III and IV. The most commonly encountered species were *D. compacta* (11 localities) and *D. whitei* (21 localities). Both were fairly widely distributed, although *D. compacta* was absent from area I and *D. whitei* from area IV. *Reticypris* sp.nov. 1 was collected from four localities covering areas II, III and IV, while *R.* sp.nov. 2 was collected once only, from L. Annean, in area I. Both species occurred at moderate salinities (Table 17.4). The three described species of *Diacypris* are known from eastern Australia (Herbst 1958), and one of the three undescribed species, *D.* sp.nov. 1, has been recorded as 'genus C' by Bayly (1970) from salt lakes near Robe, South Australia (see De Deckker 1975). The other new species has not been collected before and may be restricted to Western Australia. One of the species of *Reticypris, R.* sp.nov. 1, has been collected in South Australia (De Deckker & Geddes 1980) while the other has not previously been collected.

Conchostraca

Conchostracans were collected from two localities, viz., 3 and 4 in which salinities were 4.42 and 4.76‰. The material was referable to *Eulimnadia* but in the present confused taxonomic state of the group further identification was not attempted.

Amphipoda

Amphipods were collected once. The species was *Austrochiltonia subtenuis* from Lake Chidnup (locality 7) at a salinity of 9‰. The record is of little interest as the species has been recorded from many localities in Western Australia before (Williams 1962), and 9‰ is well within its known salinity tolerance. The virtual absence of *Austrochiltonia* from the present series of localities is not surprising for, although many of the localities when sampled had salinities tolerable to *Austrochiltonia,* almost all seem likely to be too ephemeral for amphipod survival. Habitats in eastern (and Western) Australia where the genus occurs are more or less permanent, though it is *sometimes* recorded from ephemeral habitats (cf. De Deckker & Geddes 1980).

Insecta

Insects were collected from only nineteen localities, all within the lower part of the salinity range (Table 17.2). Nowhere were they abundant, and because of this and the inevitable taxonomic problems (especially with larval forms) little attention was given them. Summarizing our data, we note only the groups, the number of localities, and the maximum salinity recorded were as follows:

Odonata, 3 localities, 15.9‰
Corixidae, 2 localities, 9.0‰
Notonectidae, 2 localities, 9.0‰
Culicidae, 3 localities, 15.9‰
Chironomidae, 8 localities, 64.4‰
Ephydridae, 3 localities, 55.5‰
Stratiomyidae, 1 locality, 15.9‰
Ceratopogonidae, 2 localities, 17.0‰
Tipulidae, 1 locality, 70.3‰
Coleoptera, 10 localities, 46.2‰

Generally, this list provides no surprizes when compared with the known insect fauna of south-eastern salt lakes: all the groups except the Stratiomyidae have been recorded in the south-east in similar localities, and apart from the Ephydridae and Tipulidae at higher salinities there. Our records of the Ephydridae and Tipulidae exceed – though not markedly – south-eastern salinity maxima according to Bayly & Williams (1973), viz. 53‰ for both groups.

The similarity between south-eastern and south-western Australian salt lakes in their relative lack of an insect fauna is noteworthy. In this they differ from salt lakes in many places elsewhere. In such localities coleopterans, corixids and ephydrids frequently occur (Macan 1963; Scudder 1969; Beadle 1974; Hammer *et al.* 1975). Thus, in the desert areas of California, salt lakes in playa basins are occupied by the beetle *Deronectes coelamboides,* the corixid *Trichocorixa reticulata,* the ephydrids *Ephydra* sp. and *Lamproscatella salinaria* and several other dipteran larvae (Kubly & Cole 1979). The absence or rarity of these groups in various eastern Australian salt lakes has previously been commented on by Bayly & Williams (1966), Knowles & Williams (1973) and Williams (1978). The only locality in the present series where insects were at all abundant or diverse was locality 11. However, this locality was a most unusual habitat in that it was a flowing saline *stream* which may have been permanent or semi-permanent.

Mollusca

The only molluscans collected were the halobiont gastropod, *Coxiella.* Specimens were not identified further for although several species have been described from Western Australian salt lakes (Macpherson 1957), it now appears that there is considerable variation in many taxonomic criteria used by her (Mellor 1979). *Coxiella* was collected from ten localities (Table 17.2); in five (salinities 14.6–59.5‰), animals were active, while in five they were inactive. The localities were from all four geographic areas indicating considerable tolerance to high temperatures and aridity. *Coxiella* is also known from eastern Australia.

Nematoda

Nematodes were noted only once in collections; they were noted in locality 12 at a salinity of 17‰, well within the salinity range of this group in south-eastern Australia (Bayly & Williams 1966).

Microscopic biota

No attempt to collect benthic microscopic (<400 μm) animals and plants was made, and plankton (phytoplankton, Rotifera) collected with the fine plankton net (60 μm mesh) are not considered in this paper.

Aquatic macrophytes

Aquatic macrophytes were collected from thirteen localities and their seeds from two more (Table 17.2). Time constrained efforts to collect macrophytes and so they were probably present in further localities. All macrophytes collected were species of *Ruppia* (Ruppiaceae), a cosmopolitan halophyte genus, or *Lepilaena* (Zannichelliaceae), an Australasian endemic genus of halophyte. *Ruppia* was widely distributed and was recorded over the salinity range 4.8 to 78.3‰. *Lepilaena* was collected from only three localities, all in the vicinity of Lake Grace, and over the salinity range 20.0 to 32.5‰. In addition, *Ruppia* seeds were collected from two lakes of higher salinity. The salinity ranges recorded for both genera are within those recorded by Brock (1979) for these genera in south-eastern South Australia.

Discussion

The major ion chemistry of the lakes studied requires little comment; as in other Western Australian salt lakes (Williams & Buckney 1976) and those in the south-east, the pattern of major ionic dominance was almost always Na > Mg > Ca > K and Cl > SO_4 > HCO_3, with Na and Cl the dominant cation and anion on all occasions.

Although the present study confirms the occurrence of similarities between the fauna of salt lakes in the south-west and south-east of Australia, it also highlights the differences. The most notable of these (in lakes studied in the west) are the greater faunal diversity, the absence of *Haloniscus* (Isopoda), the rarity of amphipods, the lack of fish in the less saline lakes, and the absence of any animals of clear marine affinity. Greater ephemerality and remoteness from the sea are likely explanations for the absence or scarcity of some groups. Almost all the lakes surveyed were ephemeral, and in fact in the whole area there is little permanent water. This situation contrasts with that in south-eastern Australia where there are many permanent saline and freshwater lakes.

In the present study, as in many others elsewhere, salinity is a major factor clearly influencing the occurrence of species in the lakes. Although the lakes were sampled only once – and thus no account is taken of considerable temporal changes in salinity – Table 17.2 indicates the strong relationship between salinity and species occurrence. In studies made in eastern Australia (Bayly & Williams 1966; Geddes 1976; De Deckker & Geddes 1980), salinity often appears to be the *only* factor controlling distribution. This appears not to be so in the present study. Here, because the area surveyed was very large and covers different climatic regions, the distribution of the fauna seems determined in part by geographic and climatic factors as well. Thus different species within a genus occur in different areas, and certain genera, *Calamoecia* and *Platycypris*, are absent from the hotter more arid areas (I and II), while the new genus of large ostracod is possibly restricted to area I. The restricted distribution of the calanoid copepod, *Calamoecia*, is of particular interest. Even though *Calamoecia* is unique amongst calanoids in its degree of tolerance to highly saline water (Bayly 1969), it is apparently similar to other calanoids in not occupying short-lived waters in extremely arid regions.

Two further comments can be made concerning the effect of geographic location on the occurrence of species. First, the exclusion of some groups from certain areas will affect the relationship between salinity and species diversity outlined by Williams (1972). Lakes of similar salinity in areas I and III are likely to have a different species number because of the absence of calanoids and some ostracods from area I. Second, area I appears to have a high level of endemism. Further collections need to be made from salt lakes in the truly arid regions of central and western Australia to elucidate the fauna of ephemeral waters in these regions.

The present lakes possess almost all the genera of crustaceans found in salt lakes in eastern Australia (the amphipod *Austrochiltonia* and the isopod *Haloniscus* which were only once or not collected in this study are also known from coastal areas of southern Western Australia). In some cases the species in the east and west are the same, as noted previously. However, it appears that, even though the salt lakes in eastern Australia are better studied, the salt lake fauna of Western Australia is indeed more diverse than that in the east. In the genera *Microcyclops* and especially *Parartemia*, there has been more speciation in western salt lakes than in eastern ones. This *may* also be true for *Coxiella*, the gastropod (Macpherson 1957). Increased speciation may be related to the more stable geology and climate of the area as opposed to that of the east. A large part of Western Australia has been geologically stable and climatically arid since early Tertiary (van de Graaff *et al.* 1977; Lowry & Jennings 1974), and so presumably the area has had ephemeral saline lakes as a major limnic environment over this long period. This long history of large numbers of salt lakes extending over various climatic regions may have provided the conditions for speciation to proceed. In eastern Australia, on the other hand, areas where most salt lakes presently occur have been subject to recent vulcanicity (Victoria) or result from recent changes in coastal topography (South Australia).

The most significant result of our studies, then, is the addition of further evidence of greater diversity in the salt lake fauna in the west. It seems possible that the area of Western Australia surveyed has been the centre of evolution for the many endemic genera found in Australian salt lakes and hitherto known primarily from eastern Australia.

Appendix 17.1 Location and other details of water bodies studied. Localities are numbered (extreme left column) according to increasing salinity within each area (see also Fig. 17.1).

Locality No.	Locality	Position	Coordinates	Playa?	Approx. depth (cm)	Salinity (‰)
Area I						
5	roadside pool	nr Lake Raeside	121°21′28″E 28°58′55″S		10	6.69
11	pool in flowing creek	nr Lake Mongers	117°26′45″E 29°05′08″S		120	15.9
12	Lake Raeside	10 km S. Leonora	121°21′48″E 28°57′50″S	yes	30	17.0
14	Lake Annean	40 km S. Meekatharra	118°20′55″E 26°53′47″S	yes	60	21.3
20	pool at lake edge	nr Lake Cowan	121°44′46″E 32°08′58″S	yes	30	34.4
28	Lake Mongers	North end of lake	117°16′52″E 29°02′42″S	yes	30	61.9
32	Lake Mongers	1 km S. loc. 28	117°15′56″E 29°03′39″S	yes	30	74.1
33	pool on bed of Lake Austin	24 km S. Cue	117°54′02″E 27°36′21″S	yes	30	80.6
35	small lake	27 km S. Norseman	121°42′57″E 32°25′57″S		5	88.5
41	Lake Ballard	15 km N.E. Menzies	121°07′49″E 29°37′11″S	yes	5	112.2
43	Lake Austin	23 km S. Cue	117°54′02″E 27°35′25″S	yes	5	122.0
50	Lake Miranda	40 km N. Agnew	120°32′46″E 27°39′03″S	yes	dry	153.9

Appendix 17.1 (Cont.)

Locality No.	Locality	Position	Coordinates	Playa?	Approx. depth (cm)	Salinity (‰)
Area II						
4	lake	nr Kalannie	117°03′35″E 30°04′32″S		50	4.76
6	semi-permanent lake	nr Lake Hillman	117°10′56″E 30°22′18″S		150	8.45
8	roadside pool	nr Lake Koombekine	117°01′58″E 31°04′54″S		10	9.50
9	lake	nr Lake O'Grady	117°24′32″E 30°21′53″S		20	11.2
15	temporary lake	E. of Lake Dowerin	117°03′45″E 31°14′52″S		30	27.4
16	pool in lake basin	Lake Cowcowing	117°23′55″E 30°56′29″S	yes	20	29.9
24	large shallow lake	nr Kalannie	117°04′32″E 30°04′44″S		30	52.4
25	large lake	nr Goddard	117°02′40″E 31°05′25″S		15	55.5
27	Lake DeCourcey	S. end of lake	117°06′53″E 30°18′39″S	yes	20	61.7
29	Lake O'Grady		117°24′50″E 30°22′58″S	yes	10	62.3
30	large lake	near Lake Koombekine	117°00′56″E 31°04′03″S		20	64.4
31	small lake	nr Lake DeCourcey	117°06′53″E 30°18′39″S			70.3
37	Lake Samphire		117°29′41″E 30°27′02″S	yes	30	95.1
39	Lake Goorly	nr Wubin	117°00′28″E 29°58′23″S		80	101.2
40	lake	adjacent to Lake O'Grady	117°25′23″E 30°25′41″S			106.6
44	Lake Dowerin (semi-permanent)		117°03′08″E 31°15′16″S		>100	122.6
45	Lake DeCourcey	nr Kalannie	117°05′28″E 30°13′39″S	yes	20	123.1
46	lake	nr Kalannie	117°04′32″E 30°04′44″S		10	126.3
47	Lake Moore		117°29′13″E 30°20′00″S	yes	10	129.9
48	Lake Moore	E. of loc. 47	117°29′23″E 30°20′08″S	yes	20	137.6
51	Lake Moore	S. of loc. 47	117°29′04″E 30°20′25″S	yes	25	186.2
53	Lake Cowcowing	nr Conda	117°23′45″E 30°56′05″S	yes	20	246.9
54	small lake	nr Koombekine	117°01′25″E 31°04′54″S		>100	262.5
Area III						
1	deep pool	adjacent to Lake Grace	118°22′54″E 33°06′37″S		>120	2.98
2	Lake Biddy		118°56′46″E 33°01′22″S		>200	3.57
3	roadside pool	25 km N.W Corrigin	117°38′32″E 32°10′25″S			4.42

Appendix 17.1 (Cont.)

Locality No.	Locality	Position	Coordinates	Playa?	Approx. depth (cm)	Salinity (‰)
13	small lake	15.3 km S. Lake Grace	118°28′44″E 33°15′16″S		30	20.0
17	small lake	nr Lake Grace township	118°26′17″E 33°05′44″S		20	30.6
18	shallow lake	nr Lake Biddy homestead	118°57′16″E 33°01′21″S		10	32.5
19	lake	between Corrigan and West Bendering	118°01′25″E 32°20′25″S		40	33.3
22	small lake	600 m W. Lake King	119°02′14″E 33°05′08″S		15	48.5
23	small lake	15.3 km S. Lake Grace	118°28′43″E 33°15′08″S		40	48.5
26	Lake Grace	north basin of lake	118°24′02″E 33°06′29″S	yes	20	59.5
34	small lake	nr Lake Biddy homestead	118°55′17″E 33°00′49″S		30	87.9
36	lake Stubbs	nr Newdegate	119°01′26″E 33°03′31″S		30	91.4
38	Lake King	nr township	119°34′47″E 33°05′25″S	yes	20	99.6
49	Lake Burkett	nr Newdegate	119°02′54″E 33°05′08″S		20	151.8
Area IV						
7	Lake Chidnup		119°53′33″E 33°21′46″S		30	9.01
10	small lake	between Pink Lake and Lake Warden	121°50′49″E 33°49′11″S		20	14.6
21	small lake	18 km N. Grass Patch	121°41′17″E 33°04′19″S		30	46.2
42	Lake Warden	nr Esperance	121°53′29″E 33°49′28″S		30	120.2
52	Pink Lake	nr Esperance	121°49′53″E 33°51′13″S		15	192.6

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