

# A new species of *Boeckella* (Copepoda: Calanoida) from arid Western Australia, an updated key, and aspects of claypan ecology

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**ABSTRACT** – *Boeckella pilkililli* sp. nov. is described from a single, turbid, freshwater claypan located in the arid zone of Western Australia. The type locality is currently the only known location for the species. It was collected during an opportunistic survey of wetlands in the State's arid zone following a significant summer rainfall event in 2014. The most important diagnostic feature is located on the distal segment (B2) of the 2-segmented basipodite of the male fifth right leg where the distal inner edge is grossly transformed into a large, blunt, tongue-like outgrowth. As with other *Boeckella* inhabiting temporary wetlands, *B. pilkililli* sp. nov. is a relatively large species. A mini-review of claypan ecology and a discussion of ecological aspects of body size and shape in *Boeckella* are included. An updated key to species of *Boeckella* occurring in the Australasian region is also presented. This incorporates three additional species.

**KEYWORDS:** *Boeckella pilkililli*, claypans, arid zone, wetlands, aquatic invertebrates, Australia, Zealandia

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## INTRODUCTION

Twenty species of *Boeckella* from Australasia (Australia and Zealandia) were recognised in Bayly's (1992) comprehensive work on the non-marine Centropagidae. The only additions to this have been *Boeckella spinogibba* Defaye, a species endemic to New Caledonia (Defaye, 1998), and *Boeckella timmsi* Bayly recorded from a shallow turbid claypan in Queensland (Bayly 1998). The recent discovery of the new species described below from a single shallow, turbid, freshwater claypan in Western Australia (WA) brings the total number of species now known from this region to 23, with 53 now known worldwide.

In Australia, many wetlands (including claypans) are ephemeral in nature, and those in more arid areas may fill only after significant, episodic rainfall events and then hold water for only a few weeks to a few months (Hancock and Timms 2002). Such unpredictable filling, combined with difficult access to many of these wetlands after rain, constrains surveying for aquatic invertebrate fauna in the arid zone. Consequently, the aquatic fauna has been documented from only a small number of arid zone claypans during biological surveys of the southern Carnarvon Basin, Wheatbelt, Pilbara, and Goldfields regions of WA (Halse et al. 2000; Pinder et al. 2004; Pinder et al. 2010; Quinlan et al. 2016) and

of the Paroo region in New South Wales and south-western Queensland (e.g. Hancock and Timms 2002; Timms and Boulton 2001) in eastern Australia. Many of these arid zone claypans are turbid, caused by the suspension of fine sediments, and typically have a 'muddy' appearance. While species richness is often lower in these turbid pans than other wetland types, they can comprise a unique fauna (e.g. Hancock and Timms 2002; Timms and Boulton 2001).

Specimens of the new *Boeckella* were collected in March 2014 during an opportunistic survey of a number of ephemeral wetlands (including two turbid claypans that had not been sampled previously) in WA's arid zone, following significant summer rainfall (Quinlan et al. 2016). The collection locality is within the Matuwa and Kurrara Kurrara Indigenous Protected Area (IPA), an area jointly managed by Martu (Tarlka Matuwa Piarku Aboriginal Corporation) traditional owners and the State Government of Western Australia (via Department of Biodiversity, Conservation and Attractions; Figure 1).

A description of this new species follows and includes an update to Bayly's (1992) original key for *Boeckella* species occurring in the Australasian region. This key incorporates all three of the post-1992 species, *B. spinogibba*, *B. timmsi* and *B. sp. nov.*

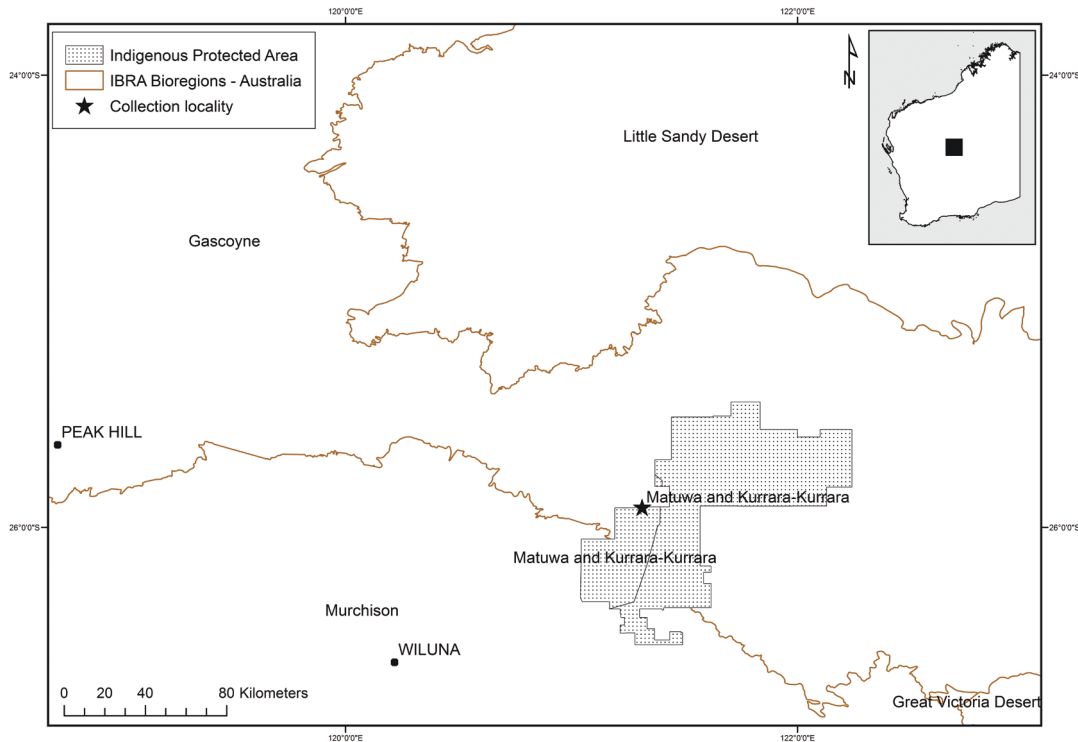


FIGURE 1 Map showing the collection locality for *Boeckella pilkililli* sp. nov. within the Matuwa and Kurrara Kurrara Indigenous Protected Area in Western Australia. Bioregions (IBRA7 <http://www.environment.gov.au/land/nrs/science/ibra#ibra>) are also illustrated.

## MATERIAL AND METHODS

### FIELD METHODS

Copepods were collected by two methods: a 50 m sweep of a plankton net (50  $\mu\text{m}$  mesh) through open water only, and a 50 m sweep of a coarser net (250  $\mu\text{m}$ ) through benthic sediments and open water. Samples were immediately preserved with 100% ethanol. Turbidity (NTU), electrical conductivity ( $\mu\text{S cm}^{-1}$ ), salinity ( $\text{g L}^{-1}$ ), water temperature ( $^{\circ}\text{C}$ ) and pH were measured in-situ using hand held calibrated meters (TPS WP-81 and WP-88).

### LABORATORY PROCEDURES

Calanoids were hand-picked from preserved samples, dissected and mounted on slides with polyvinyl lactophenol mountant. Whole specimens were measured using a Leica MZ16 stereomicroscope. Line drawings of several appendages (Figures 3A–B, 4C–D) were made by Jane McRae using a camera lucida attached to a Leica DM2500 differential interference compound microscope. A whole female specimen was drawn (J. McRae, figure 4B) using a camera lucida attached to a Leica MZ16 dissecting microscope. All scanning electron microscopy (SEM) work and images were undertaken by Dr. Russell Shiel. The specimens were prepared by dehydration through graded ethanol concentrations (50%, 75% and 100%), critical-point dried, transferred to an aluminium stub, and coated with carbon using a Quorum Q150TE carbon coater. Specimens were then examined with a Quanta 450FEG microscope. Material was deposited in the Western Australian Museum (WAM), Perth.

## SYSTEMATICS

### Subclass Copepoda H. Milne-Edwards, 1840

### Order Calanoida Sars, 1903

### Family Centropagidae Giesbrecht, 1893

### Genus *Boeckella* De Guerne and Richard, 1889

### *Boeckella pilkililli* sp. nov.

Figures 2A–C, 3A–D and 4A–D

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### MATERIAL EXAMINED

#### *Holotype*

**Australia: Western Australia:** male, collected from a shallow, temporary, turbid, freshwater claypan situated within the Matuwa and Kurrara Kurrara Indigenous Protected Area (Figure 1), 150 km north-east of Wiluna ( $25^{\circ}54'40.6''\text{S}$ ,  $121^{\circ}18'46.6''\text{E}$ ). Collected by K. Quinlan and J. Futter, 17 March 2014 (WAM C70150, dissected on slide).

#### *Allotype*

**Australia: Western Australia:** female, collected by K. Quinlan and J. Futter, 17 March 2014 from the type locality (WAM C70151, dissected on slide).

### Paratypes

**Australia: Western Australia:** All specimens collected by K Quinlan and J Futter (17 March 2014) from the type locality. 1 male, (WAM C70152, dissected on slide); 1 female, unmounted whole animal in vial with 100% ethanol (WAM C70153); 3 males and 3 females, unmounted whole animals in vial with 100% ethanol (WAM C70154); 2 males mounted on aluminium stub for SEM images (WAM C70155).

### DIAGNOSIS

This species is easily distinguishable from all other *Boeckella* by the large, blunt, tongue-like outgrowth observed on the inner edge of the B2 segment of the male fifth right leg. Of the species described to date, the new species shares some morphological affinity with *Boeckella geniculata* Bayly, which has a somewhat similar outgrowth on the right B2 segment, albeit with a markedly different shape. However, the new species differs from *B. geniculata* in many respects, including the lack of a pseudochelate right Re claw, in addition to differences in the structure and form of both the left and right Ri segments.

### DESCRIPTION

In the following description we follow the terminology, conventions and abbreviations set out in Bayly (1992, figure 1) for legs 1–5. Alternative terms for our use of B1 and B2 are coxa and basis respectively and for Re and Ri, alternative terms are exopodite and endopodite respectively. Additionally we use the symbol ‘X’ to mean ‘times’ in the multiplication sense.

#### Male

**Size:** Length of prosome (measured along midline) ranges from 1.48–1.83 mm (mean 1.66 mm; n = 9); length from front of prosome to end of caudal rami 2.30–2.67 mm (mean 2.47 mm; n = 9).

Antennule, antennae and buccal appendages shown in Figures 2A and 2B.

**Antennule:** Left antennule 25-segmented, as in female. Right antennule 22-segmented, hinged between segments 18 and 19.

**Antennae:** Re 7-segmented, terminating in 3 setae. Ri 2-segmented. Ri2 prolonged by a lobe, giving the appearance of a third segment, but with no complete suture line visible. Proximal segment with 8 setae and lobe with 6 long setae, 1 shorter, thinner seta, and a row of spinules on inner margin.

**Labrum:** rounded anterior edge, ornamented with a dense fringe of long hairs (Figure 2A).

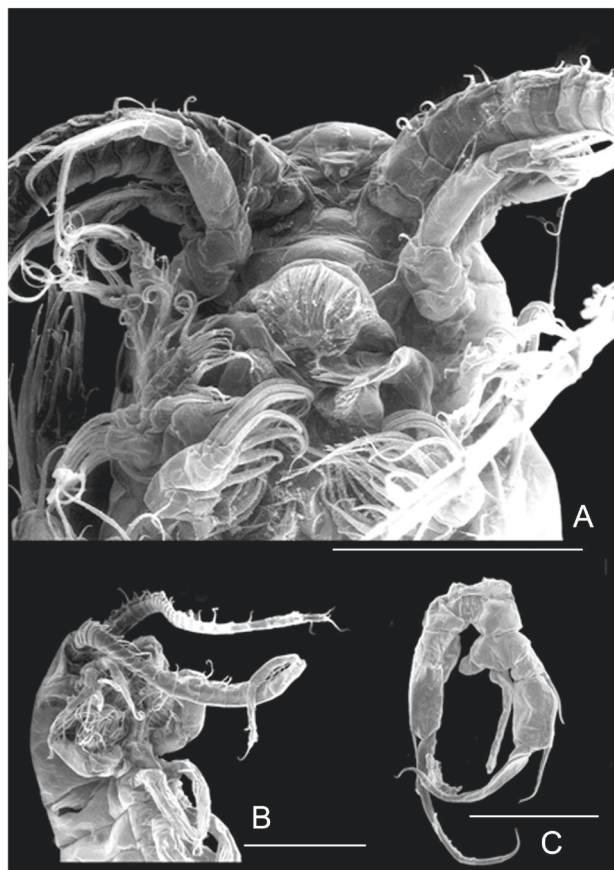
**Mandible:** Masticatory edge with 8 teeth and 1 spinulose seta. Re of palp 4-segmented, Ri of palp 2-segmented, proximal segment with 4 setae, terminal

segment with 8 setae and a row of spinules on the inner margin.

**Maxillule:** External lobe bearing usual 9 plumose setae, internal lobe with 9 + 4 spine-like setae; B1 endites with 4 setae. B2 with 5 marginal setae, Ri 2-segmented, separated from B2, with 4 setae on proximal segment and 5 on distal segment. Re unsegmented with 9 setae.

**Maxilla:** The first endite (proximal) bearing 3 long spinulated setae and 2 shorter setae. Endites 2–4 bearing 2 long spinulated and 1 shorter setae. The fifth endite bears 2 long spinulated setae, 1 shorter seta and 1 large spine-like seta. Ri 3-segmented with setation pattern: 2, 1, 2.

**Maxilliped:** B1 segment slightly shorter than B2, bearing a submarginal row of fine spinules along the distal margin of segment. B2 with a submarginal row of fine spinules along the proximal inner half and 3 setae along the distal inner half of this segment. Ri 5-segmented, although full segmentation is difficult to distinguish.



**FIGURE 2** *Boeckella pilkililli* sp. nov. scanned electron micrograph (SEM) images of male paratypes, mounted on an aluminium stub (WAM C70155): A, ventral view of the anterior end of prosome; B, anterior half of body, showing hinged antennule; C, fifth leg (posterior aspect). Scale: A & C = 0.3 mm, B = 0.5 mm.

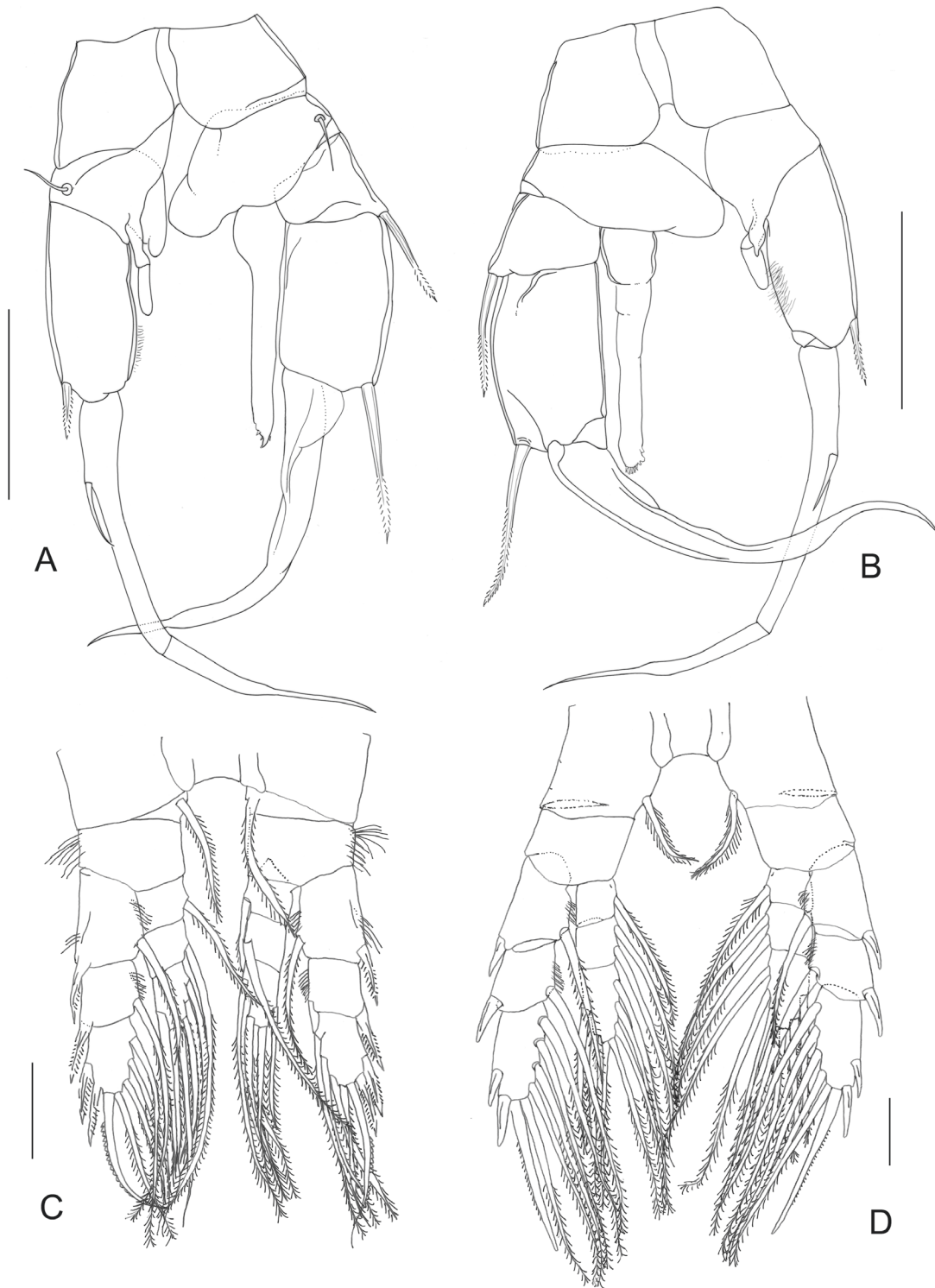


FIGURE 3 *Boeckella pilkililli* sp. nov.; A & B, posterior and anterior aspects, respectively, of male fifth legs (WAM C70150 and WAM C70152); C, first pair of legs of male holotype (WAM C70150); D, fourth pair of legs of male holotype (WAM C70150). Scale: A & B = 0.2 mm, C & D = 0.1 mm.

*Urosome*: Composed of 5 somites. Caudal rami symmetrical; each ending in five long terminal setae lined with fine hairs, and one shorter, thinner seta inserted on the inner distal corner. The setation pattern is same as female.

*Legs 1–4*: Re and Ri of legs 1–4 distinctly 3-segmented. Legs increasing in size from 1 through 4. Re1 and Re2 of each leg bearing a robust spine at outer distal corner of segment. Re3 bearing two short outer spines, one longer terminal spine on distal edge, and five long setae (four in leg 1) along inner edge of segment (Figures 3C–D). The serrations along each of the spines on segments Re1–Re3 of leg 1 are longer and more robust, than the spine serrations on legs 2–4 (Figures 3C–D). Setae all bearing fine hairs. The formulae of spines and setae for legs 1–4 are as follows:

	B1	B2	Re	Ri
leg 1	0–1	0–0	I–1; I–1; II–I–4	0–1; 0–1; 1–2–3
leg 2	0–1	0–0	I–1; I–1; II–I–5	0–1; 0–2; 2–2–4
leg 3	0–1	0–0	I–1; I–1; II–I–5	0–1; 0–2; 2–2–4
leg 4	0–1	0–0	I–1; I–1; II–I–5	0–1; 0–2; 2–2–3

*Fifth leg* (Figures 2C, 3A–B): Inner edge of right B2 with large, blunt, tongue-like outgrowth extending inwards beyond median plane and almost to edge of left B2 segment. *This is undoubtedly the most diagnostic character of this new species.* Right Ri swollen near basal attachment, greatly elongated, reaching well beyond junction of right Re2 and Re3 (Re claw), 6X as long as maximum width near basal attachment, with distal extremity bearing small, curved, spine-like process and several minute serrations. Right Re2 bearing long spine at outer distal corner, with length of spine equal to length of segment bearing it. Left B2 segment with small lobe at inner distal corner. Left Ri 2-segmented with terminal segment (Ri2) digitate, extending c. half-way along inner edge of left Re1. Left Re claw 2-segmented with Re2 c. 1.2X longer than Re3. Outer spine inserted at 0.3X distance along Re2. Both left and right Re claws narrow abruptly before tapering to a point at the distal extremity.

#### *Female*

*Size*: Length of prosome (measured mid-dorsally to exclude large ‘wing’ structures on last prosomite) 1.69–1.98 mm (mean 1.86 mm; n = 8); length from front of prosome to end of caudal rami 2.48–2.81 mm (mean 2.65 mm; n = 8). Prosome with pedigerous somites 1 and 2 and 4 and 5 separate. ‘Wing’ structures at the posterior lateral margin of last prosomite well

developed and extend c. 0.8 of the way along genital compound somite (Figure 4B).

*Antennule*: 25-segmented. Aesthetascs on segments 1, 2, 3, 5, 7, 9, 11, 12, 14, 16, 19 and 25. Short spine present on segments 8 and 12 (Figure 4A). Antennule c. 1.8 mm in length, and when extended posteriorly reaching only as far as the posterior end of the prosome (Figure 4B). Antennae and buccal appendages as in male.

*Urosome* (Figure 4C): Genital compound somite c. 1.2X as long as maximum width. Free urosomites 2 and 3 approximately equal in width, but somite 3 1.3X length of somite 2. Caudal rami c. 2X as long as maximum width, each ending in five long terminal setae lined with fine hairs, and one shorter, thinner seta inserted on the inner distal corner, Caudal rami lined with hairs along innermost margins.

*Legs 1–5*: Re and Ri of legs 1–4 distinctly 3-segmented. Formulae of spines and setae for legs 1–4 identical to those of male. Fifth leg of female similar in size to leg one, both of which are smaller than legs 2–4. Re1 of fifth leg with one outer spine, Re2 with one outer spine and the usual centropagid inner process, Re3 with two outer spines, one terminal spine and four inner setae (Figure 4D). Ri1 of fifth leg with fine hairs on outer edge and one plumose seta on inner edge, Ri2 with one inner plumose seta, Ri3 with 2 inner, 2 terminal and 2 outer plumose setae (Figure 4D).

#### ETYMOLOGY

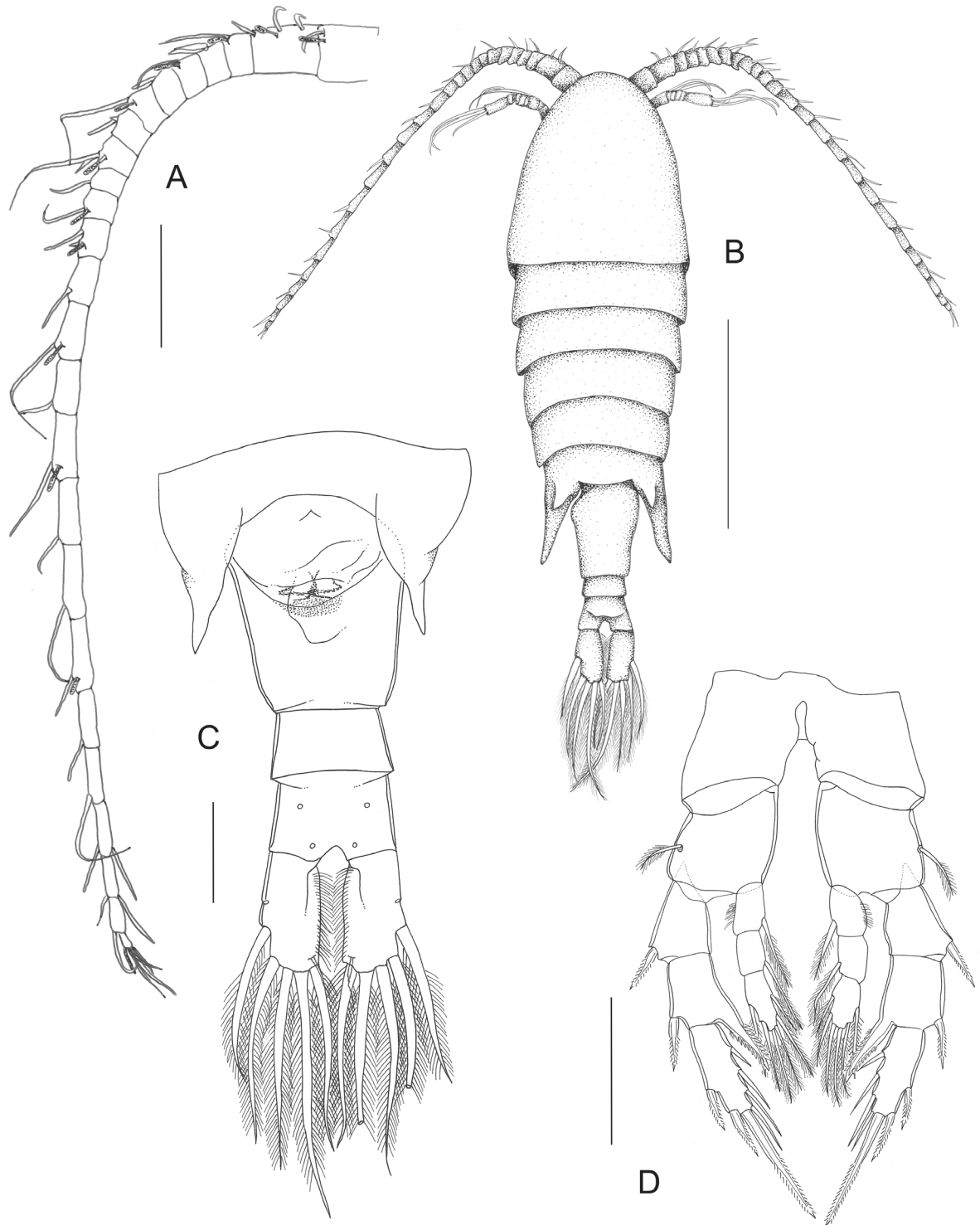
The specific name ‘pilkililli’ is the word for claypans in the language of the southern Martu Aboriginal people (Tarlka Matuwa Piarku Aboriginal Corporation, 2015) and refers to the habitat type from which this species was collected; noun in apposition.

It was named in consultation with Elders from the Tarlka Matuwa Piarku Aboriginal Corporation, the traditional custodians of the Matuwa and Kurrara Kurrara Indigenous Protected Area, to acknowledge the land on which it was found.

## DISCUSSION

### COMPARATIVE ASPECTS OF THE MALE FIFTH RIGHT BASIPODITE IN SPECIES SEPARATION

In the male fifth pair of legs of *Boeckella* the right basipodite, which has 2 segments (B1 and B2), is typically of little importance among the secondary sexual structures that allow the separation of species. There are, however, exceptions. The South American (SA) species, *B. bergi* Richard, is the only species in which the B1 is sexually transformed by having a prominent projection at the inner distal corner. Modification of the right B2, however, occurs in a minority of species:



**FIGURE 4** *Boeckella pilkilli* sp. nov.; A, Antennule of female allotype (WAM C70151); B, whole animal, dorsal view of female paratype (WAM C70153); C, ventral aspect of female urosome, including genital compound somite (WAM C70151). D, fifth pair of legs of female allotype (WAM C70151). Scale: A, C & D = 0.2 mm, B = 1mm.

1. in *B. rubra* Smith it bears a prominent spine at the inner distal corner;
2. in *B. geniculata* it has a broad expansion along the whole of the inner edge;
3. in *B. bispinosa* Bayly, *B. propinqua longisetosa* Smith, *B. bergi*, *B. meteoris* Kiefer (SA) and *B. poopoenensis* Marsh (SA) there is a blunt projection on the inner edge.

*B. pilkililli* sp. nov. approximates somewhat to *B. geniculata* and joins species in group (3) in a highly exaggerated manner. The inner edge of B2 is produced into a large, tongue-like expansion that crosses the median plane. In summary, *B. pilkililli* and *B. geniculata* possess the most highly transformed male fifth right B2 in the entire genus. However, *B. pilkililli* differs markedly from *B. geniculata* in that the right Re claw is not pseudochelelate, and the right Ri is straight rather than possessing a geniculate bend.

#### DISTRIBUTION

*Boeckella pilkililli* sp. nov. is currently known only from its type locality; a characteristically shallow (< 40 cm deep), temporary, turbid (turbidity 319 NTU), freshwater (salinity 0.09 g L<sup>-1</sup>) claypan, which had a pH of 7.76 and a water temperature of 28.6 °C (Quinlan et al. 2016). The new species may be more widespread and associated with other turbid claypans within the Gascoyne and Murchison IBRA (Interim Biogeographic Regionalisation for Australia; Australian Government 2012) bioregions. However, additional survey opportunities to determine its distribution are limited in the short-term by the unpredictable nature of rainfall in the arid zone, the temporary nature of these pans and the difficulty in accessing them after episodic rains.

#### ASPECTS OF AUSTRALIAN CLAYPAN ECOLOGY

##### *General features and life-histories of calanoids*

Claypans are a distinctive aspect of the arid and semi-arid regions of Australia, and famous nineteenth century explorer, Ernest Giles, was perhaps the first (Giles 1889, vol. 1, p.39) to give a good definition of one. The use of claypans as a source of fresh water by desert Aborigines was discussed by Bayly (1999).

Williams (1985), in his general classification of temporary standing waters, assigned claypans to a distinct type ('Type D') characterised by being discrete, unpredictably filled and having fresh water. Halse et al. (2000) studied a series of claypans in the southern Carnarvon Basin, Western Australia, and found that less turbid ones, and those where water levels were still high (pre-recession phase) had higher species richness. Hancock and Timms (2002) studied the ecology of four

claypans in the Paroo region of semi-arid Australia and concluded that among the more important factors characterising these habitats were: shallowness, high turbidity, short filling phase, low conductivity, highly variable temperatures and lack of vegetation. This list, which also fits the habitat of *Boeckella pilkililli* sp. nov., contains several stress factors which would suggest that claypans should contain lower species richness or a more simplified community structure than deeper, more permanent, clear-water, vegetated, freshwater ponds or lakes. In the Paroo region, where Australian claypans have been best studied, this expectation is met, but not to the extent that one would expect. Timms (2002) makes two important statements on this issue: (1) 'Compared with other wetlands in the Paroo, claypans are one of the least speciose'; (2) 'Even so they are surprisingly rich considering the lack of vegetation and the homogeneous habitat.'

There are preliminary indications that flooded claypans may contain distinctive, specialist species. Paroo crustacean species characteristic of, or known only from, claypans (Timms 2002) include: *Branchinella* 5 spp, *Ozestheria* (formerly *Caenestheria*) 2 spp, *Triops australiensis* Spencer & Hall, *Daphnia projecta* Hebert, *Moina australiensis* Sars, *Latonopsis brehmi* Petkovski, *Calamoecia* 3 spp, *Boeckella robusta* Sars and *B. timmsi*. The last mentioned species is currently known only from highly turbid claypans in the Currawinya National Park (Bayly 1998) and the Paroo region (Hancock and Timms 2002) where it appears fleetingly and very early in succession between 7 and 18 days after filling. *B. pilkililli* may approximate to a counterpart species in the western half of the Australian arid core.

The type locality filled after significant rainfall across the Gascoyne and Murchison bioregions in early and late January of 2014. Remote sensing data acquired from Landsat satellites 7 and 8, indicated that the claypan held water from 28 January to 12 May 2014. Specimens of *B. pilkililli* were collected on 17 March 2014 about 6–7 weeks after filling near the middle of the hydroperiod. We do not know when this species first appeared in the wetland, or how long it persisted, but it evidently appears later in succession than *B. timmsi*. More is known about the life-history of some other temporary-water species of *Boeckella*. *B. robusta* Sars is a short-lived (c. 15–30 days after filling) species in claypans in the Paroo region (Timms 2001). *B. major* Searle matures rapidly, typically within a few weeks after a wetland fills, produces resting eggs and then disappears (Green et al. 1999). *B. pseudocheleae* Searle reaches maximum numbers later, more towards the middle of a pool's hydroperiod (Morton and Bayly 1977). At this stage more information is needed to determine the life-history of *B. pilkililli*.

### *Ecological aspects of body size in Boeckella*

Of the 22 known species of *Boeckella* in the Australasian region, *B. robusta* and *B. major* are two of the largest, with body lengths >4 mm recorded, and *Boeckella minuta* Sars, with a male body length <1.2 mm (female <1.57 mm), one of the smallest (Bayly 1964, 1978; Green et al. 1999; Timms 1968). Of the remaining species, there is considerable overlap in the range of mean body size, owing largely to the differences in size between males and females (sexual dimorphism) and differences due to seasonal variation (Bayly 1964; Bayly 1978). Despite this variation, it is noted here that *B. pilkhilli* is one of the larger species of the genus, with males ranging from 2.30–2.67 mm in length (to end of caudal rami; n = 9) and females 2.48–2.81 mm in length (n = 8).

Given that body size can be quite variable, both within and between populations of a species, it has been suggested (Bayly 1978) that the actual ratio between the mean body size of males and females in a given population of a species, is a more reliable metric to use for comparison between species of *Boeckella*. According to Bayly (1978), the magnitude of sexual dimorphism is larger in some species (e.g. *B. minuta*, *B. symmetrica* Sars, *B. opaqua* Fairbridge and *B. bispinosa*), and less so in others (e.g. *B. rubra*, *B. nyoraensis* Searle and *B. tanea* Chapman). With such a small sample size, it is difficult to provide a statistically valid conclusion, however, for *B. pilkhilli*, the ratio of female length: male length (from front of prosome to end of caudal rami) is 1.07, and is therefore not considered to be highly dimorphic. This is also true for other large species such as *B. robusta* and *B. major* (Bayly 1978).

Distinct differences in body proportions exist between calanoid copepods which occupy a limnetic habitat and those that occupy a more littoral/pond habitat, as discussed in Timms (1979). To better understand the type of habitat perhaps utilised by *B. pilkhilli* sp. nov, body proportions for this new species were quantified. Timms (1979) calculated ratios of metasomal length: metasomal width (ML:MW) and antennule length: metasomal length (AL:ML) to determine the variation in body build between species. His calculations of so called 'metasomal' (=prosomal) length and width are equivalent to prosomal length (PL) and prosomal width (PW). The ratio of PL:PW for males of *B. pilkhilli* was  $2.57 \pm 0.19$  SD (n = 9) and  $2.62 \pm 0.18$  (n = 8) for females. The AL:PL ratio was  $1.04 \pm 0.08$  for males and  $0.98 \pm 0.08$  for females. With only a limited sample size, a more statistically valid conclusion is difficult. However, these body proportions for *B. pilkhilli* are intermediate between the ratios for littoral and limnetic copepods (2.1–2.3

and 3.0–3.4 respectively) given in Timms (1979). *B. pilkhilli* is therefore considered to be of a medium build with short antennules, having a AL:PL ratio less than that of littoral species such as *B. major* (e.g. <1.28). These body proportions would suggest that *B. pilkhilli* is unlikely to be limnetic in habit. If this hypothesis is correct, it may be important in sampling claypans to ensure collection from all habitats (benthic and limnetic) as was done in the present study. Traditionally, planktonologists try to avoid doing this because 'dirty' collections are difficult to examine.

*Calamoecia halsei* Bayly, another centropagid calanoid, co-existed with *B. pilkhilli* at the type locality. It is also an ephemeral wetland specialist and was easily distinguished from the new species by the clear difference in size. *Boeckella pilkhilli* is approximately two times larger, with a mean body length (to end of caudal rami) of 2.47 mm for males and 2.65 mm for females, whereas the mean body length of *Calamoecia halsei* was 1.10 mm for males (n = 5) and 1.30 mm for females (n = 5). The co-occurrence of calanoids is common in the genera *Boeckella* and *Calamoecia* in WA (e.g. Bayly 1982, 1985; Maly and Maly 1997; Maly et al. 1997; Quinlan et al. 2016; Storey et al. 1993; Williams 1979) and so too is size difference between species of co-occurring calanoids (e.g. Maly and Maly 1997; Halse and McRae 2001).

An updated key to the described Australasian species of *Boeckella*, based on characters of the male fifth leg, is provided below. As far as practicable, the key has remained true to Bayly's (1992) original dichotomous key. The first of three new additions (*B. pilkhilli*) enters the key at couplet 7. From there, the original key is altered, with *B. timmsi* appearing in the revised couplet 10 and *B. spinogibba* appearing in the revised couplet 18. *B. spinogibba* and the three species endemic to New Zealand (*B. dilatata* Sars, *B. hamata* Brehm and *B. tanea*) are denizens of the largely sunken continent of Zealandia with which they may be presumed to have had an ancient association (Bayly and Boxshall 2009; Mortimer et al. 2017).

### AN UPDATED KEY TO SPECIES OF *BOECKELLA* OCCURRING IN THE AUSTRALASIAN REGION (AUSTRALIA AND ZEALANDIA)

(Key features refer to the male fifth leg unless otherwise stated. All figures in the key, with the exception of Figures 11, 13 and 21, are taken (with permission) from Bayly, 1992; pp. 11–19).

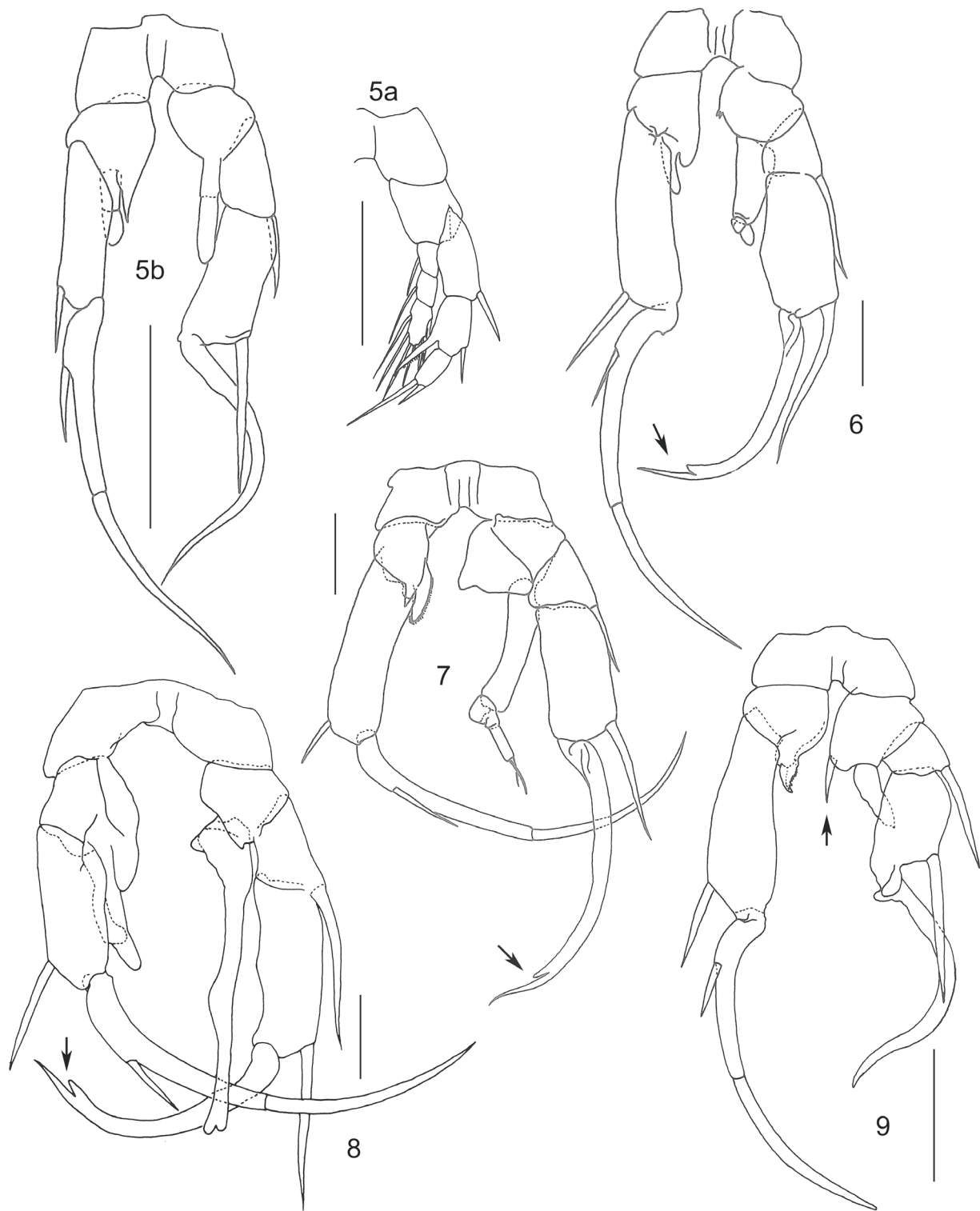


1. Re3 of *female* fifth legs with 2 spines (Figure 5A) (For male fifth legs see Figure 5B).  
.....*B. minuta* Sars, 1896
- Re3 of *female* fifth legs with more than 2 spines ..... 2
2. Right Re claw pseudochelate at extremity (see arrows in Figures 6–8) ..... 3
- Right Re claw not pseudochelate (tapering smoothly to single point) at extremity ..... 5
3. Right Ri extending no more than halfway along inner edge of right Re2 (Figure 6).  
.....*B. shieli* Bayly, 1985
- Right Ri extending to distal limit of right Re2 or beyond..... 4
4. Right B2 extending inwards at least as far as median plane; right Ri 3-segmented, without basal inner projection, distal quarter bent outwards through about 45 degrees (Figure 7).  
.....*B. geniculata* Bayly, 1964
- Right B2 not extending inwards as far as median plane; right Ri extremely long but 1-segmented, with basal inner projection, distal quarter not bent outwards (Figure 8).  
..... *B. pseudochela*e Searle, 1912
5. Right B2 with prominent spine at inner distal corner, half as long as, and in addition to, right Ri (see arrow Figure 9). .....*B. rubra* Smith, 1909
- Right B2 with no spine (but sometimes with blunt outgrowth) at inner distal corner in addition to right Ri..... 6
6. Right Ri with 2 or 3 spines at distal extremity (see arrow Figure 10). ..... *B. bispinosa* Bayly, 1967
- Right Ri either smoothly rounded, or with single spine-like process at distal extremity..... 7
7. Right B2 with large, blunt, tongue-like outgrowth at inner distal corner, extending inward beyond median plane; right Ri elongate, extending beyond junction of right Re2 and Re3 (Figure 11).  
.....*B. pilkililli* sp. nov.  
(A large species endemic to Western Australia. Recorded from a shallow, turbid, freshwater claypan in the State's inland).
- Right B2 lacking large, blunt, tongue-like outgrowth at inner distal corner..... 8
8. Distance between right B2 and left B2 at level of their attachment to B1 greater than proximal width of either right or left B2 (see arrows Figure 12). ..... *B. dilatata* Sars, 1904
- Distance between right B2 and left B2 at level of their attachment to B1 less than proximal width of either right or left B2. .... 9
9. Right Ri with inner projection or sharp angle near proximal attachment to right B2 (see arrows Figure 13–17). ..... 10
- Right Ri lacking inner projection or sharp angle near proximal attachment to right B2. .... 14
10. Right Ri sub-triangular and 2- or 3-segmented, reaching less than half-way along inner edge of right Re2 (Figure 13). ..... *B. timmsi* Bayly, 1998  
(A rare species, collected from a shallow, highly turbid freshwater claypan in Queensland) (Note: Figure 13 is after Bayly, 1998).
- Right Ri not sub-triangular, typically 1-segmented and of variable length (Figures 14–17). ..... 11
11. Left B2 with conspicuous teeth attached in vicinity of inner distal corner (see arrow or arrows in Figures 14–15). ..... 12
- Left B2 with no conspicuous teeth attached in vicinity of inner distal corner. .... 13
12. Left B2 with teeth in single row (see single arrow Figure 14). .....*B. triarticulata* Thomson, 1883
- Left B2 with teeth in two rows (or apparently so) (see two arrows Figure 15). ..... *B. fluvialis* Henry, 1922
13. Right Ri extending only c. half-way along right Re2, right Re claw with abrupt narrowing near distal extremity (see arrow Figure 16). .....  
.....*B. hamata* Brehm, 1928
- Right Ri extending to distal extremity of right Re2, right Re claw tapering evenly to distal extremity (Figure 17). .....*B. robusta* Sars, 1896
14. Left Re1 long relative to right Re, distal extremity lying directly opposite distal extremity of right Re2 (see dotted lines at right angles in Figures 18–20). ..... 15
- Left Re1 short relative to right Re, distal extremity lying directly opposite a point only 0.4–0.7 times distance along inner edge of right Re2 (in nearly all cases it is the point of insertion of the outer spine of left Re2, instead of the extremity of left Re1, that lies opposite the extremity of right Re2). ..... 17

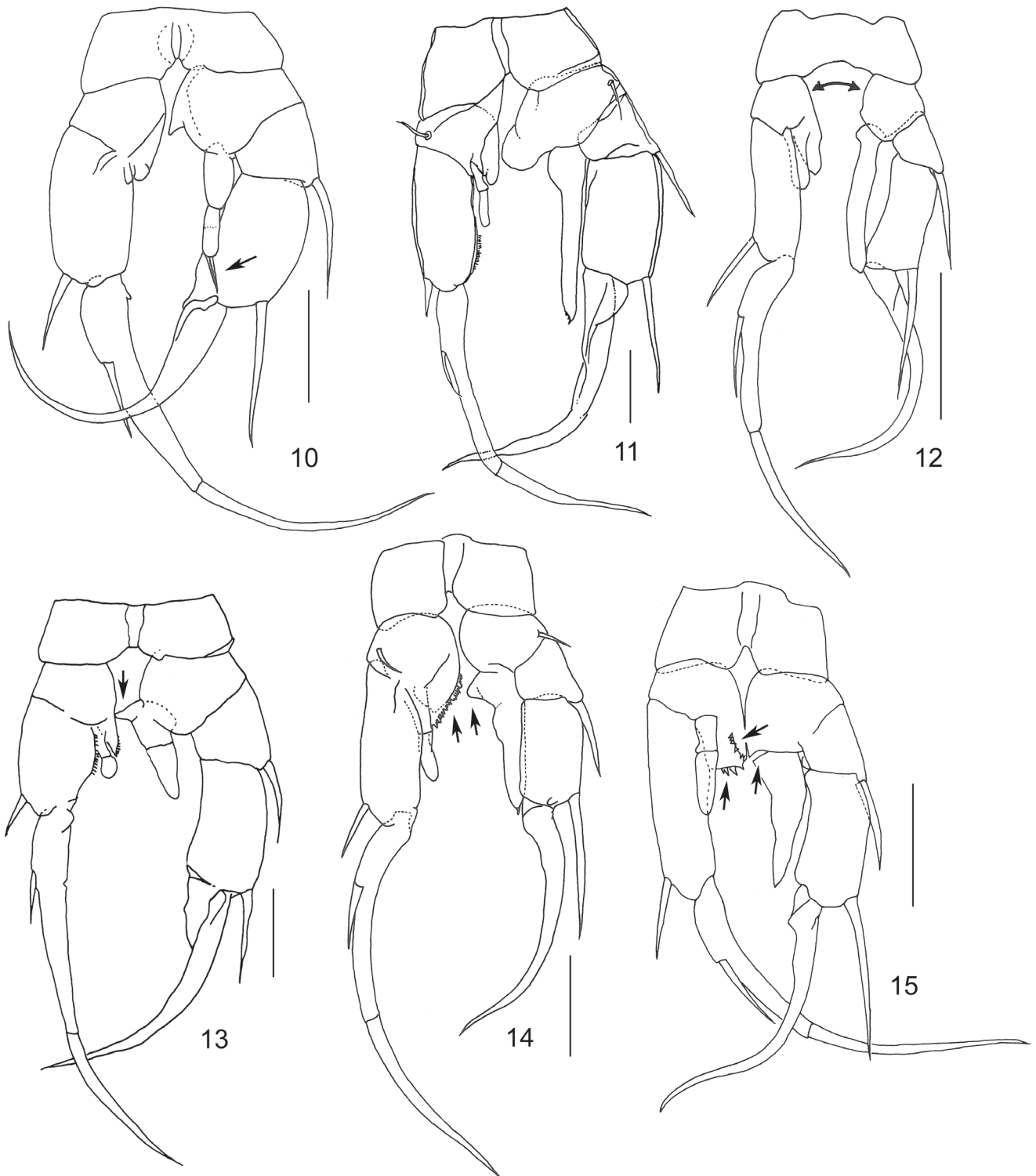
15. Right Ri with 45° bend (Ri3 at angle of 45° to long axis of Ri1) (see arrow Figure 18); right Re claw not recurved, narrowing abruptly about  $\frac{2}{3}$  length from distal extremity (see arrow Figure 18).  
..... *B. nyoraensis* Searle, 1912
- Right Ri straight (typically distinctly or indistinctly 2- or 3-segmented); right Re claw recurved and tapering evenly to distal extremity..... 16
16. Left B2 produced at inner distal corner into pointed process bearing small spines along inner edge only, this segment with no upraised semi-circular lobe on anterior aspect (Figure 19).  
..... *B. delicata* Percival, 1937
- Left B2 produced at inner distal corner into pointed process bearing small spines on both inner and outer edges, this segment with upraised semi-circular lobe on anterior aspect immediately proximal to pointed process (Figure 20).  
..... *B. montana* Bayly, 1964
17. Right Ri 1-segmented and narrowing slightly towards distal extremity (Figures 21–23)..... 18
- Right Ri 2- or 3-segmented (sometimes indistinct), with variable articulation. .... 20
18. Left Ri small, reduced to a triangular plate and hidden by a rounded process covered in thick spiniform hairs; left B1 noticeably longer than right B1 (Figure 21) ..... *B. spinogibba* Defaye, 1998 (A small species collected from shallow water bodies in New Caledonia) (Note: Figure 21 is after Defaye, 1998).
- Left Ri large, 2-segmented, extending at least  $\frac{2}{3}$  distance along inner edge of left Re1. .... 19
19. Outer spine left Re2 (= basal portion left Re claw) large, extending to distal extremity of left Re2 (see arrow Figure 22) or at least  $\frac{2}{3}$  distance from point of insertion to distal extremity of Re2  
..... *B. opaqua* Fairbridge, 1945
- Outer spine left Re2 (= basal portion left Re claw) small, extending only about half distance from point of insertion to distal extremity of Re2 (see arrow Figure 23). .... *B. symmetrica* Sars, 1908
20. Left Ri thumb-like (typically 2-segmented), at least twice as long as basal width, extending about 0.3 times distance along inner edge of left Re1 (see arrow Figure 24) (large body size; length both sexes > 2.5mm). .... *B. major* Searle, 1938
- Left Ri vestigial (1 sub-circular segment largely obscured between inner distal corner of left B2 and inner proximal corner of left Re1), not extending along inner edge of left Re1 (see small dotted circles in Figures 25, 27–28) (small or medium body size; length both sexes < 2.5 mm)..... 21
21. Right Re claw recurved (initially turned inwards, then turned outwards towards extremity) (see arrows Figure 25). .... *B. saycei* Sars, 1908
- Right Re claw not recurved (continuously curved inwards from proximal attachment to extremity).. 22
22. Left B2 with large, complex (bearing c. 6 small teeth and a small terminal cone-like process) projection at inner distal corner, extending c. 0.5 times distance along inner edge of left Re1 (Figure 26). .... *B. tanea* Chapman, 1973
- Left B2 with small, simple projection at inner distal corner, extending no more than 0.25 times distance along inner edge of left Re1. .... 23
23. Mean ratio (length right Ri1)/(length right Ri2 plus length right Ri3) less than 2.5 (Figure 27).  
..... *B. propinqua propinqua* Sars, 1904
- Mean ratio (length right Ri1)/ (length right Ri2 plus length right Ri3) greater than 2.5 (Figure 28).  
..... *B. propinqua longisetosa* Smith, 1909

## ACKNOWLEDGEMENTS

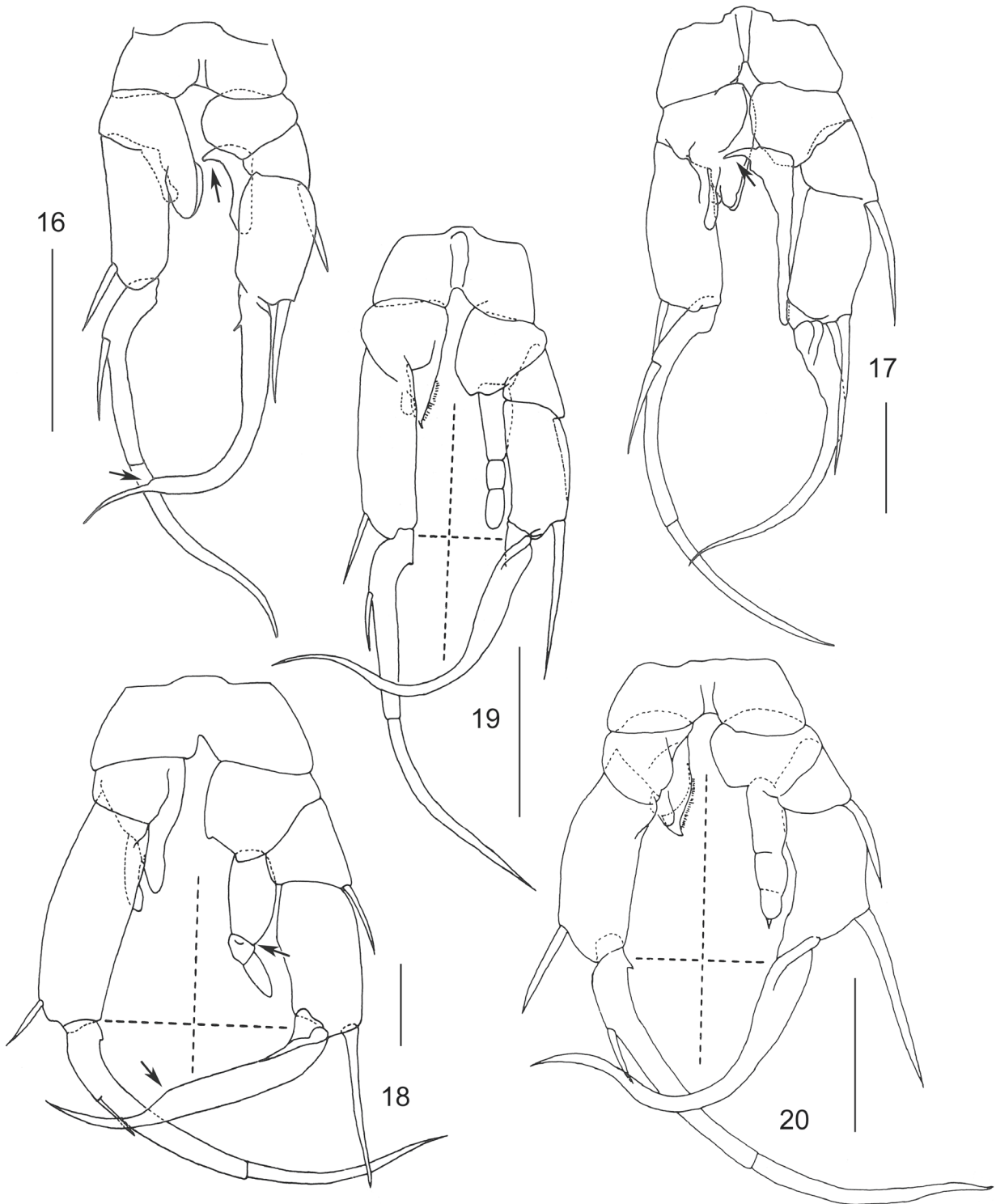
We thank the Martu (Tarlka Matuwa Piarku Aboriginal Corporation) for accepting the honour of naming this new species, and to Hamish Morgan and Stephen van Leeuwen for valued assistance in this process. We are grateful to Jane McRae for specimen illustrations (3A–B, 4B–D) and are indebted to Russell Shiel and the staff of Adelaide Microscopy (Angus Netting and Lyn Waterhouse) for providing, and assisting with, the SEM work and images. Acknowledgement and thanks go to Ian Keally, Jennifer Jackson and Julie Futter for advice on site selection and field assistance during the survey work and to Rebecca Coppen for technical support in the laboratory. We also thank Adrian Pinder, Juliet Wege, Bart Huntley and David Cale for providing assistance with components of the manuscript. Finally we thank the two reviewers for their valued comments on the manuscript. Funding of this work was provided by the WA Department of Biodiversity, Conservation and Attractions (Science and Conservation, and Goldfields Region).



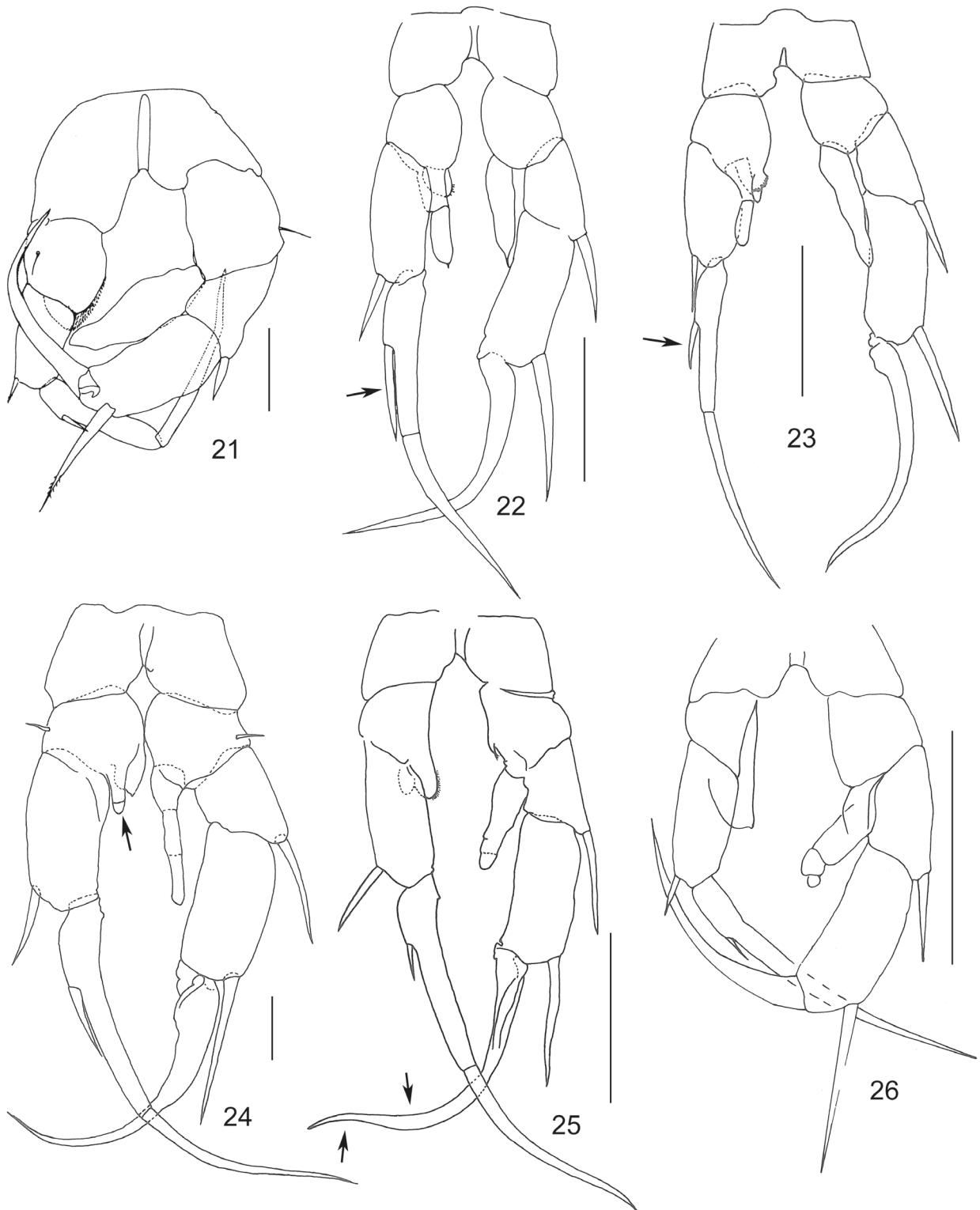
FIGURES 5-9 *Boeckella* fifth legs (posterior aspect); 5A, *B. minuta* female right fifth leg; 5B, *B. minuta* male fifth legs; 6, *B. shieli* male fifth legs; 7, *B. geniculata* male fifth legs; 8, *B. pseudochelae* male fifth legs; 9, *B. rubra* male fifth legs. Scale = 0.1 mm.



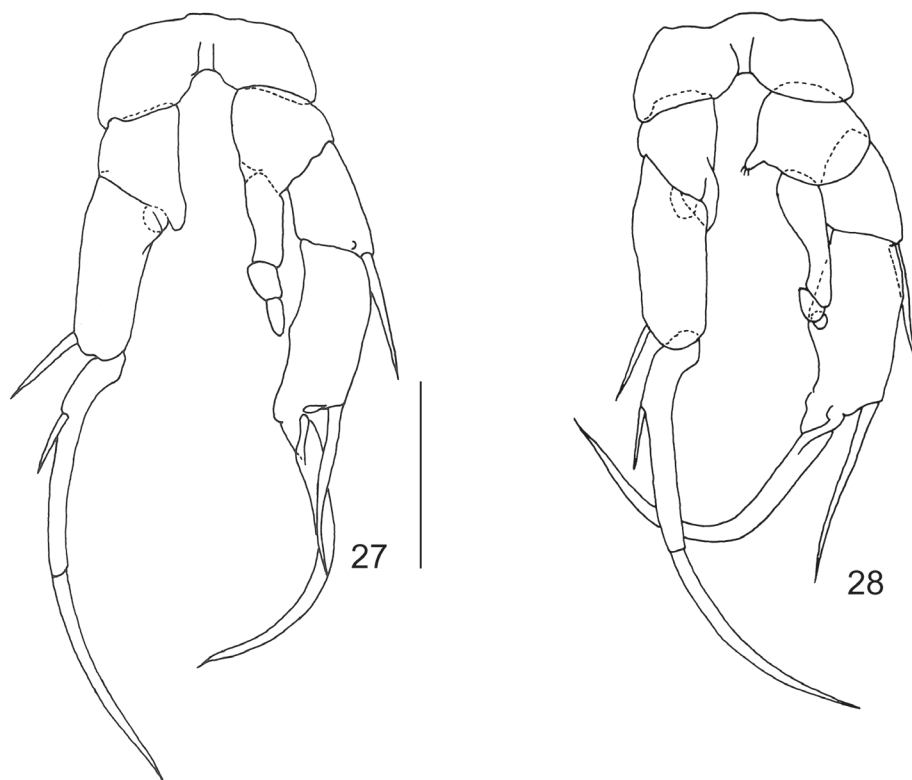
FIGURES 10–15 *Boeckella* male fifth legs (posterior aspect); 10, *B. bispinosa*; 11, *B. pilkililli* sp. nov; 12, *B. dilatata*; 13, *B. timmsi*; 14, *B. triarticulata*; 15, *B. fluvialis*. Scale = 0.1 mm.



FIGURES 16–20 *Boeckella* male fifth legs (posterior aspect); 16, *B. hamata*; 17, *B. robusta*; 18, *B. nyoraensis*; 19, *B. delicata*; 20, *B. montana*. Scale = 0.1 mm.



FIGURES 21–26 *Boeckella* male fifth legs (posterior aspect); 21, *B. spinogibba*; 22, *B. opaqua*; 23, *B. symmetrica*; 24, *B. major*; 25, *B. saycei*; 26, *B. tanea*. Scale: 21 = 0.05 mm, 22–26 = 0.1 mm



FIGURES 27–28 *Boeckella* male fifth legs (posterior aspect); 27, *B. propinqua propinqua*; 28, *B. propinqua longisetosa*. Scale = 0.1 mm.

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**APPENDIX** Updated alphabetical checklist of Australian and Zealandia species (and subspecies) in the genus *Boeckella*.

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<i>B. bispinosa</i> Bayly, 1967	<i>B. nyoraensis</i> Searle, 1912	<i>B. saycei</i> Sars, 1908
<i>B. delicata</i> Percival, 1937	<i>B. opaqua</i> Fairbridge, 1945	<i>B. shieli</i> Bayly, 1985
<i>B. dilatata</i> Sars, 1904	<i>B. pilkililli</i> sp. nov.	<i>B. spinogibba</i> Defaye, 1998
<i>B. fluvialis</i> Henry, 1922	<i>B. propinqua longisetosa</i> Smith, 1909	<i>B. symmetrica</i> Sars, 1908
<i>B. geniculata</i> Bayly, 1964	<i>B. propinqua propinqua</i> Sars, 1904	<i>B. tanea</i> Chapman, 1973
<i>B. hamata</i> Brehm, 1928	<i>B. pseudochelae</i> Searle, 1912	<i>B. timmsi</i> Bayly, 1998
<i>B. major</i> Searle, 1938	<i>B. robusta robusta</i> Sars, 1896	<i>B. triarticulata</i> (Thomson, 1883)
<i>B. minuta</i> Sars, 1896	<i>B. robusta maxima</i> Bayly, 1964	
<i>B. montana</i> Bayly, 1964	<i>B. rubra</i> Smith, 1909	

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