Calamoecia trilobata n sp (Copepoda: Calanoida) from salt lakes in south-western Australia

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Abstract

A new species of calanoid copepod, *Calamoecia trilobata* n sp, is described from saline lakes in the central and southern Wheatbelt of south-west Western Australia. *Calamoecia trilobata* appears to occur in comparatively few lakes and to be restricted to south-west Western Australia. It is unusual in that the size ratio between sexes, as well as female size, varies significantly among lakes. The genus *Calamoecia* now contains three saline-water species, all of which occur in Western Australia. *Calamoecia salina* and *C. clitellata* are also found in eastern Australia.

Keywords: *Calamoecia trilobata*, Copepoda, salt lakes, sexual dimorphism, Western Australia

Introduction

Most calanoid copepods in inland waters of Western Australia belong to the genera *Calamoecia*, *Boeckella* and *Hemiboeckella* in the family Centropagidae (Maly & Bayly 1991; Maly *et al*. 1997). With the recent description of *Calamoecia halsei* (Bayly 1998), ten described species of *Calamoecia* have been recorded in Western Australia. Two additional taxa that are probably distinct species await description: *Calamoecia* cf *lucasi* (Bayly 1998) and *Calamoecia tasmanica* sl (Bayly 1992), which was wrongly referred to as *Calamoecia tasmanica tasmanica* by Maly *et al*. (1997).

Most species of *Calamoecia* are restricted to fresh water, with the only described species in saline water bodies being *Calamoecia salina* and *Calamoecia clitellata* (Bayly 1992). A third species of *Calamoecia* from saline lakes in the central and southern Wheatbelt regions of south-west Western Australia is described below.

Methods

Specimens were collected using pondnets with 50 µm or 250 µm mesh and preserved in 1-2 % phosphate-buffered formaldehyde or 70 % alcohol. Lake salinities were measured *in situ* with a WTW Multiline P4 meter. Specimens were measured under a Leica MZ12 stereomicroscope fitted with an eyepiece micrometer and dissected with entomological pins in polyvinyl lactophenol mountant on a microslide under the same microscope. Dissected specimens and appendages were examined with differential interference contrast illumination using a Zeiss Axioskop 2 microscope and drawn under bright field illumination using a Zeiss Jenamed microscope and *camera lucida*. The system of abbreviations given by Bayly (1992) was used in the description of the legs; the system of Huys & Boxshall (1991) was used for mouthparts.

Statistical significance of variation among lakes in size and size ratio between sexes was tested using 1-way analysis of variance and Duncan's multiple range test (SAS statistical package, SAS Institute 1989). Prosomal and overall length ratios were tested separately. Prosomal length was measured along the midline, overall length excluded the caudal setae.

Taxonomy

Family Centropagidae Giesbrecht
Genus *Calamoecia* Brady
***Calamoecia trilobata* n sp**

Type material

Holotype: male, dissected on microslide, Western Australian Museum of Natural Science WAM C 24446, Ardath Lake (32° 05' 52" S 118° 09' 21" E), 10.xi.1998, S A Halse & D J Cale. Allotype: female, dissected on microslide, WAM C 24447, same location and collecting details. Paratypes: male, dissected on microslide, WAM C 24448; female, dissected on microslide, WAM C 24449; 15 males and 15 females undissected in vial, WAM C 24450, same location and collecting details.

Additional material

Male, dissected on microslide, WAM C 24451; female dissected on microslide, WAM C 24452; 10 males and 10 females undissected in vial, WAM C 24453, Shackleton Lake (31° 56' 36" S 117° 53' 41" E), 21.x.1997, A M Pinder & J M McRae. Male, dissected on microslide, WAM C 24454; female dissected on microslide, WAM C 24455, Baandee Lake (31° 35' 28" S 117° 57' 21" E), 21.x.1997, A M Pinder & J M McRae. 10 males and 10 females, WAM C 24521, un-named wetland in Frank Hahn National Park (32° 57' 50" S 120° 21' 41" E), 20.viii.1998, A M Pinder & J M McRae. 5 males and 5 females, WAM C 24522, Lake Campion (31° 8' 28" S 118° 20' 17" E), 10.xi.1998, S A Halse & D J Cale.

Description of female

Size: Length of prosome of 10 females from type locality 0.73 – 1.06 mm (mean 0.83 mm); length to end of caudal rami (excluding caudal setae) 1.01 – 1.38 mm (mean 1.15 mm).

Whole animal (Fig 1A): Body of typical *Calamoecia* form, without obvious distinguishing features on 4th prosomal segment.

Antennule (Fig 1A): Antennule of 25 segments.

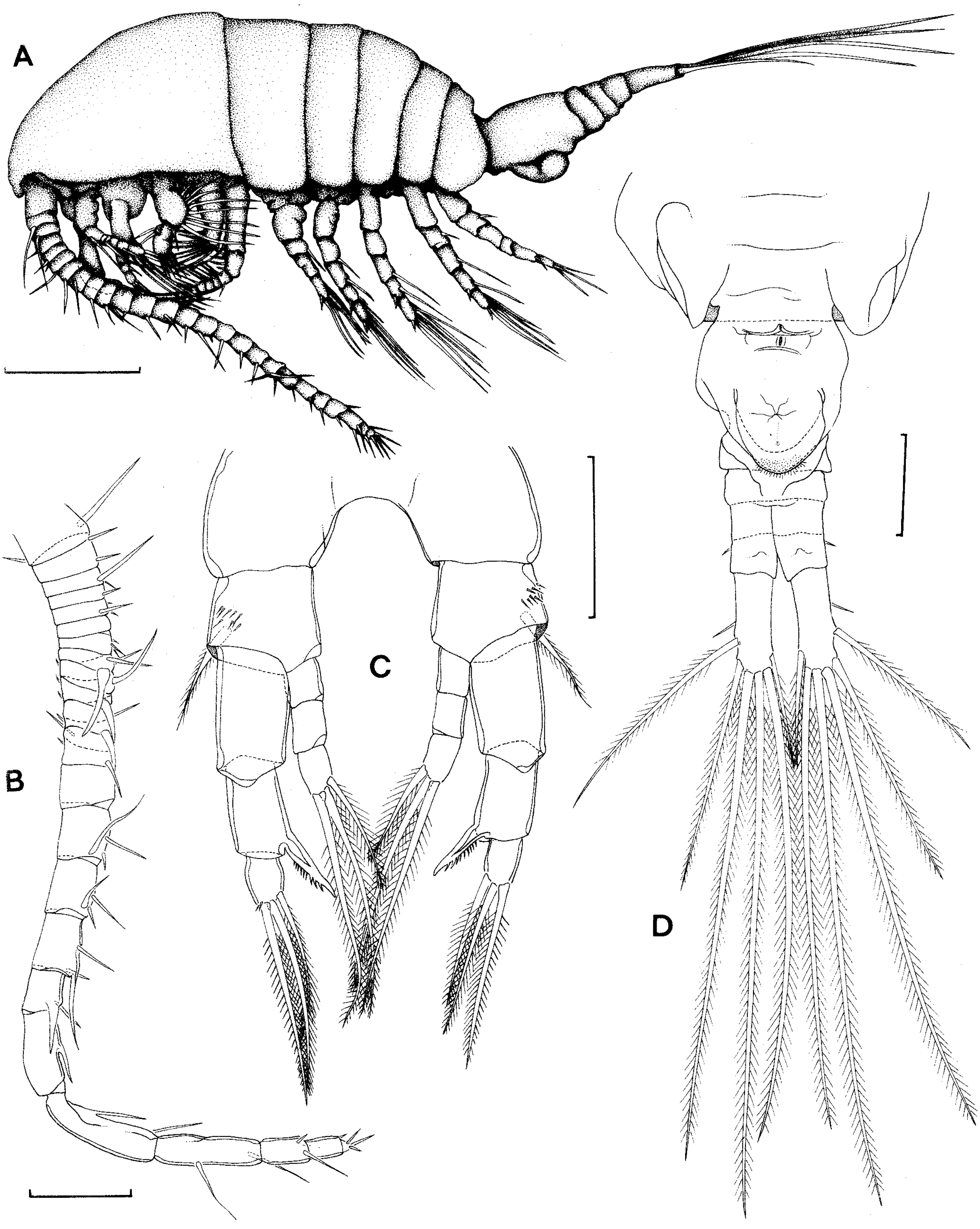

Figure 1. *Calamoecia trilobata* n sp; **A**, whole animal, lateral view of female; **B**, right antennule of male holotype (WAM C 24446); **C**, fifth leg of female allotype (WAM C 24447); **D**, ventral view of female genital segment. Scale: A = 0.5, B-D = 0.1 mm.

Antenna (Fig. 2B): Coxa with 1 seta, basis with 2 distal setae. Exopod with 7 segments and setation 1.3.1.1.1.2.3, distal segment small. Endopod with 3 segments; 2 setae on proximal segment, row of 6-9 lateral setae usually increasing in size distally on penultimate segment, 6 large terminal and 1 smaller offset seta on ultimate segment.

Mandible (Fig. 2D): Cutting edge with 8 teeth, ventral tooth low and intercusp depression between it and second tooth small. Basis with 3 setae, exopod with 5 segments and setation 1.1.1.1.2. Endopod with 2 segments, proximal segment with 3 setae, distal with 11.

Maxillule (Fig. 2C): Praecoxa with 9 spine-like setae and 3+1 finer setae on arthrite, coxal epipodite with 9 large plumose setae, coxal endite with 4 setae. Proximal basal endite with 4 setae, distal with 6, basal exite with 1, exopod with 8. Endopod with 9 setae but poorly differentiated from basis and segmentation unclear.

Maxilla (Fig. 2A): Proximal praecoxal endite with 3 large and 2 small setae and small spine on inner distal corner, distal endite with 2 large and 1 small setae. Coxal endites with 2 large and 1 small setae. Allobasis with 2 large plumose setae and 1 spine-like seta, endopod 3-segmented with setation 2.1.2.

Maxilliped (Fig. 2E): Praecoxa with 1 seta (not obviously differentiated from coxa). Coxal edites with 2, 3 and 4 setae, and tufts of spinules that become more pronounced distally. Basis with 3-4 setae and proximal row of spinules. Endopod 6-segmented with setation 2.4.4.3.3+1.4.

First leg (Fig 3A): Re2 and Re3 sometimes poorly differentiated. Outer Re spine formula 0.0.1, secondary spinules on spine not unusually large (see Bayly 1998). Re3 with 3 terminal and 1 inner setae, Re2 sometimes with 1 seta on inner edge. Re1 with 1 seta on inner edge. Ri1 with 3 distal and 1–2 inner setae. Seta on inner distal corner of B1 reaching distal edge of B2.

Fourth leg (Fig 3B): Outer Re spine formula 0.1.1 or 0.1.2. Re3 with 3 terminal and 2 inner setae, Re2 with 1 seta near inner distal corner, Re1 with 1 seta near inner distal corner. Ri2 with 1 outer, 3 terminal and 2 inner setae, Ri1 with 1 (Fig 3B) or 2 seta on inner distal third.

Fifth leg (Fig 1C): Outgrowth from inner distal corner of Re2, with obvious secondary spinules on distal side, extending approximately to distal end of Re3, which has 3 terminal setae, the inner slightly shorter than the outer 2. Ri with 3 clearly differentiated segments and not extending past Re2. Ri3 with 3 terminal seta, inner of which slightly shorter than outer 2.

Urosome (Fig 1D): Genital segment about as wide as long, viewed ventrally, with pronounced bulge on right side midway along segment and an indentation posterior to the bulge.

Description of male

Size: Length of prosome of 10 males from type locality 0.56 – 0.65 mm (mean 0.60 mm); length to end of caudal rami 0.79 – 0.93 mm (mean 0.86 mm).

Mouthparts: **Antennule** (Fig. 1B) of 22 segments with hinge between 18 and 19. Other mouthparts similar to those of female.

Fifth leg (Fig 3C-E): Right Re claw curved with small protuberance at inner distal corner of Re3 and seta on distal anterior face of Re2. Stout spine on distal inner corner of right Re1. Right Ri delicate, 3-segmented and without setae; often distorted during preservation (Ri3 bends over and all segments shrivel - *e.g.* Fig 3C); Ri3 conically shaped. Left Re 2-segmented; Re1 with ridge on outer edge of anterior face that continues into Re2 (Fig 3C); Re2 with stout terminal seta. Left Ri 1-segmented, broad and plate-like with distal portion divided into 3 lobes (Fig 3E). Left Ri often closely adpressed to left Re1 with outer lobes of Ri wrapped around inner face of Re. The 3 lobes of Ri difficult to distinguish and often distort during fixation; anterior lobe largest and posterior lobe notched (Fig 3C,E). Left B2 with small mesially directed projection or spine on inner surface.

Derivation of name

The name *trilobata* is derived from the Latin *lobus* for lobe or rounded protuberance, referring to the three lobes of the male fifth left Ri, which are one of the unique features of the species.

Remarks

Both sexes of *C. trilobata* are readily distinguished from the other 2 salt-lake *Calamoecia* species, *C. salina* and *C. clitellata*, on characters of the fifth leg. Female *C. trilobata* have 3-segmented Ri that are much shorter than on *C. clitellata* (Bayly 1962) and slightly shorter than on *C. salina* (Bayly 1961). Ri of *C. trilobata* and *C. salina* can be distinguished by the 3 long setae on the former and 2 short setae on the latter. Re3 of *C. salina* have only 2 setae, those of *C. clitellata* have 1 long and 2 very short setae, whereas *C. trilobata* have 2 long and 1 shorter setae. Another distinctive feature of female *C. clitellata* is the dorsal prominent saddle on the 4th prosomal segment (Bayly 1962). Males of the salt-lake *Calamoecia* species are even more easily separated using morphology of the fifth leg: *C. clitellata* males have 2-segmented right Ri with a lobe on Ri2, *C. salina* 3-segmented Ri with 2 small distal setae and *C. trilobata* 3-segmented Ri without setae. Left Ri of *C. clitellata* are 1-segmented and conical in shape, Ri of *C. salina* are 3-segmented with 2 terminal setae and *C. trilobata* are 1-segmented, plate-like and lobed. *Calamoecia salina* can also be distinguished by the long processes arising from B2 (Bayly 1961) and *C. trilobata* by the stout spine on the inner distal corner of right Re1.

If one attempts to key out *C. trilobata* using the dichotomous key in Bayly (1992), the following key numbers apply: 1, 2, 8, 9, 11. Dichotomy 11 contains *C. gibbosa* and *C. lucasi*, both of which have distinctly different male and female fifth legs from *C. trilobata* and are restricted to fresh water (Bayly 1961, 1979).

Most previous descriptions of species of *Calamoecia*, other than *C. t. subattenuata* (Fairbridge 1945b), place little emphasis on mouthparts or legs 1-4 because fifth legs, particularly of males, are such a reliable taxonomic character (Bayly 1961, 1962, 1992). Mouthparts and legs 1 and 4 of *C. trilobata* have been described to provide information about characteristics of the genus *Calamoecia* and in case, at a later

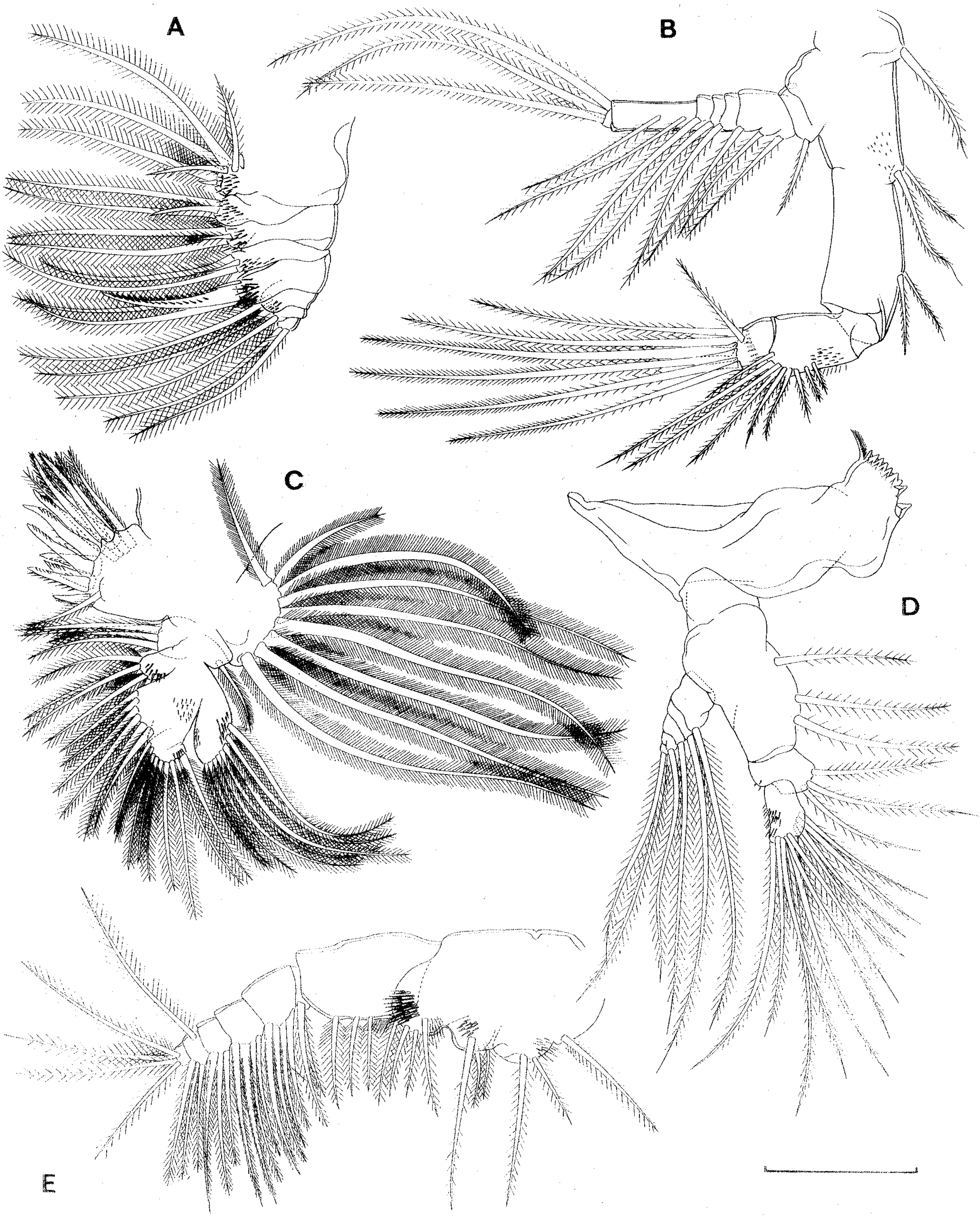

Figure 2. *Calamoecia trilobata* n sp, female paratype (WAM C 24449); **A**, maxilla; **B**, antenna; **C**, maxillule; **D**, mandibule; **E** maxilliped. Scale: 0.1 mm.

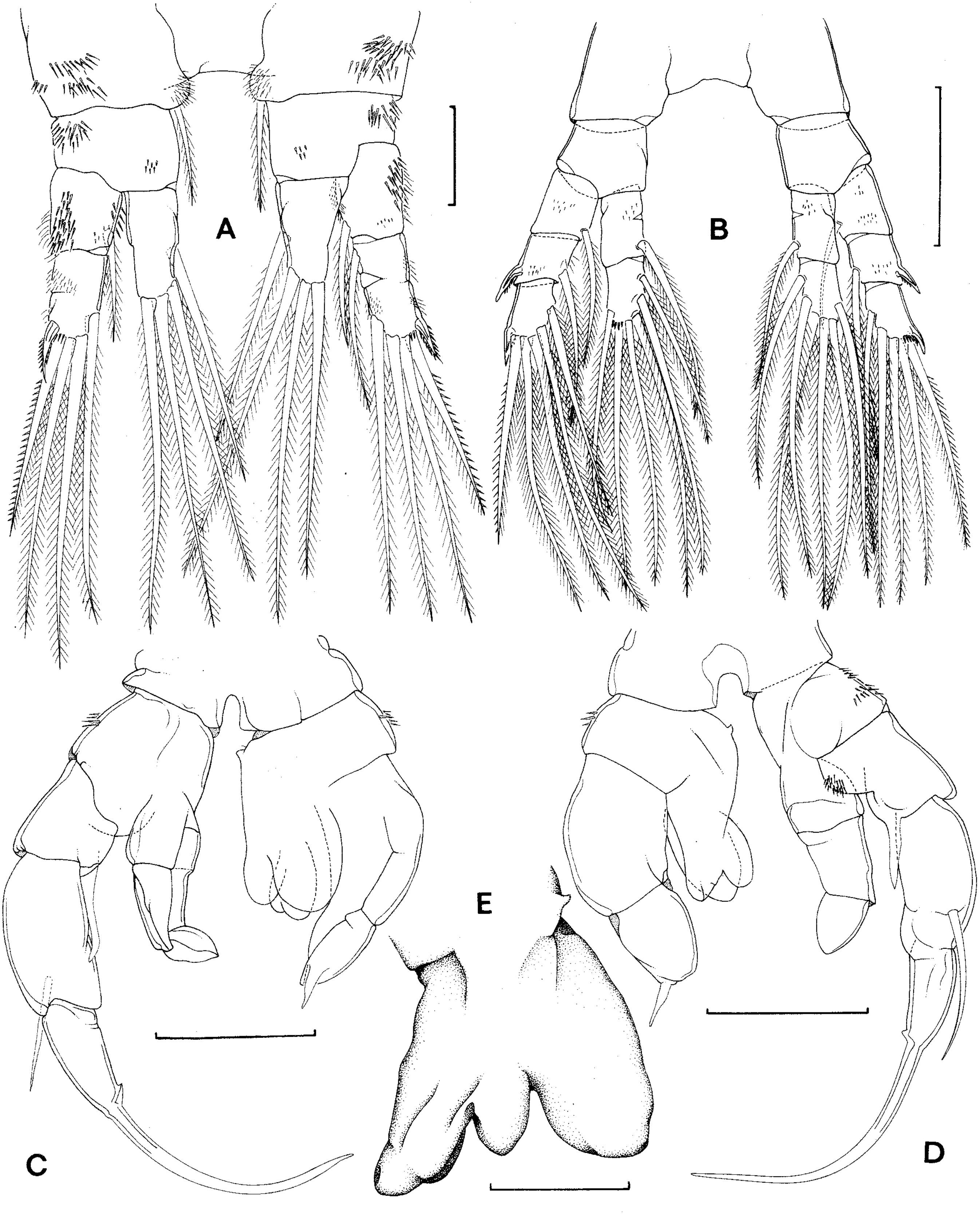

Figure 3. *Calamoecia trilobata* n sp; **A**, first leg of female allotype (WAM C 24447); **B**, fourth leg of female allotype; **C**, anterior view of fifth leg of male holotype (WAM C 24446); **D**, posterior view of fifth leg of male paratype (WAM C 24448); **E**, medial view of left endopod of male fifth leg, flattened to show the 3 lobes that characterize the species. Scales: 0.1 mm.

Table 1. Mean (± se) prosomal and overall lengths in mm, and ratio between sexes, for randomly selected adult male and female *Calamoecia trilobota* from 4 water bodies in south-western Australia. Female lengths and ratios of male:female length varied significantly between sites (*P*<0.001, means with different superscripts differed with *P*<0.05).

Site	Depth (m)	Salinity (g L^{-1})	Measure	Male	Female	Ratio ♀/♂	*n*
Ardath	ca 0.5	60	Prosome	0.60 – 0.01	0.83 – 0.01^{A}	1.38 – 0.06^{A,B}	10
			Overall	0.86 – 0.02	1.15 – 0.02^{A}	1.34 – 0.05^{A,B}	10
Campion	ca 2.0	160*	Prosome	0.61 – 0.02	0.77 – 0.03^{A}	1.26 – 0.04^{A}	5
			Overall	0.86 – 0.03	1.08 – 0.04^{A}	1.25 – 0.04^{A}	5
Frank Hahn	0.15	33	Prosome	0.59 – 0.01	1.06 – 0.02^{C}	1.79 – 0.04^{C}	10
			Overall	0.91 – 0.02	1.47 – 0.01^{C}	1.62 – 0.04^{C}	10
Shackleton	0.1	240*	Prosome	0.64 – 0.02	0.94 – 0.02^{B}	1.49 – 0.05^{B}	10
			Overall	0.93 – 0.02	1.30 – 0.03^{B}	1.40 – 0.04^{B}	10

* probably all dead at this salinity

date, more subtle taxonomic characters are used to resolve species complexes within the genus, as happened with the cyclopoid genus *Mesocyclops* (*e.g*. Dussart & Fernando 1988). While the ancestral calanoid condition of a 3-segmented endopod on legs 1-4 (Huys & Boxshall 1991) is present in centropagids such as *Boeckella* (Fairbridge 1945a; Green & Shiel 1999), segmentation is reduced in *Calamoecia* with a 1-segmented endopod on leg 1 and 2-segmented endopod on legs 2-4 (Bayly 1961). The separation between Re2 and Re3 of leg 1 is frequently indistinct in *C. trilobata* and some other species of *Calamoecia* (*e.g. C. t. subattenuata*, Fairbridge 1945b).

Some reduction of segments from the ancestral condition also occurs in mouthparts of *Calamoecia trilobata* and *C. t. subattenuata* (Fairbridge 1945b). This is most noticeable in the exopod of the antenna and the endopod of the maxillule (*cf* Huys & Boxshall 1991; Green & Shiel 1999). There are pronounced differences in the cutting edge of the mandibular coxae in *C. trilobata* and *C. t. subattenuata*, with the latter having a proportionally larger ventral tooth and greater intercusp distance between the ventral and second tooth. Such differences have been shown to be related to diet (Itoh 1970; Green & Shiel 1999).

Some species of Centropagidae, although rarely *Calamoecia*, show considerable overall variation in size, owing to a combination of sexual dimorphism and differences between season in absolute size of both sexes. Bayly (1978) suggested size ratios between sexes of the same species are usually stable, however, with species typical of temporary water bodies having greater dimorphism than those of permanent waters. *Calamoecia trilobata* differs from this pattern and displayed a variable amount of dimorphism, which was the result of changes in female size while male size remained constant (Table 1). Bayly (1978) related large size differences to low competition and predation pressure and, in agreement with this hypothesis, dimorphism in *C. trilobata* was most strongly expressed in ephemeral pools where species richness was low and few predators and competing planktivores were present. Contrary to Bayly's suggestion that dimorphism is under genetic control, it appeared to be environmentally induced in *C. trilobata*.

Ecology and biogeography

Calamoecia trilobata has been recorded from Frank Hahn National Park at a salinity of 33 g L^{-1} TDS, Ardath Lake at 56 g L^{-1} on 9.x.1997 and 60 g L^{-1} on 10.xi.1998, Baandee Lake at 63 g L^{-1}, Campion Lake at 160 g L^{-1} and Shackleton Lake at 240 g L^{-1}. Populations of the species in Ardath Lake in 1998 and in Shackleton Lake were extremely large, although it is probable that animals in Campion and Shackleton Lakes were dead (and preserved in brine) at the time of collection. Four of the lakes where *C. trilobata* has been collected are within 90 km of each other in the central Wheatbelt region of south-west Western Australia but the other (Frank Hahn National Park) is 300 km away. Given that *C. trilobata* has been collected from only 5 lakes, despite widespread collecting (Maly *et al*. 1997; S A Halse unpublished data), it is likely the species is a halobiont restricted to a comparatively small number of naturally saline lakes. *Calamoecia salina* also occurs at comparatively few lakes in Western Australia (Maly *et al*. 1997; S A Halse, unpublished data) and appears restricted to naturally saline water bodies. *Calamoecia clitellata* occurs in both naturally and secondarily saline lakes throughout the south-west and is by far the most commonly encountered of the 3 species in Western Australia.

Why more salt-adapted species of *Calamoecia* occur in Western Australia than other parts of Australia is not fully understood but is probably the result of Western Australia being an old and geologically stable landscape with a relatively long history of natural salinity. The current distribution of lakes and rivers in Western Australia reflects palaeodrainage systems that have existed since the late Cretaceous or early Tertiary. Most of these ceased to flow by the mid-Miocene (Graaff *et al*. 1977) and subsequently became saline, meaning that salt lakes have been present in the landscape since at least the beginning of the Quaternary (Salama *et al*. 1992). Many salt lakes in the Wheatbelt and Goldfields regions are 100,000s of years old (Commander *et al*. 1994) and a highly diversified salt-adapted crustacean fauna has become established, and has evolved, over this time (see De Deckker 1983; Bayly 1993). *Parartemia*, the endemic Australian anostracan genus, provides the most extreme example of radiation with 7 of the 9 described species occurring in, and 6 restricted to, the south-west (Geddes

1981). Undescribed, and presumably endemic, salt-lake species of ostracods belonging to the genera *Australocypris*, *Diacypris*, *Reticypris* and *Heterocypris* occur in the same area (S A Halse, unpublished data) and the discovery of *C. trilobata* provides further evidence that extensive radiation has occurred within several crustacean groups in saline habitats in south-west Western Australia.

Acknowledgments: I A E Bayly generously confirmed that *C. trilobata* is a new species, pointed out important characters differentiating it from other species and provided other insights into the biology of calanoid copepods in Western Australia. D P Commander supplied information about the history of salt lakes in Western Australia.

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