THE FAUNA AND CHEMICAL COMPOSITION OF SOME ATHALASSIC SALINE WATERS IN NEW ZEALAND

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SUMMARY

The fauna and chemical composition of two athalassic saline waters located near central Otago are discussed, and available rainfall and evaporation data for the region summarised. One water (dominated by Na and Cl) had a salinity of 15‰ and contained the rotifer *Brachionus plicatilis*, the copepod *Microcyclops monacanthus*, the ostracod *Diacypris*, and larvae of the dipteran *Ephydrella*. The second water (dominated by Na and HCO_3) had a salinity of 6‰ and contained larvae of *Ephydrella* (adults of *E. novaezealandiae* occurred on the shore), and the hemipterans *Sigara arguta, Anisops wakefieldi* and *Anisops assimilis*. The relationship between *Microcyclops monacanthus* and *M. arnaudi* (an Australian species), and the basis of their current taxonomic separation is discussed in some detail.

At a minimum, the faunas of Australian and New Zealand athalassic saline waters have in common the following distinctive (non-cosmopolitan) forms: *Ephydrella, Diacypris,* and two closely related halobiont species of *Microcyclops*.

INTRODUCTION

In contrast to Australia, New Zealand is generally well watered and inland or athalassic saline waters are very scarce. Thus 87% of the total area of Australia is enclosed by the 30 in. average annual isohyet (calculated from the Australian Commonwealth Bureau of Meteorology 1960) and 68% of the total area receives less than 20 in. average annual rainfall (calculated from Australian Commonwealth Bureau of Meteorology 1959). The corresponding values for New Zealand are only 13% and 1.6% (calculated from Seelye 1945), and regions with less than 30 in. mean annual rainfall are restricted to the South Island. Nimmo (1949, fig. 5) shows that regions in which the mean annual rainfall exceeds the potential evapotranspiration loss comprise only 5.4% of the total area of the Australian mainland. Suitable evaporation data for New Zealand are not available but it can safely be assumed that the corresponding percentage is much greater.

In spite of the big climatic differences between Australia and New Zealand, the two countries have a great deal in common from the viewpoint of biogeography. This is true of the freshwater fauna, but has not hitherto been established for the fauna of athalassic saline waters. Although it has been claimed that the fauna of athalassic saline waters is essentially of a cosmopolitan nature, recent work (Bayly and Williams 1966) shows that this is not true of these environments in Australia.

Since, in general, rainfall is high, evaporation is low, and endorheic drainage systems are absent, the athalassic saline environment has attracted little attention in New Zealand, and it might be doubted whether such an environment could exist in New Zealand at all. Figure 1 shows that the most likely region for the existence of athalassic

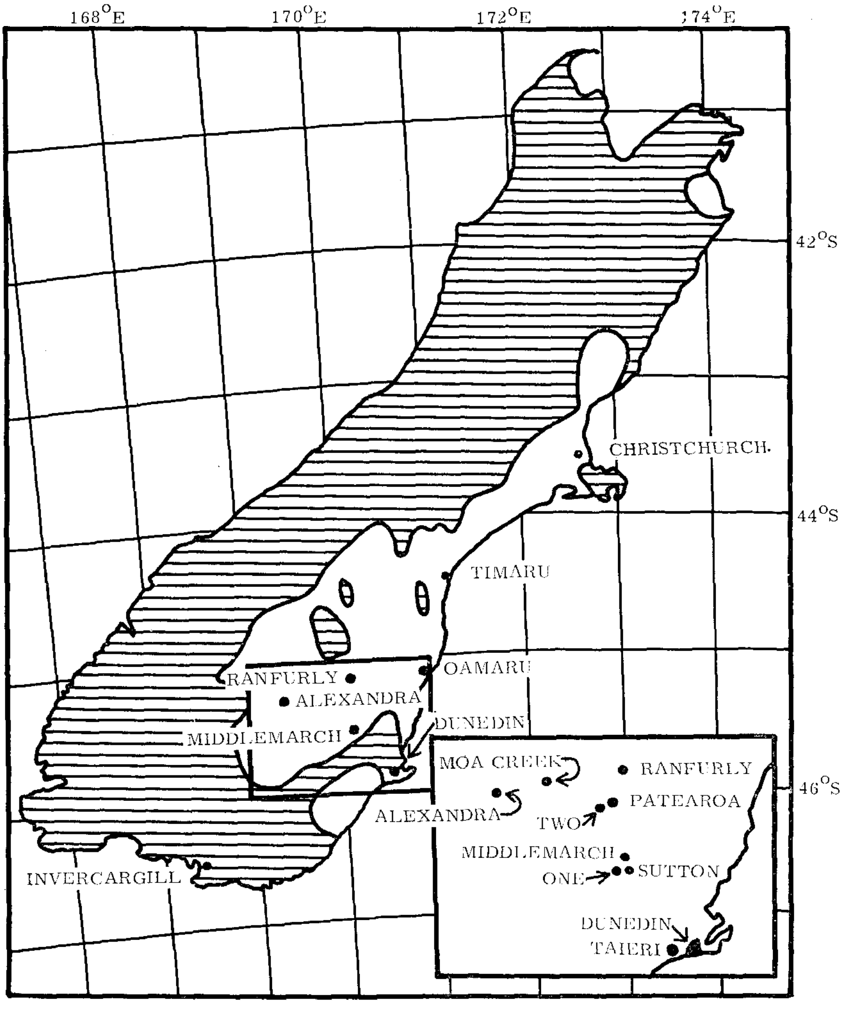

FIG. 1—Locality map of the South Island. The unshaded portions represent the only regions of New Zealand in which the average annual rainfall is less than 30 in. One: Salt Lake, Sutton. Two: saline pond near Patearoa.

saline waters is Otago or the hinterland of Dunedin. Marples (1962, p. 13) stated, "At least one [inland saline lake] exists in this country, a small lake in Otago", and he further stated (pers. comm.) that this was a shallow, temporary, saline lake at Sutton. This lake (grid reference 793073, Sheet S 154, N.Z.M.S.1 (1:63,360)) is one of the two bodies of water considered in this paper, and is 2.7 km from Sutton and 8 km from the township of Middlemarch. When full, this lake has an area of 3.7 hectare (9.3 acres), and a depth of only about 30 cm.

The second locality was a small, slightly saline pond on Patearoa Station (grid reference S 33-6839, Sheet 23, N.Z.M.S.18 (1:250,000)), about 8 km from the small township of Patearoa, and approximately equidistant from Middlemarch and Ranfurly. The occurrence of salt pans and local areas of saline soil in this region is mentioned by Raeside, Cutler, and Miller (1966).

The mean annual rainfall at Middlemarch for the period 1921–50 was 19.0 in. (J. Finkelstein, pers. comm.), and the mean for the same period at Ranfurly was 17.6 in. (N.Z. Meteorological Service 1963). The annual mean at Patearoa (1927–55) was only 14.9 in. (Raeside, Cutler, and Miller 1966, p. 11). No evaporation data are available for Middlemarch or Ranfurly but the estimated annual open water evaporation for Alexandra, Moa Creek, and Taieri, the three closest available stations, is 27, 30, and 29 in., respectively (Finkelstein 1961). There can be little doubt, therefore, that in this restricted part of New Zealand evaporation exceeds rainfall. This is also indicated by the climatological data presented by Raeside, Cutler, and Miller (1966, fig. 4 and table 1).

THE FAUNA AND CHEMICAL COMPOSITION

SALT LAKE, SUTTON (Figs 2,3)

Collections of fauna and a water sample were taken from this lake on 25 January 1966. The fauna consisted of the following:

Rotatoria: *Brachionus plicatilis* Müller; very abundant.

Copepoda: *Microcyclops (Metacyclops) monacanthus* (Kiefer); scarce, but 11 specimens present in collections including four mature females and one mature male. Mean length of females exclusive of furcal setae 1.07 mm.

Ostracoda: *Diacypris* sp.; abundant.

Diptera: *Ephydrella* sp.; scarce, but several larvae present in collections.

The alga *Chara* sp. was present in abundance.

The results of a chemical analysis of the water sample are given in Table 1. The methods used were as follows: for sodium and potassium, flame photometry; for calcium and magnesium, direct complexometric titration with EDTA; for chloride, titration with standard silver nitrate using potassium chromate as an indicator; for carbonate (–bicarbonate), titration with standard hydrochloric acid to a pH endpoint of 4.5.

Sulphate was estimated by difference, but for this first locality the apparent equivalent sum of chloride and bicarbonate slightly exceeded that of the cations so that the low sulphate concentration could not be estimated by this method.

SALINE POND NEAR PATEAROA

Faunal collections and a water sample were taken from this pond on 26 January 1966. The fauna consisted of the following:

Diptera: *Ephydrella* sp(p). (larvae) and *E. novaezealandiae* Tonnoir and Mallock (adults); numerous larvae were present in the aquatic collections, and several adults were captured from the thick swarms flying around the margins of the pond.

Hemiptera:

(i) *Sigara arguta* (White); very abundant.

(ii) *Anisops wakefieldi* White; abundant.

(iii) *Anisops assimilis* White; scarce. These three hemipteran species were represented by 123 (53 ♂, 70 ♀), 42 (20 ♂, 22 ♀), and 3(♀) adult specimens, respectively, in the sample taken.

The results of the chemical analysis of the water sample are presented in Table 1.

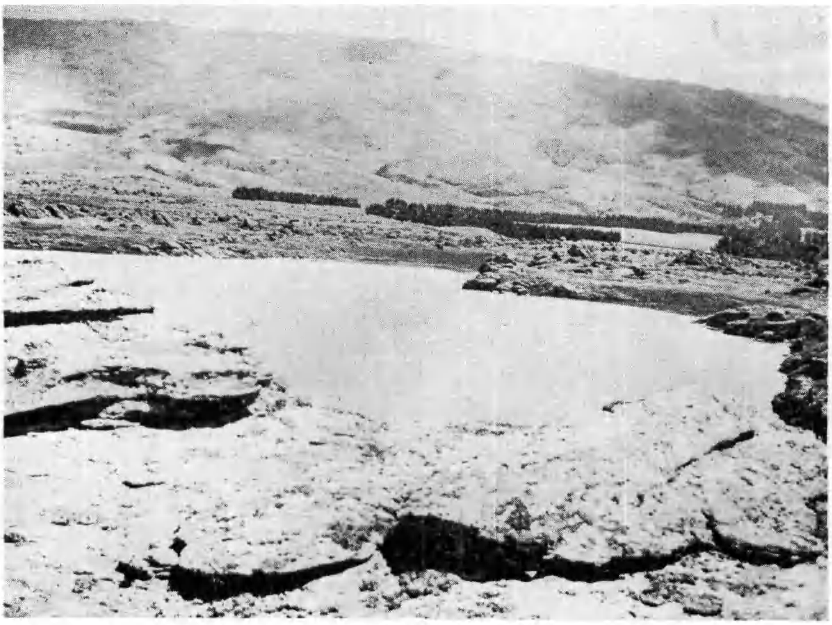

FIG. 2—A view of Salt Lake, Sutton, looking westwards. The Rock-and-Pillar Range is in the background.

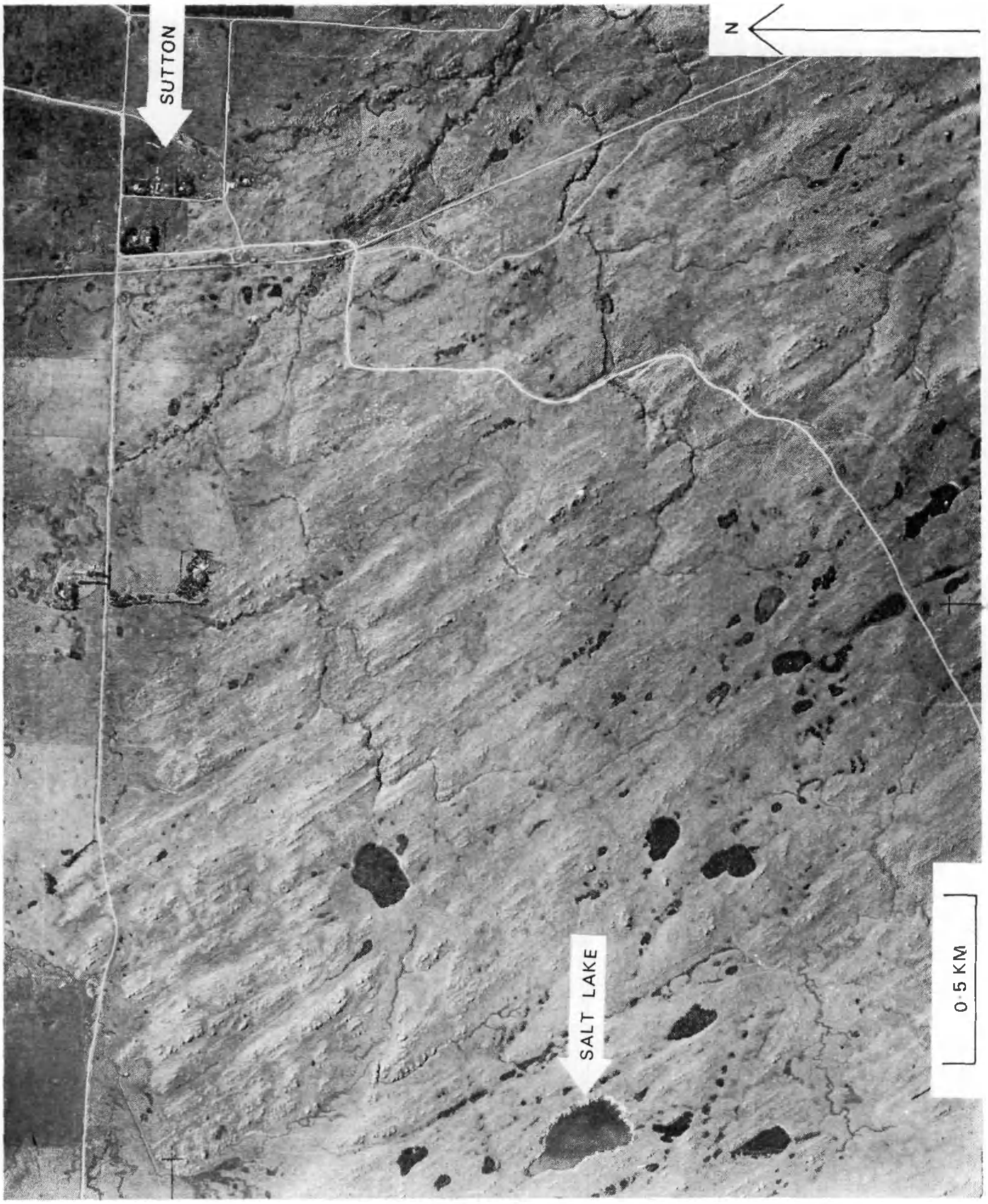

FIG. 3—A vertical aerial photograph of Sutton and nearby lakes including Salt Lake. (Reproduced by permission of the Surveyor-General, Lands and Survey Department, Wellington.)

TABLE 1—Chemical composition of two athalassic saline waters in New Zealand
(Water samples taken 25–26 January 1966)

Locality	Value*	Na	K	Mg	Ca	Cl	HCO_3	SO_4	Salinity	K_{18} (μ mhos)	pH†
Salt lake Sutton	A	5.30	0.23	0.16	0.04	8.98	0.43	—	15.18	20,700	7.7
	B	91	2	5	1	100	3	—	—		
Saline pond Patearoa	A	1.76	0.06	0.01	0.03	1.20	2.83	0.10	5.99	6,200	8.8
	B	94	2	1	2	42	56	2	—		

* A = absolute amount in ‰ B = relative amount as % of total cations † Measured in laboratory 6.iv.1966

DISCUSSION

FAUNAL ASPECTS

The rotifer *Brachionus plicatilis* is the only one of the several species recorded above that can be regarded as being cosmopolitan. As mentioned by Bayly and Williams (1966) this species has been repeatedly recorded from widely separated athalassic saline waters. It has previously been recorded from a saline habitat in New Zealand by Russell (1962), but this record evidently relates to marine-brackish water. This species did not occur in any of the highly saline Australian lakes recently investigated by Bayly and Williams, but was recorded from two of the less saline lakes.

The family Ephydridae is noted for its occurrence in athalassic saline waters throughout the world. The genus *Ephydrella,* however, is an Australasian one and is replaced in the northern hemisphere by *Ephydra,* and in South America largely by *Dimecoenia. Ephydrella* was recorded from Australian athalassic saline lakes by Bayly and Williams (1966), and was recorded (as "*Ephydra*") from a saline pool at Barewood, Central Otago by Benham (1905). The place-name "Barewood" went out of use some time between 1912 and 1925, it being listed in the New Zealand Index for the former year but not for the latter (M. G. Hitchings, pers. comm.). It referred to a railway siding and mining settlement 16 km from Hindon and 19 km from Middlemarch. The material discussed by Benham was possibly collected from one of the two pools shown on N.Z.M.S.1, S154, grid reference 905031. *E. novaezealandiae* is endemic to New Zealand.

Corixids have usually been present in athalassic saline waters investigated outside of the Australasian region (Macan 1963), but they were not collected during a recent survey of athalassic saline lakes in Victoria and South Australia (Bayly and Williams 1966). Corixids were, however, very recently recorded (together with notonectids) from a strongly saline (salinity 52‰) athalassic habitat in New South Wales by Ettershank, Fuller, and Brough (1966). *Sigara arguta* occurs in fresh-waters throughout New Zealand (Young 1962, p. 371, fig. 103), but probably has not previously been recorded from athalassic saline waters. Young (loc. cit., p. 337) notes, however, that *S. arguta* is found " . . . along the margins of estuaries, sometimes appreciably brackish . . . ". The notonectids *Anisops wakefieldi* and *A. assimilis* are both widely distributed in South Island fresh waters (Young 1962, p. 372, fig. 106), but again the present records are probably the first from non-marine saline waters. All three hemipteran species are endemic.

The above record of *Microcyclops (Metacyclops) monacanthus* is only the second for this species. It was originally described by Kiefer (1928) from Lake Ellesmere near Christchurch. To the present author *M. monacanthus* seems very closely related to *M. arnaudi* (Sars). This close relationship is also conceded by Kiefer (1928, p. 7) who stated "*Cyclops monacanthus* nov. spec. besitzt eine auffalende, ohne Zweifel auf Verwandtschaft beruhende Ähnlichkeit mit *C. arnaudi* Sars". More recently (pers. comm. 1966) Kiefer stated "*M. monacanthus* ist, wie ich bei der Erstbeschreibung schon hervorgehoben habe, dem *M. arnaudi* sehr ähnlich, beide sind offenbar nahe verwandt".

Microcyclops arnaudi was described by Sars (1908) from only two female specimens collected from St. Arnaud, Victoria, and he gave no description of the habitat. For more than fifty years no further records appeared. In May 1962, however, this species was collected in considerable abundance from a saline lake near the Victorian township of Meerlieu. The salinity of this lake at the time was 39‰. Since then *M. arnaudi* has been collected at: salt lake 112 km north of Kelowna Station between Colona and Ooldea, South Australia (no salinity data); Lake Beeac, Beeac, Victoria (salinity 93‰); Calvert's Lagoon near Opossum Bay, Tasmania (salinity 6‰); and Red Morass Lagoon, Meerlieu (July 1966) (salinity 34‰). On the basis of these data, and the absence of a single authentic record from fresh water, it seems very probable that *M. arnaudi* is a halobiont, that is, it appears to be restricted to athalassic saline waters. Most of the material collected since 1962 has been examined by Professor Kiefer.

Kiefer (1928, p. 7) separated *M. monacanthus* from *M. arnaudi* on the basis of the following criteria: the length of the furcal rami, and the position of the outer edge seta of these; the length of the first antenna; the ratio (length endsegment): (length endspine) in the fourth endopodite; the form and armature of the fifth pair of legs. As shown in Table 2, some of these features are subject to variation within both Australian and New Zealand forms. Thus, with respect to the fourth endopodite the material from Salt Lake, Sutton, was closer to the Australian material than that from Lake Ellesmere. Similarly, with respect to the location of the outer seta of the furcal rami, the material from Red Morass Lagoon was closer to that from Salt Lake than that from St. Arnaud. It is possible that a critical examination of a large number of specimens from several localities in both countries would reveal sufficient variability and overlap to provide a basis for synonymising the two species.

Kiefer refers both the Australian and New Zealand species to the genus *Metacyclops*. The present author, however, is inclined to agree with Rylov (1963, pp. 66–7) that there are insufficient grounds for separating *Metacyclops* from *Microcyclops*. Rylov's (1963, pp. 77 and 264) placement of these two Australasian species in the genus *Microcyclops* is therefore followed here. At the same time there is perhaps some merit in retaining subgeneric status for Kiefer's name if for no other reason than to provide a simultaneous reference to the Kiefer and Rylov systems. It may be noted that although Kiefer (1929, p. 46) specifically refers *M. arnaudi* to a group of species in which the terminal spines on the fourth endopodites attain a length at least equal to that of the terminal segments, Sars (1908, pl. 4, fig. 6) shows that in this species they are distinctly shorter. This is confirmed by the material from Red Morass Lagoon in which these spines are even slightly shorter on the average than is shown by Sars (see Table 2).

TABLE 2—Comparison of structural features of two species of *Microcyclops (Metacyclops)*
(Data relate to female specimens)

Name	Locality	Taxonomic character			
		P_4 endopodite	P_5	Furcal rami	
		(length terminal segment) / (length terminal spine)	(length inner spine) / (length outer spine)	length : width	location outer edge seta††
Microcyclops (Metacyclops) arnaudi (Sars)	St. Arnaud, Victoria*	1.21	0.3	8.3	0.71
	Red Morass Lagoon, Meerlieu, Vic.†	1.39	0.8	5.1	0.55
Microcyclops (Metacyclops) monacanthus (Kiefer)	Lake Ellesmere, Christchurch, N.Z.‡	0.77	—	4.0	—
	Salt Lake, Sutton, N.Z.§	0.93	0.07	4.2	0.57

* From Sars (1908, plate 4) (N = 2)
† Original, mean ratios for 4 specimens (N = 8)
‡ From Kiefer (1928, figs. 1–3) (N = 2)
§ Original, mean ratios for 1 specimen (N = 2)

†† Ratio (distance from outer proximal corner) : (length outer edge)

Although the type-locality of *M. monacanthus* was stated to be Lake Ellesmere (a marine-brackish environment), the possibility that it may in fact have been an immediately adjacent body of water not actually connected to the main lake at the time of collection, should not be overlooked. Situations in which a body of sea water permanently loses connection with the sea, and dries up before influx of fresh water restores a saline body of water, are regarded by Bayly (1967) and Bayly and Williams (1966) as athalassic in nature. It is noteworthy that Red Morass Lagoon is very close to a complex of true marine-brackish environments, and much of its salt may be of marine relictual origin. Since, however, it is now permanently cut off from the sea and undergoes periodic drying, it is regarded as an athalassic saline environment. It will be interesting to see if any future records appear of *M. monacanthus* from true marine-brackish waters in New Zealand.

The known distribution of the two closely related Australasian forms of *Microcyclops (Metacyclops)* is shown in Fig. 4. The restriction of these forms to Australasia is almost certainly due to historical factors, but the restriction, as far as is known, of *M. monacanthus* within New Zealand to Otago and Canterbury is probably due to ecological factors since these are probably the only regions with athalassic saline waters. Likewise, while the restriction of the calanoid *Boeckella* to the southern hemisphere (except for one Mongolian species) is undoubtedly due to historical influences, the apparent restriction of *B. triarticulata* within New Zealand to Otago and Canterbury (see Bayly 1964, pp. 196–7)

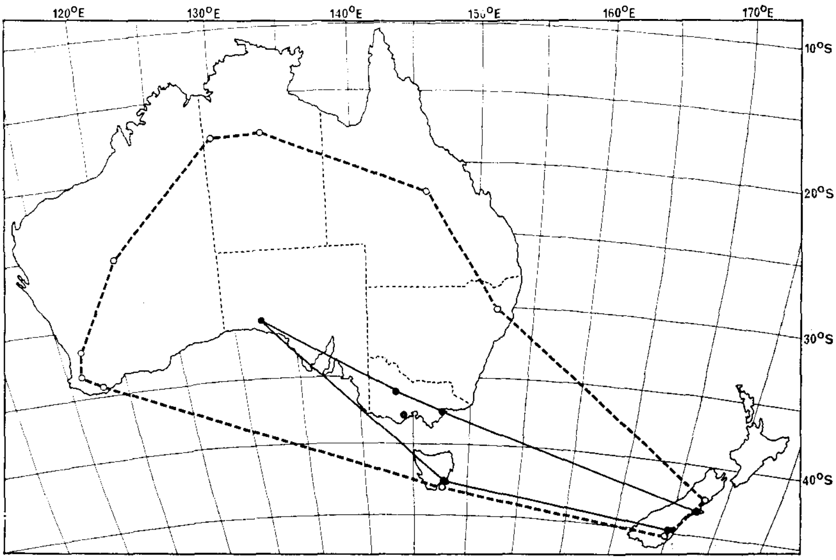

FIG. 4—Map showing the distribution of *Boeckella triarticulata* (broken line), and of two closely related species of *Microcyclops (M. arnaudi, M. monacanthus)* (solid line).

may be related to the fact that these are the most arid areas. It is noteworthy that *B. triarticulata* is the only species of *Boeckella* whose distribution extends into the arid central portion of Australia (it has been recorded from central Queensland, Northern Territory, and central Western Australia). The parallel between the distribution of *B. triarticulata* and *M. arnaudi–M. monacanthus* can be seen from Fig. 4.

The above record of *Diacypris* is the first from New Zealand. This genus was described from South Australia by Herbst (1958, 1961), and was later shown (Bayly and Williams 1966) to be a common inhabitant of athalassic saline lakes in south-east Australia. The New Zealand material will be discussed in a forthcoming paper by Dr H. Löffler. The known distribution of *Diacypris* closely parallels that of the two closely related species of *Microcyclops* shown in Fig. 4.

The above fauna is seen to be an impoverished one when compared with that found in Australian athalassic saline waters (see Bayly and Williams 1966), but the times and intensities of sampling differ. The New Zealand list is based on collections made at one time only, and both basins had not long been filled after heavy unseasonal rain. Many forms probably had insufficient time to develop, for it is noteworthy that nearly all of the ostracods and most of the copepods collected at Sutton were immature. One reason for the smaller New Zealand fauna would be the absence of permanent athalassic saline waters. In south-east Australia large lakes such as Lake Corangamite and deep maars such as Lake Gnotuk probably act as refuges for the less resistant forms during time of drought. Later these would function as nuclei for recolonisation of adjacent waters of a more temporary nature.

CHEMICAL ASPECTS

Both waters were only mildly saline by Australian standards. In athalassic saline lakes in south-east Australia salinities in excess of 50‰ and even 100‰ are by no means uncommon (Bayly and Williams 1966).

With respect to relative ionic proportions the two Otago waters are quite different; Salt Lake at Sutton is a chloride water and the pond at Patearoa is a (bi–)carbonate water. At Sutton the cationic order of dominance was $Na > Mg > K > Ca$ and the anions were strongly dominated by chloride. This is in full agreement with what obtains for athalassic saline waters found near Lake Corangamite and Centre Lake in Victoria (Bayly and Williams, 1966). In the pond at Patearoa the ionic orders of dominance were $Na > K = Ca > Mg$ and $HCO_3 > Cl > SO4$. Ionic dominances identical to these have not yet been reported for any athalassic saline waters in Australia. However, the relative ionic proportions shown in Table 1 for this locality are closely comparable with those listed for a New Zealand fresh-water lake (Lake Aroarotamahine, Mayor Island) by Bayly and Williams (1964, table 2). Presumably in both cases an appreciable amount of sodium carbonate is present in the surrounding rocks and soils. This is almost certainly true of the Patearoa locality; the occurrence in this general area of sodium carbonate and pH values in excess of 8.4 is pointed out by Raeside, Cutler and Miller (1966, pp. 50, 54 and 55). Furthermore, the locality is located in an area designated on the soil map of these authors as "Linnburn silt loam, very salty phase". This soil type is characterised by the presence of numerous salt pans some of which are alkaline (loc. cit., pp. 24, 25 and 63, fig. 7).

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