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A revised identification guide to the fairy shrimps (Crustacea: Anostraca: Anostracina) of Australia

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Abstract

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Following an introduction to the anatomy and ecology of fairy shrimps living in Australian fresh waters, identification keys are provided for males of two species of *Australobranchipus*, one species of *Streptocephalus* and 39 species of *Branchinella*. A key to females of the three genera is also provided, though identification to species is not always possible.

Keywords *Australobranchipus*, *Branchinella*, *Streptocephalus*, distributions

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Introduction

Most anostracans, or fairy shrimps, are about 10-30 mm long (extreme range 5-150 mm worldwide; 8-50 mm Australia), and consist of a long cylindrical body divided into a head, a thorax with many pairs of foliaceous limbs and the genitalia, and an abdomen. Significantly, fairy shrimps swim upside down. Typically they inhabit temporary waters and are generally found in the less well watered parts of Australia. Their occurrence is spatially and temporally erratic.

Classification and main taxonomic features

The Anostraca is one of the orders of the Class Branchiopoda. They are so different from the other orders/suborders (Notostraca, Laevicaudata, Spinicaudata, Cyclestherida (last three used to be the Conchostraca) and Cladocera) that they are placed within their own subclass, the Sarsostraca. Anostracans are divided into two suborders: the Artemiina containing two genera *Artemia* and *Parartemia* and which live in saline waters and hence are called brine shrimps (Timms, 2012), and the Anostracina which accommodate the freshwater fairy shrimps (though some live in saline waters) arranged in six extant families.

Their distinguishing characteristics separating them from other crustaceans include the lack of a carapace, foliaceous limbs (shared with other branchiopods), paired stalked eyes (though many crustaceans have stalked eyes), a body consisting of a head and a thorax of 13 segments with foliaceous limbs and the genitalia, then six abdominal segments, and a telson bearing a pair of cercopods (Fig. 1). Different numbers of body segments occur in *Polyartemia* (19) and *Polyartemiella* (21), but they are not found in Australia.

As in all crustaceans the head bears two pairs of antennae. In both sexes the first pair are typically short and filamentous, and of little taxonomic interest, though their length relative to parts of the second antenna is sometimes useful. The second antenna of the female is also of little taxonomic interest, though again its relative length and shape can sometimes be important. However, the second antenna of the male is elaborate and most important in distinguishing between species. It consists of two antennomeres (proximal and distal) and various outgrowths (Fig. 2). Taxonomists focus on the form of the two antennomeres and on the structure of the various outgrowths on these structures. In *Branchinella* and some other genera, during larval development, an appendage on each second antenna

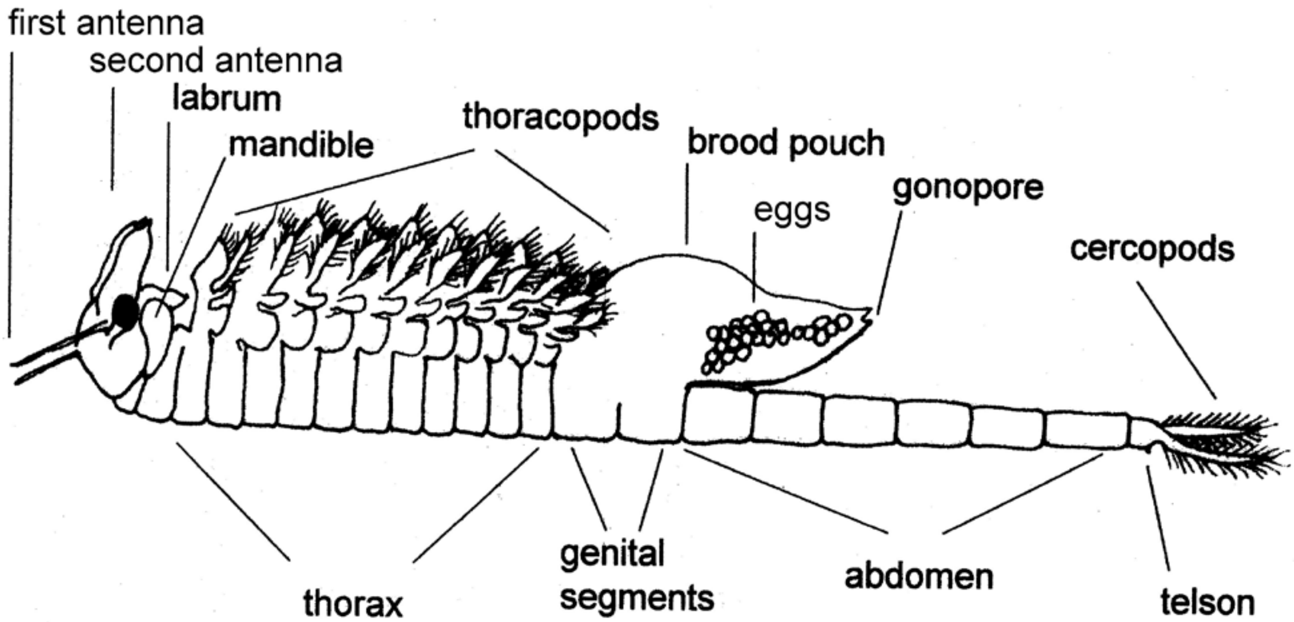

Fig 1. Lateral view of an adult female fairy shrimp showing its structure.

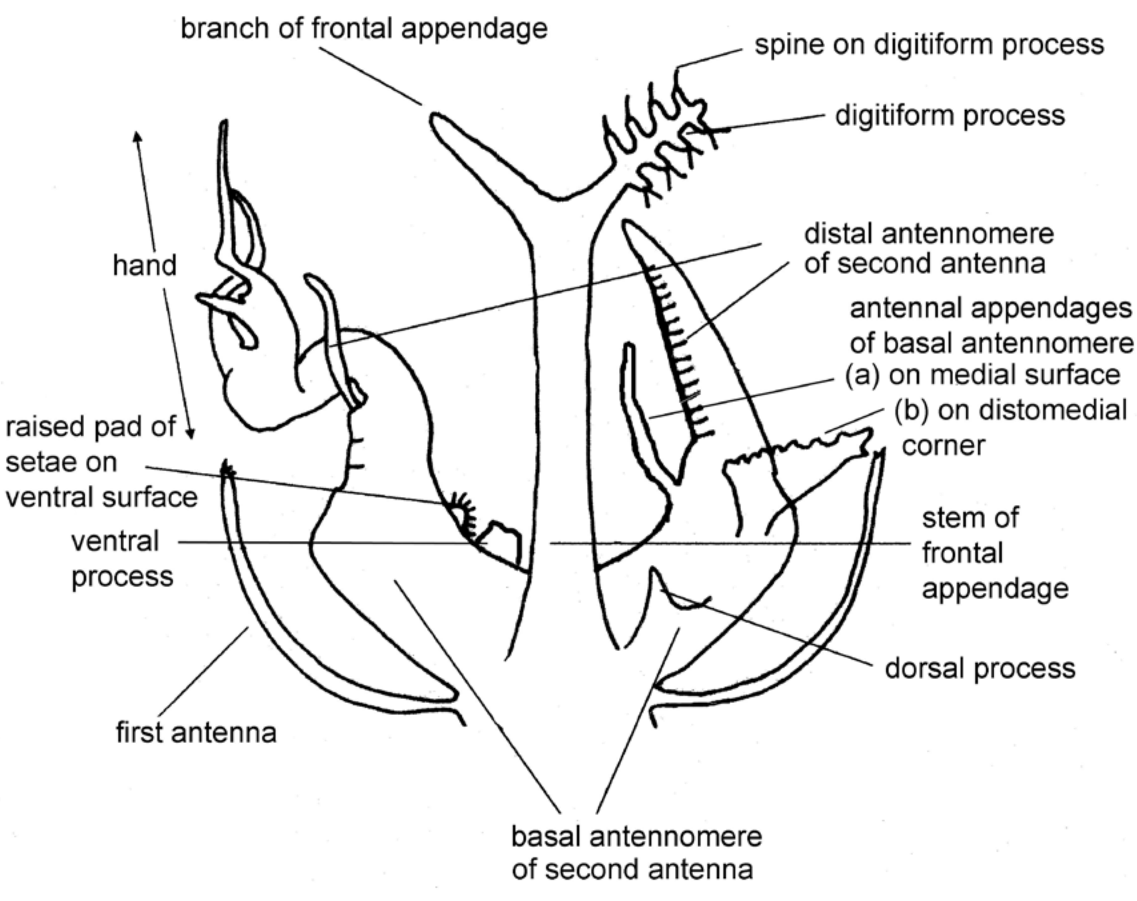

Fig 2. Dorsal view of a hypothetical second antenna of a male showing major structures likely to be seen in Australian specimens.

migrates to a region between the two antennae, fuse with each other and develop in to what is called a frontal appendage. Its detailed structure, almost alone, serves to separate the various species of *Branchinella*. In *Australobranchipus* the trunk of the frontal appendage is heavily chitinized. In *Streptocephalus*, the antennal appendages are distomedial on the proximal antennomere and are very large, displacing the distal antennomere laterally. The antennal appendage in this genus has developed into an elaborate hand-like cheliform structure. The paired stalked eyes are similar in most Australian species and are not used in species separation, except in one species where they are much reduced in size. Relative to other branchiopods, the labrum and mandibles are large and the first and second maxillae reduced.

The first 11 thoracic segments each usually bear a pair of foliaceous limbs called phyllopods or thoracopods or even legs. These are of complex structure and consist (from lateral to medial surface) of a preepipodite, epipodite, exopodite, endopodite, and six endites (Fig. 3). All except the two epipodites bear setae, often complexly structured and arranged. For any one species the thoracopods are fairly similar, though in many species there is some reduction in size and complexity in the first and last few thoracopods. The structure of the endopodite and anterior setae of the endites are useful in detailed taxonomical studies, but are not used in these keys.

Posterior to the thoracopods are two partly fused thoracic segments with the genitalia and called the genital segments (Fig. 1). In the male, these have a pair of gonopods on the ventral surface. The gonopods are composed of a proximal, usually rigid, basal part and a distal retractable part. The proximal part may have spines and lateral swellings (lateral

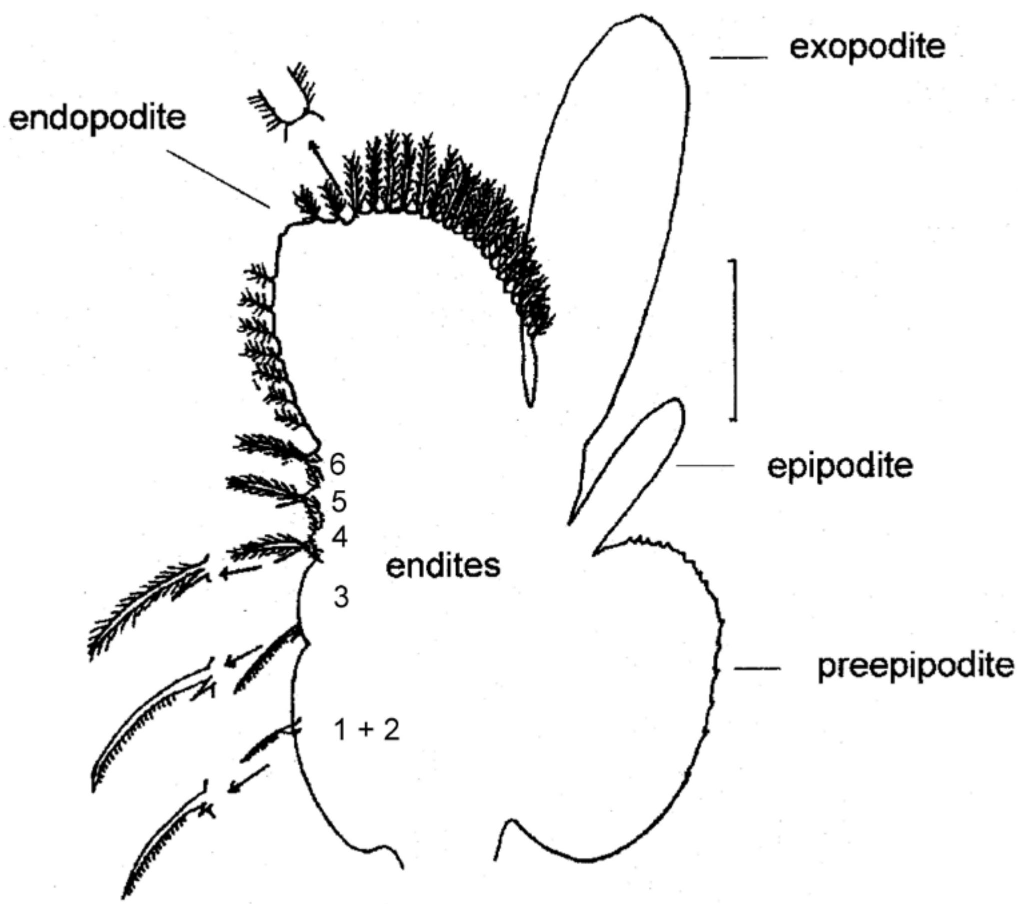

Fig 3. Thoracopod of a fairy shrimp (*B. halsei*) showing its structure. Note that the ordinary (anterior) setae of the endites and exopod have been omitted, so that only the taxonomically useful anterior setae of the endites are shown. The anterior setae of the endopodite are also useful taxonomically and are shown.

processes) which are useful in separating species, particularly in *Branchinella*. The complex distal part is usually withdrawn and is not used in these keys. However in detailed taxonomical studies its structure gives important clues to species and generic relationships. Females have a brood pouch (composed of two 'lateral pouches' and a central 'ovisac') on the ventral surface.

The six segmented abdomen is of quite uniform structure throughout the group, as are the telson and cercopods in Australian species.

All fairy shrimps produce drought resistant eggs. These are carried in the brood pouch where they mature. Many species discharge these eggs regularly while some retain them even in death. The eggs often have a sculptured surface (polygons and honeycombing patterns are common) which may be anti-predation structures, but for taxonomists provide yet another method of separating species. Details of egg structure are now known for most Australian species (Timms et al., 2004; Timms and Lindsay, 2011) but information is not provided here as a high powered microscope or a Scanning Electron Microscope is needed.

Species in the genus *Branchinella* have been subjected to molecular studies (Zofkova and Timms, 2009; Pincel et al. 2013a). For almost all species morphological differences are supported by differences in their DNA, though in the variable and isolated populations of *B. longrostris* on Western Australian inselbergs the structure of the frontal appendage is not aligned with their cytochrome *c* oxidase I differences. Interestingly there is a close match between Cenozoic climate changes and diversification of Australian fairy shrimps presumably linked to changes in the abundances and diversity of temporary aquatic habitats (Pincel et al., 2013b).

Size of fairy shrimps is not a good descriptor. This is because not only is size dependent on nutritional conditions, but fairy shrimps grow throughout life, so old fairy shrimps are much bigger than newly mature individuals. Nevertheless some species are characteristically big when mature and others always of medium or small size. So size is of limited use in the keys, and always as a subsidiary character, but be aware that unusual individuals may be outside the size range generally applicable to a species.

Colour is rarely used in the keys. Almost all Australian species have cercopods fringed with red, which is useful when trying to see otherwise transparent fairy shrimps in a sorting tray. Sometimes individual fairy shrimp are pastel green or light blue and in turbid waters some may be pink or even red. Eggs are often blue-black-silver so females with eggs are sometimes easily detected. Except for egg colours, body colours are lost in preservation.

Biology of Fairy Shrimps

Fairy shrimps live almost exclusively in temporary standing waters, i.e. in clay pans, gnammas on rock outcrops, vegetated pools, newly filled freshwater lakes, salt lakes, ephemeral farm dams, roadside ditches, disconnected creek pools, in fact almost anywhere where water is ponded for more than a few days. These kinds of habitats abound in the poorly drained inland areas of Australia that receive occasional flooding rains. They do not occur in waters with fish, as fairy shrimps are defenceless against their predation. This does not mean they are not eaten in their temporary pools; in fact these can be full of invertebrate predators, animals such as flatworms, beetles (larva and some adults) and dragonfly larva to name common assailants. But a proportion of fairy shrimps prevail by developing first, fast and by fantastic fecundity.

Anostracans survive the dry period in their habitat as drought-resistant eggs. These contain an embryo in an arrested stage of development and remain viable in the surface sediments for many years. They hatch 12-48 hours after filling, but only a proportion hatches each filling, a bet hedging strategy in case there is insufficient water to allow the shrimps to reach maturity and reproduce. Growth is very rapid, some species maturing within four days, though 2-3 weeks is more normal. Once mature, they produce a batch of eggs every day or so and eventually die of old age (if not eaten earlier) within a month or two or sometimes three, should the pool last that long. In that the eggs of most species must endure a period of desiccation before hatching, only one generation of shrimps is produced at the start of each wet phase of the pool.

Almost all fairy shrimps are filter feeders. They use their setose thoracopods to filter out small particles and then pass these forward to the mouthparts for processing and then ingestion. The particles range from algae and protistans to bacteria on clay particles and organic matter. At least one Australian species is predatory on smaller fairy shrimps and on other larger zooplankters.

Sexes are separate and reproduction is usually sexual, although it is suspected some populations of Australian *Streptocephalus* are parthenogenetic. Males actively pursue females and commence copulation by clasping the female just anterior to the genital segments on the "amplexial groove" with their specially developed second antenna. Although males have two gonopods, only one is needed to insert into the brood pouch. Encounters are typically brief and the two do not become locked together for hours/days as in some *Parartemia* and *Artemia*. The female produces a batch of ca 20-300 eggs at intervals of one to many days and each batch needs to be separately fertilized. It is possible some Australian species retain their eggs and die with them in their brood pouch. Anyhow, eggs end up being deposited on the bottom mud, as usually they do not float like those of *Artemia*.

The zoogeography of Australian Anostraca has been studied by Rogers and Timms (2014). They suggest three bioregions for Australia, western, eastern and southern, with endemism highest (72%) in the west and least (40%) in the south. Over the last 65 MY the Australian continent has dried and presumedly this has increased the abundance and diversity of temporary aquatic habitats. Fairy shrimps have responded by diverging in isolation in these habitats, so that from a limited generic diversity of four genera, there now at least 42 species of freshwater fairy shrimps and 20 native brine shrimps (Pinceel et al., 2013a).

Collection and preservation

Fairy shrimps are easily collected by sweeping a dip net through the water of a temporary pool. It often comes as a surprise what is caught in a turbid pool, as there is no indication such pools harbour a diverse and abundant fauna. Sometimes the larger species in clear waters, eg. *Branchinella buchananensis,* can swim strongly enough to escape on oncoming net in which case stalking them becomes the only option. Fairy shrimps distort and shrink when preserved, so that placing them directly into 4 - 5 % formalin or particularly 70 % alcohol is unsatisfactory. This is however the best way to get the males to evert their gonopods, which are sometimes important for taxonomic studies. If this has to be done then formalin gives a better result than alcohol, though of course formalin should be handled with upmost care as it is carcinogenic. However, alcohol generally is better than formalin, particularly if stronger at 90 – 100% as the animals can then be used for DNA and other biochemical analyses. Two ways to get better preserved specimens are to let them die through lack of oxygen or to narcotize them with carbonated water before preservation.

Key to families and genera of Anostraca in Australia

At present five genera in five families are reported to occur in Australia: *Artemia* in the Artemiidae, *Branchinella* in the Thamnocephalidae, *Parartemia* in the Parartemiidae, *Streptocephalus* in the Streptocephalidae and *Australobranchipus* in the Branchipodidae. Of these *Artemia* may have been introduced and *Parartemia* is endemic. This diversity is not remarkable by world standards, but even so there has been has been considerable radiation at the species level in *Branchinella* and *Parartemia*, so that the Australian fauna is not as depauperate as it might at first seem.

The key is based mainly on male characteristics.

1a. Antennal appendage in distolateral position on the basal antennomere of male second antenna developed into hand-like cheliform structure connected by an S-shaped peduncle (Fig 4); distal antennomere of second antenna like first antenna and shorter than antennal appendage. Females with an elongated, slender brood pouch, reaching to about the fourth abdominal segment; mature eggs tetrahedral .... **Streptocephalidae**, *Streptocephalus*.

1b Typically lacking an antennal appendage in distolateral position on the basal antennomere of male second antenna, though if present, then small and not cheliform; distal antennomere of second antenna well developed into a cylindrical or flattened grasping organ about the same size as the basal segment (Figs. 5-8). Females with various shaped brood pouch (oval, flask-shaped, elongated), and if elongated only occasionally reaching beyond the third abdominal segment; mature eggs spherical or roughly so 2

2a (1b). Distal segment of male second antenna broadly triangular, widest half along its length and with an acute apex; basal segment with prominent knob-like apophyses on basomedial margin (Fig 5). Female with pair of ventral spines on brood pouch .... **Artemiidae**, *Artemia*

2b (1b).Distal segment of male second antenna more or less tubular (if flattened then not triangular and not widest halfway along its length)(Figs. 6-8); knob-like apophyses on medial margin of basal segment typically absent (if present then frontal appendage present). Female brood pouch without ventral spines 3

3a (2b). Basal segments of second antenna heavily chitinized (more so than remainder of body); these basal segments fused for at least half their length and bearing ventrally pointing processes (Figs. 7,8); frontal appendage, if present, with stem chitinized (Fig. 10). Female brood pouch short and oval, perhaps extending laterally 4

3b (2b). Basal segments not heavily chitinized, no more so than remainder of body; Basal segments may be fused a little, but not for as much as half of their length; frontal appendage usually present and never heavily chitinized (Fig. 6). Female with an elongated brood pouch reaching to second or third abdominal segment, occasionally more .... **Thamnocephalidae**, *Branchinella*

Fig 4. Male *Streptocephalus* sp., lateral view of head.

Fig 5. Male *Artemia* sp., Frontal view of head.

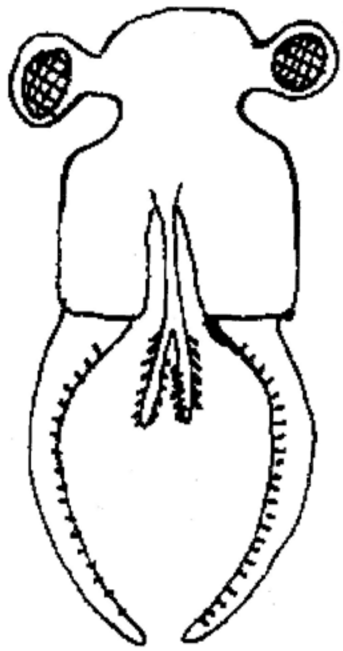

Fig 6. Male *Branchinella* sp.frontal view of head.

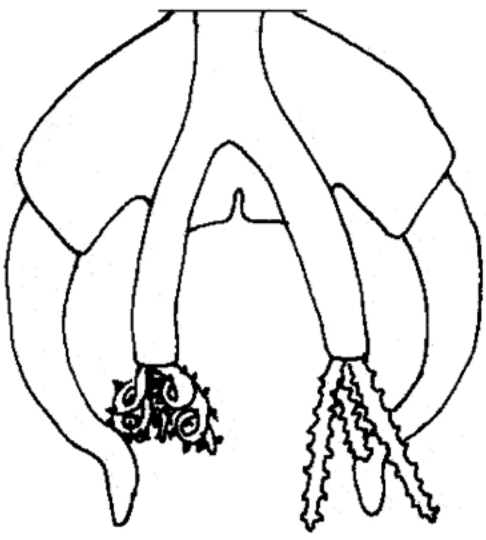

Fig 7. Male *Australobranchipus* sp., frontal view of second antenna

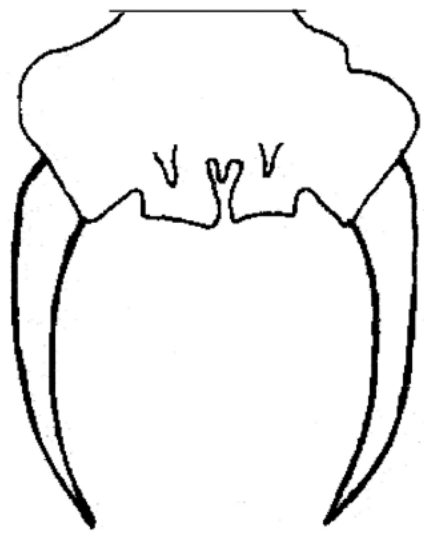

Fig 8. Male *Parartemia* sp., frontal view of second antenna

4a (3a). Bifurcated frontal appendage present; distal segment of second antenna lyriform (i.e. most of segment evenly arched and apex recurved laterally) (Fig 7); no dorsal processes on partly fused proximal segment. Labrum of females truncated .... **Branchipodidae,** *Australobranchipus*

4b (3a). Bifurcated frontal appendage absent. Distal segment of second antenna not lyriform and pointed; partly fused proximal segment typically with dorsal processes (Fig 8). Labrum of females markedly pointed .... **Parartemiidae,** *Parartemia*

Keys to *Artemia* and *Parartemia* are provided in Timms (2012). Keys to *Australobranchipus, Streptocephalus* and *Branchinella* are on the following pages.

Family Branchipodidae, Baird 1852 (sensu Daday 1910).

Australobranchipus Rogers, Timms, Jocqué & Brendonck. 2007.

This genus is the only member in Australia of the diverse Branchipodidae of Africa and Eurasia. Males (Figs. 9,10) are distinctive in (i) having the ventral part of the genital segments inflated, (ii) the rigid basal portion of each gonopod subcylindrical and bearing a small rounded projection medially, (iii) the medial surface of the fused proximal antennomeres usually bearing ventral projections (like that in *Parartemia*) and (iv) the proximal trunk of the frontal appendage is chitinized and largely subdivided longitudinally into two. Females (Figs. 11,12) are distinctive compared with other Australian fairy shrimps in (i) having the brood pouch broadly rounded and opening under abdominal segment I, (ii) having a second antenna narrowing abruptly subapically to form a distinct shoulder and a narrow acute apex and (iii) the presence of an amplexial groove between thoracic segments XI and XII. Resting eggs are also distinctive for although roughly spherical with polygonal sculpturing, the ridges are far more prominent than in the eggs of *Branchinella*. Further details are given in Rogers et al. 2007.

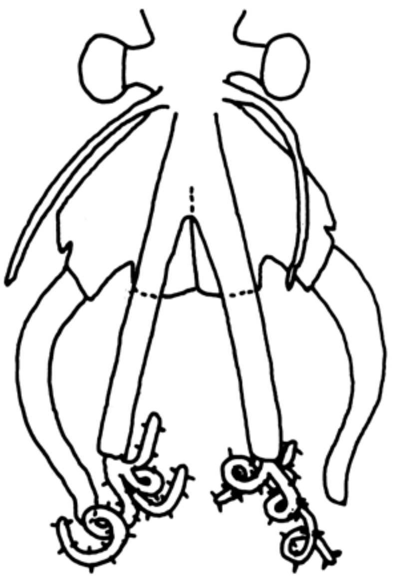

Fig 9. Male *Australobranchipus* head, frontal view.

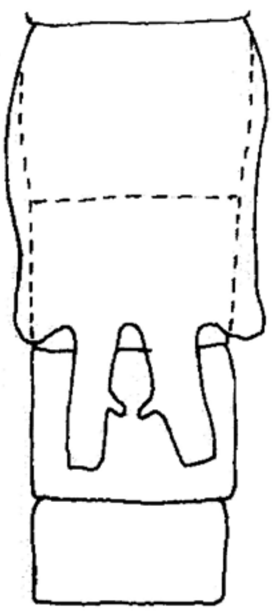

Fig 10. Male *Australobranchipus*
Genital segments and penes base, ventral view.

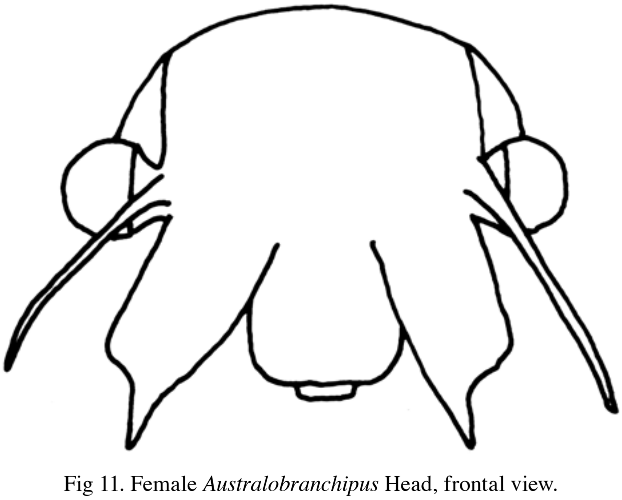

Fig 11. Female *Australobranchipus* Head, frontal view.

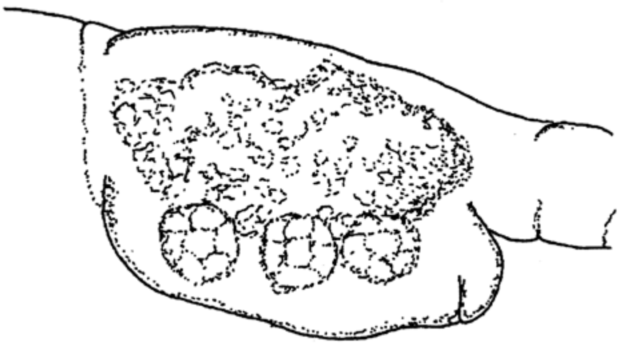

Fig 12. Female *Australobranchipus*, brood sac, lateral view

Australobranchipus so far has been found only in the Murray-Darling Basin, mainly in the headwaters in Queensland. It lives in small pools, usually of clear waters and has a very short life cycle, maturing in as few as four days and often vanished by two weeks. In so doing it largely avoids competition with slower growing *Branchinella*. It is small, with males usually < 8 mm and females < 10 mm.

Key to species based on males.

1 (a). Male frontal appendage with each branch bearing two lateral rami; Trunk of frontal appendage fused proximally for about ¼ of its length; the ventral lamella from the partly fused proximal antennomeres almost completely fused together (Fig 13) .... *A. parooensis*

(b). Male frontal appendage with each branch bearing one lateral ramus; trunk of frontal appendage only fused proximally for < 0.1 of its length; ventral lamella of proximal antennomeres completely separate (Fig 14 .... *A. gilgaiphila*

Presently females are not keyable to species.

Australobranchipus parooenis occurs in the Paroo catchment in both Qld and NSW and there is also one collection from Katarapko Island in the Murray River near Loxton, SA. It usually occurs in clear water ponds.

Australobranchipus gilgaiphila so far is known only from clear water gilgai in the Bollon-Meandarra-Moonie area in southwest Qld.

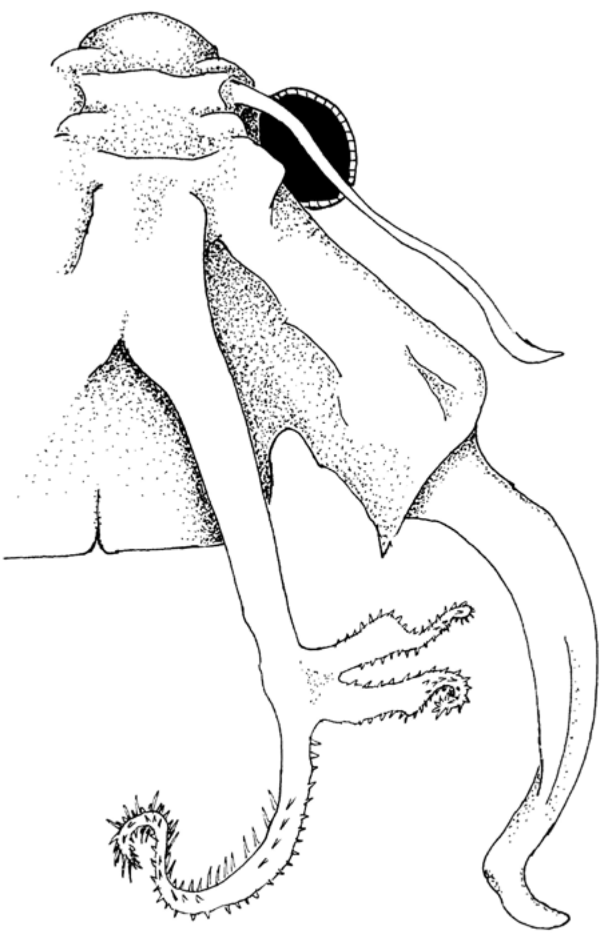

Fig 13. Frontal view of half head of *Australobranchipus parooensis* (from Rogers et al., 2007)

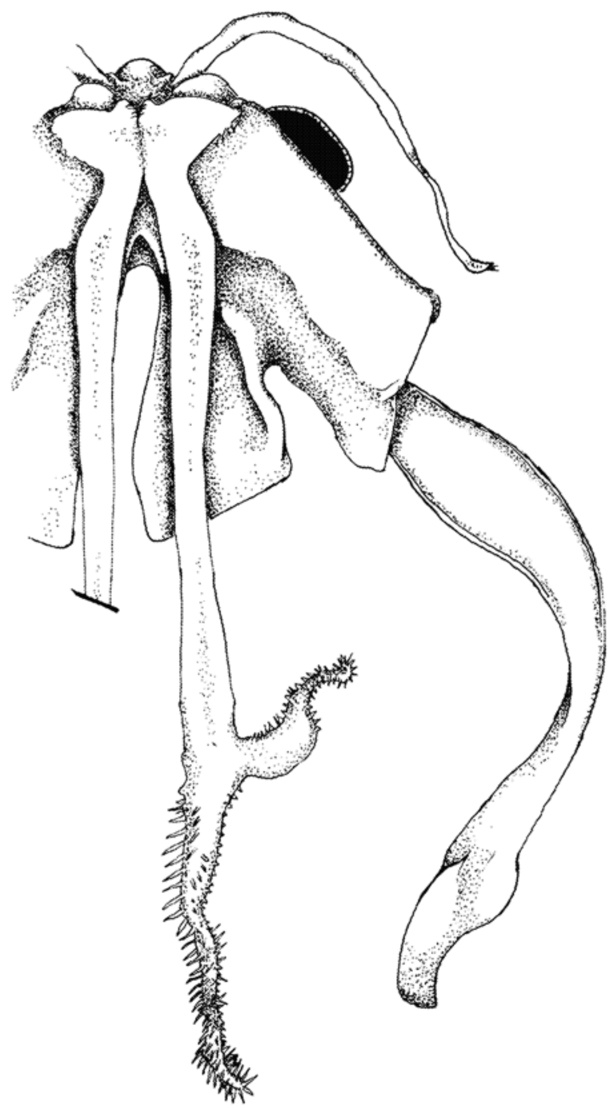

Fig 14.Frontal view of half head of *Australobranchipus gilgaiphila* (from Rogers et al., 2007)

Family **Streptocephalidae** Daday, 1910

Genus ***Streptocephalus*** Baird, 1852

The Streptocephalidae is a monogeneric family of about 60 species. Many of these occur in Africa and North America, with a few in Eurasia, and one (or two) in Indonesia. The first species to be described from Australia was of *S. archeri*, raised from resting eggs in dried mud from near Rockhampton by Sars in 1896. No males were present in the culture so the description was based entirely on females and hence not much use in comparative studies, as all useful taxonomic characteristics are in males. Linder reported 6 females from the same area in 1941; these are usually thought to be *S. archeri*, but Brtek & Mura (2000) think they are a separate species. Given the indeterminate nature of these specimens, and the lack of other finds in Australia, most reviews of aquatic invertebrates discounted the presence of *Streptocephalus* in Australia (Geddes, 1981, 1983; Williams, 1980, 1981).

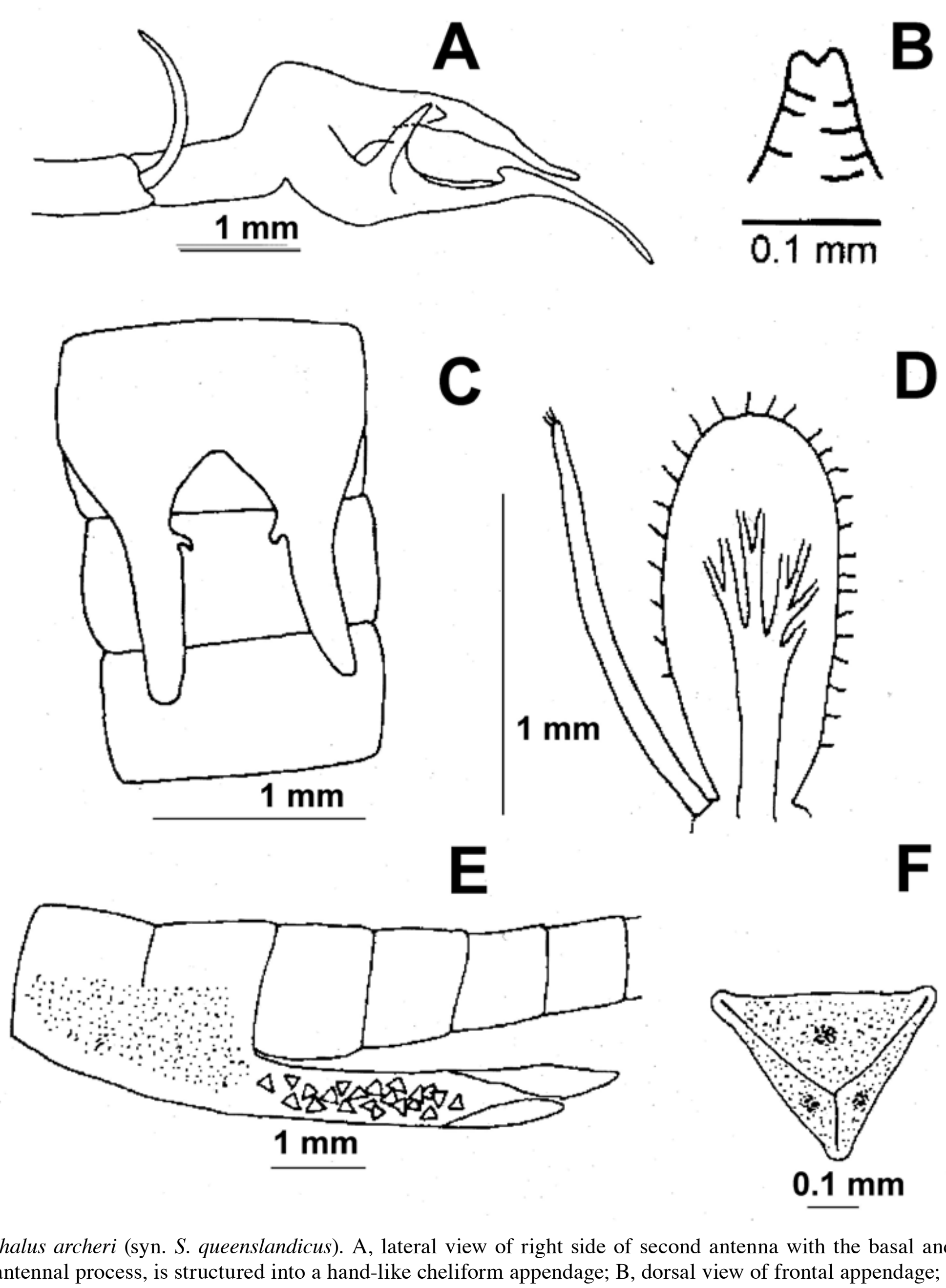

Fig 15. *Streptocephalus archeri* (syn. *S. queenslandicus*). A, lateral view of right side of second antenna with the basal and distal segments, together with the antennal process, is structured into a hand-like cheliform appendage; B, dorsal view of frontal appendage; C, ventral view of male genital region; D, female first and second anwtennae; E, lateral view of female abdomen and brood pouch F, tetrahedral egg.

However Brtek & Mura (2000) maintained *Streptocephalus* did occur in Australia, a view vindicated when Herbert and Timms (2000) published the description of a new species, *Streptocephalus queenslandicus* from the Atherton Tableland in north Queensland. The males are distinctive from all other anostracan species in Australia, by processing a hand-like cheliform process from the basal antennomere of the second antenna (Fig 15). The distal segment is thin and sickle shaped and much shorter (¼) than the antennal process. The frontal appendage is very short and with a blunt double point. The non-retractable basal part of the gonopods are long, reaching about half way into the first post-genital segment (i.e. 2 ½ segments long) and have a blunt outgrowth with 3-4 stout spines on the medial margin towards the base. Females have an oval-shaped second antenna with an evenly rounded apical surface (Fig. 15) (as opposed to lanceolate second antenna with an apical point in most *Branchinella* species). The brood pouch is more elongated in *Streptocephalus* than in *Branchinella*, reaching a total of six segments (two genital segments plus four abdominal segments) in *Streptocephalus*, compared with a maximum of five (2 + 3), in *Branchinella*. The difference from *Branchinella* is more obvious when the eggs are examined ---they are tetrahedral in shape when mature (Fig 15F), as opposed to spherical eggs in *Branchinella*. It should be noted that many overseas species of *Streptocephalus* have spherical eggs too, but those so far seen by the author in Australia have these distinctive tetrahedral eggs (but one set of Australian specimens seen by Brtek & Mura (2000) had spherical eggs). Specimens with tetrahedral eggs are placed in a separate subgenus *Parastreptocephalus* Brendonck, Hamer & Thiery, 1992.

Despite these three isolated records of *Streptocephalus*, recent collections suggest it is widespread in northern Australia. It is known from the Carnarvon district of WA (S. Halse, pers. com.), from the Lake Carey area of WA (Timms et al., 2006) from a waterhole near Papunya, ca 200 km NW of Alice Springs (Bayly, 2001) and from quite a few sites western Queensland, in the Bulloo and Paroo catchments of SW Qld and NW NSW and in central west NSW (Fig 16). Australian *Streptocephalus* species live in warmer waters, given these collections are all from the northern two-thirds of Australia, and almost all successful collections were made in mid to late summer. Most of these collections contain females only, but where males are present they conform to the description for *S. queenslandicus*. The author has raised Bloodwood *Streptocephalus* in the laboratory and despite the females producing eggs, never saw any males. So either males are of very brief presence or this species is parthenogenetic at times.

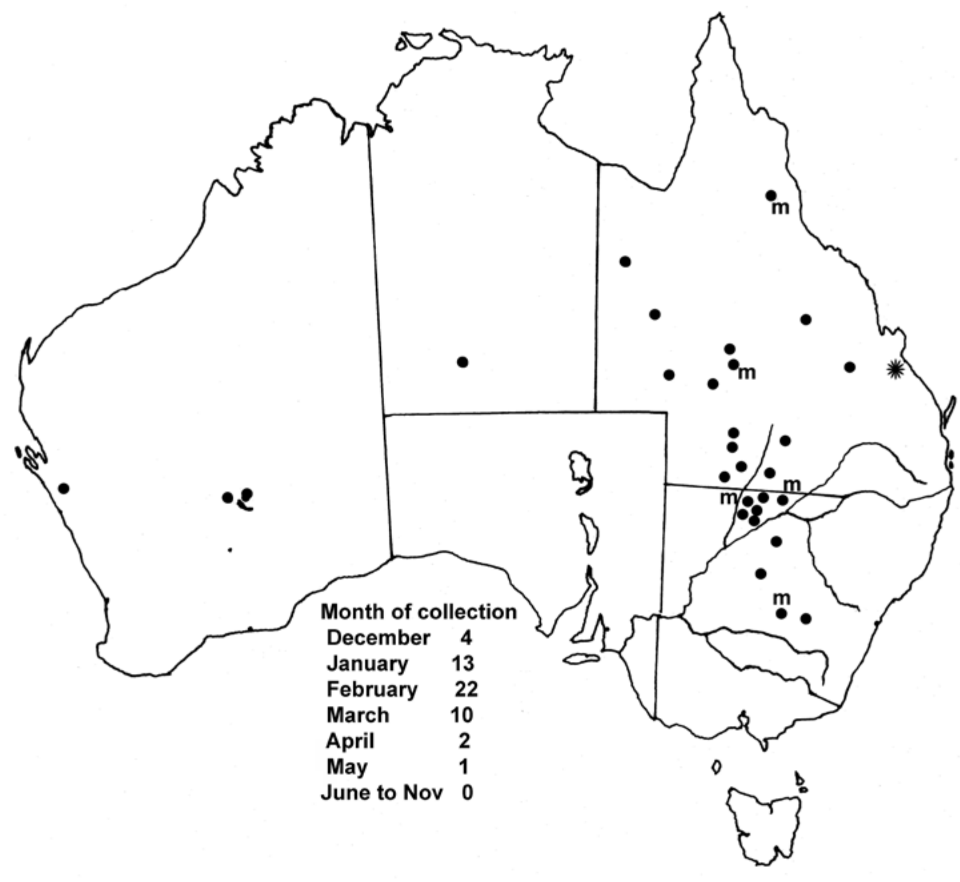

Fig 16. Map of Australia showing sites where *Streptocephalus archeri* have been found. The asterisk near Rockhampton indicates the original site for *S. archeri*, while the dots indicate sites where *Streptocephalus* sp (+ syn *S. queenslandicus*) have been collected. "m" indicates males found.

Given that many specimens have now been studied and that there is some variation in female characteristics that formerly were thought to separate *S. queenslandicus* from *S. archeri*, and that there is only one record for *S. archeri*, surrounded by many for *S. queenslandicus*, it seems the two species are indeed one. I propose that there is only one species in Australia and it is *S. archeri*; *S. queenslandicus* now becomes it junior synonym. The description of the male of *S. queenslandicus* in Herbert & Timms (2000) now becomes that for *S. archeri*.

Streptocephalus (Parastreptocephalus) archeri Sars 1896

Streptocephlaus queenslandicus Herbert & Timms 2000 new combination

Family **Thamnocephalidae** Linder 1941

Genus ***Branchinella*** Sayce 1903, sensu stricto

This nominate subgenus is restricted to Australia where it has greatly radiated into 39 species at last count. The subgenus *Branchinellites* has only six species found in Eurasia and Africa; however these are very different from those in Australia. Rogers (2006) provides a generic review of the Thamnocephalidae, in which the taxonomic position and diagnostic features of *Branchinella* are explained.

While the basal antennomere of the male second antenna in all species of *Branchinella* is chitinized and partly fused proximally, the most obvious characteristic feature in most species is a frontal appendage consisting of at least a basal stem and two branches with the latter often elaborated into further subbranches, digitiform processes or into lamellar plates or outgrowths. However a number of species have a very small frontal appendage or lack one entirely, so it cannot be a diagnostic character. The bases of the gonopods contain no diagnostic characters either, although in all except one species they lack spines of any kind. The genus is defined by its gonopods, which have two rows of spines, a wide dense row of strong sharp spines and opposite these an incomplete row of a few generally triangular spines (Fig 17A)

Females are unremarkable and most cannot be identified to species, though a limited key is provided later. Their first antennae are well developed in some species, notably *B. australiensis, B. occidentalis* and to a lesser extent in *B. buchananensis, B. compacta*, *B. hattahensis, B. hearnii, B. nichollsi*, *B. papillata* and *B. vosperi*. In the remainder they are lanceolate, usually 2-4 times longer than wide and with a small pointed area apically, and so are quite different to those of the otherwise similar-looking *Streptocephalus.* After an expanded proximal area, the brood pouches narrow abruptly into a cylindrical structure reaching to 4th to 6th genital plus abdominal segments (Fig. 17B).

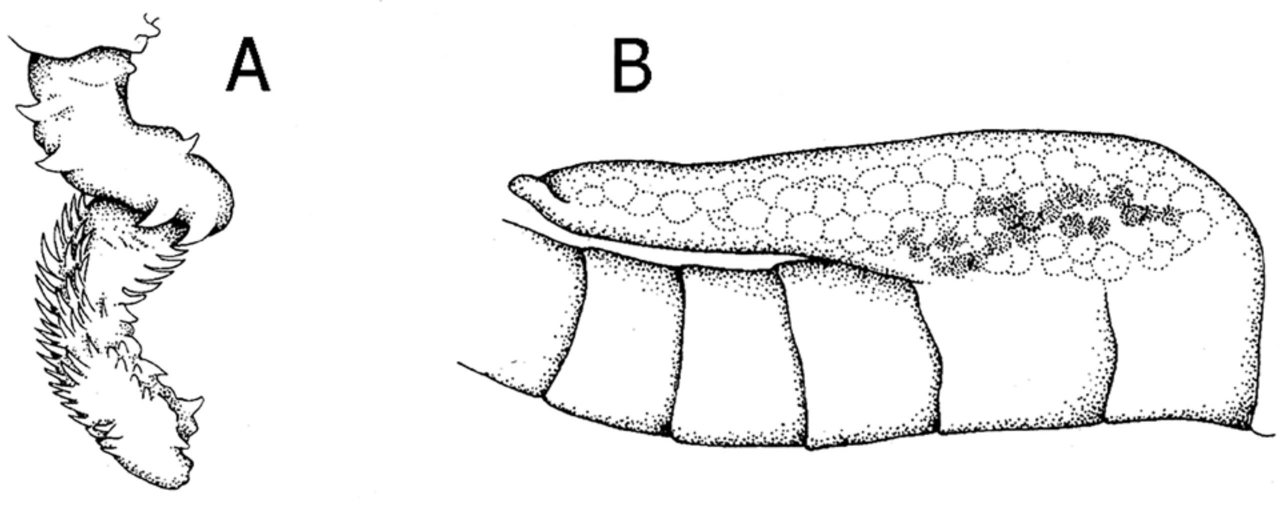

Fig 17. *B. macraeae*. A, gonopod; B, brood pouch (drawings by Jane MacRae)

Table 1. The species known from Australia are listed below, together with their presently known distribution and habitat preferences. The validity of most has been confirmed by molecular analysis (Pinceel et al., 2013b).

Species	**Distribution**	**Habitat**
B. affinis Linder 1941	Australia wide	Typically in turbid fresh waters, e.g. claypans
B. anatinorhyncha Timms 2012	N of Aramac, central Qld	Claypans
B. apophysata Linder 1941	Laverton, WA	Rare
B. arborea Geddes 1981	Central eastern inland (Qld, NSW, NT, SA)	Mainly in clearer waters; vegetated and quarry pools
B. australiensis (Richters 1876)	Australia-wide, but not north of 18° S	Common, mainly in moderately turbid waters
B. basispina Geddes 1981	Balladonia –Norseman area, WA	Pools associated with granite outcrops on edge of Nullarbor plain
B. buchananensis Geddes 1981	Qld and nw NSW	Hypo - mesosaline lakes (commonly to 15 g/L, rarely to 42g/L)
B. budjiti Timms 2001	Paroo, Bulloo & Lower L. Eyre Basin (Qld, NSW,SA)	Very turbid waters, e.g. claypans, borrow pits
B. campbelli Timms 2001	Paroo & adj. Darling R (western Qld & NSW)	Mainly in short-lived, clearer waters
B. compacta Linder 1941	Vic (Omeo, Western District), NSW (Monaro)	Hyposaline lakes (to 16g/L)
B. complexidigititata Timms 2002	WA, Eneabba area	Milky turbid swamps
B. denticulata Linder 1941	WA (Carnarvon to Kalgoorlie)	Uncommon, turbid waters?
B. dubia (Schwartz 1917)	Northern Australia (n of 18° S)	Variety of habitats in drier monsoonal areas
B. erosa Timms 2012	WA, nth of Moora	In clear water hyposaline lakes
B. frondosa Henry 1924	Middle WA, west Qld, NSW	Creek pools, swamps, floodouts somewhat turbid
B. halsei Timms 2002	Western WA, also W of Lake Eyre	Mainly in turbid waters
B. hattahensis Geddes 1981	nth Vic, w NSW, & sw Qld	Turbid freshwater lakes
B hearni Timms 2012	sw WA, nth of Moora and east of Manjimup	In clear water hyposaline lakes
B. herrodi Timms 2012	nth Qld, nw of Lake Buchanan	In clear water pools
B. insularis Timms 2002	SA, Kangaroo Is	Uncommon
B. kadjikadji Timms 2002	WA, Morewa to Wyalkatchem	Rare, claypans
B. lamellata Timms 2002	Lower L Eyre Basin and adj. Bulloo (nth SA, sw Qld)	Turbid claypans, roadside borrow pits
B. latzi Geddes 1981	Central Australia (mainly NT, also sw Qld)	Small pools in creeks and used to be on top of Uluru
B. longirostris Wolf 1911	WA, Wheatbelt and adjacent Goldfields	Clear rock pools on granite outcrops

B. lyrifera Linder 1941	Australia wide (except Vic)	Common, often in turbid longer lasting waters
B. macraeae Timms 2005	nw WA, lowland Pilbara	Turbid waters
B. minmina Timms 2012	nw Qld, around Boulia	Vegetated pools and roadside burrow pits
B. multidigitata Timms 2008	WA, Canning S Route,	Rare
B. nana Timms 2002	WA, Kalgoorlie-Norseman	Rare, hyposaline lakes
B. nichollsi Linder 1941	western WA and central Aust S of Alice Springs	In freshwater phase of saline lakes
B. occidentalis Dakin 1914	Australia wide (except Vic)	Predator! Mainly in turbid waters in arid areas
B. papillata Timms 2008	WA, ne of Esperance	In clear water pools in old sand dune swales
B. pinderi Timms 2008	WA, Pilbara	In extremely turbid claypans
B. pinnata Geddes 1981	Middle NT, inland Qld, nw NSW, nw WA?	Moderately turbid, longer lasting waters
B. proboscida Henry 1924	Australia wide (except Vic) and south of 18° S	Mainly in very turbid waters e.g. claypans
B. simplex Linder 1941	Middle WA (26° to 32° S), also sth NT and ne SA (near L Eyre)	Hyposaline lakes (commonly to 30 g/L, sometimes to 62g/L)
B. tyleri Timms 2002	NT, Victoria R and adj. areas	Mainly in flood plain pools in wet season
B. vosperi Timms 2008	WA, ne of Esperance	In turbid waters in pools in old dune swales
B. wellardi Milner 1929	Central WA, sw Qld and nw NSW.	Uncommon. In short-lived pools either turbid or clear

Key to males of the genus *Branchinella*.

(Note that the frontal appendage (i) shows increasing size and complexity within set patterns with age and (ii) shows some variation in structure between populations (Geddes, 1981; Zofkova and Timms, 2009).

1 (a) Frontal appendage absent or very small so that it does not protrude beyond the base of the proximal antennomere of second antenna (Fig 18A,B,C) 2

(b) Frontal appendage longer (often much longer) than the whole proximal antennomere of the second antenna (Fig 18D-G) 14

2 (a) No apparent frontal appendage (though a ridge may be present) (Fig. 18A,B) 3

(b) Frontal appendage small, bifurcated into two simple branches (Fig. 18C) 11

3 (a) Antennal appendage on medial surface of proximal antennomere of second antenna (Fig.18B) 4

(b) No antennal appendage on medial surface of proximal antennomere (Fig 18A 8

(Note: This outgrowth may be digitiform and located on the medial distal corner, or it may be digitiform and located mid length of the proximal antennomere or it may be laminar and located proximally. If it is laminar and located midlength, then look for a very small forked frontal appendage---if present go to couplet 11. *B. apophysa* also has a laminar outgrowth midlength on medial surface of the proximal antennomere of the second antenna, but it has a forked frontal appendage longer than the proximal segment of this antenna, so go to couplet 14).

4 (a) Antennal appendage on medial surface of proximal antennomere digitiform, either simple or complex and located mid length or terminally (Fig18 B) 5

(b) Antennal appendage on medial surface of proximal antennomere laminar and mainly basal (Fig 19) .... *B. papillata*

(In *B. papillata* the laminar outgrowth is in two parts, a small upper and larger triangular basal laminate; both crenulated marginally. The gonopod base is flanked either side by lateral lobe with a central depression, but note this character is not unique to *B. papilla*).

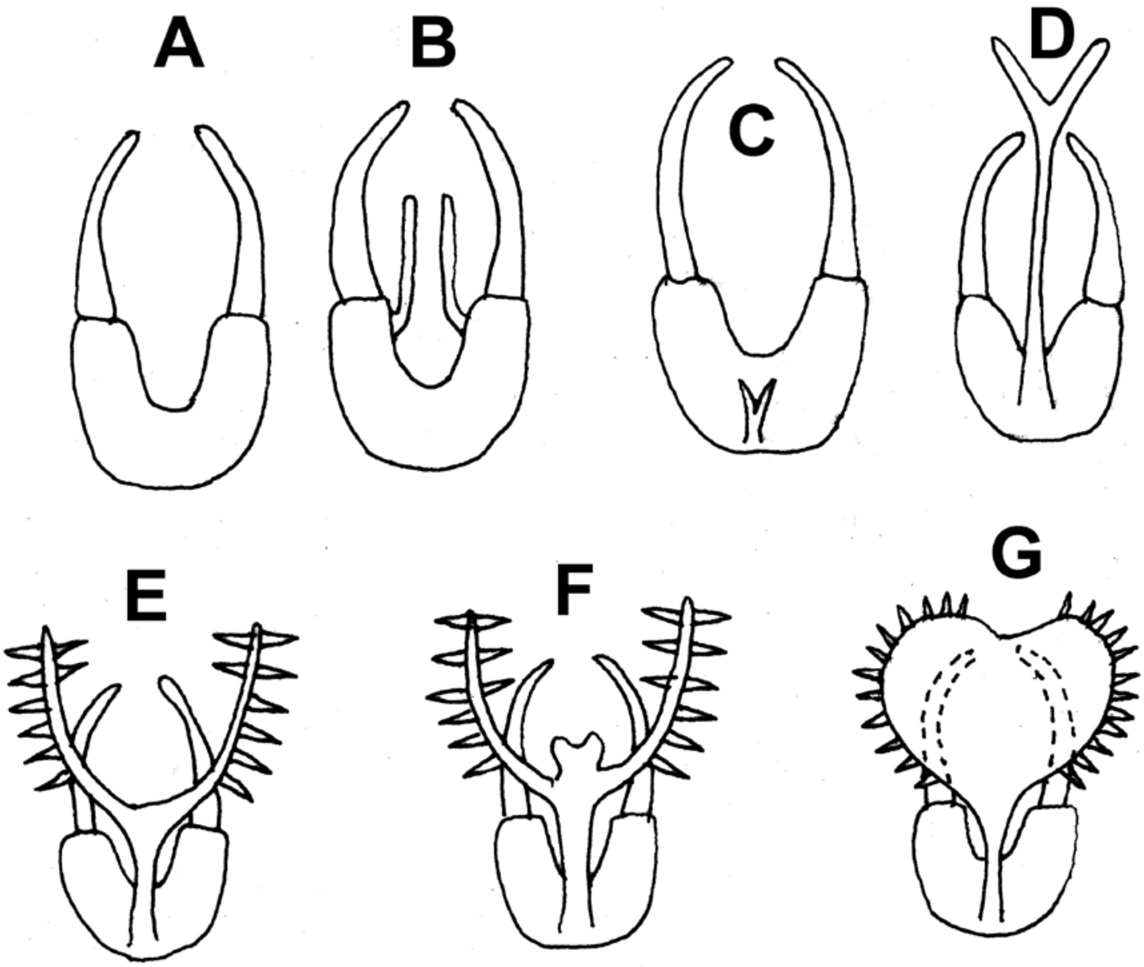

Fig 18. A, no frontal appendage; B, no frontal appendage but digitiform antennal appendages of medial surface of proximal antennomere; C, small frontal appendage shorter than proximal antennomere; D, biramous frontal appendage longer than both antennomeres; E, complexly branched frontal appendage with no lamellar outgrowth between the main branches; F, complexly branched frontal appendage with a bilobed outgrowth between the two branches; G, lamellate frontal appendage.

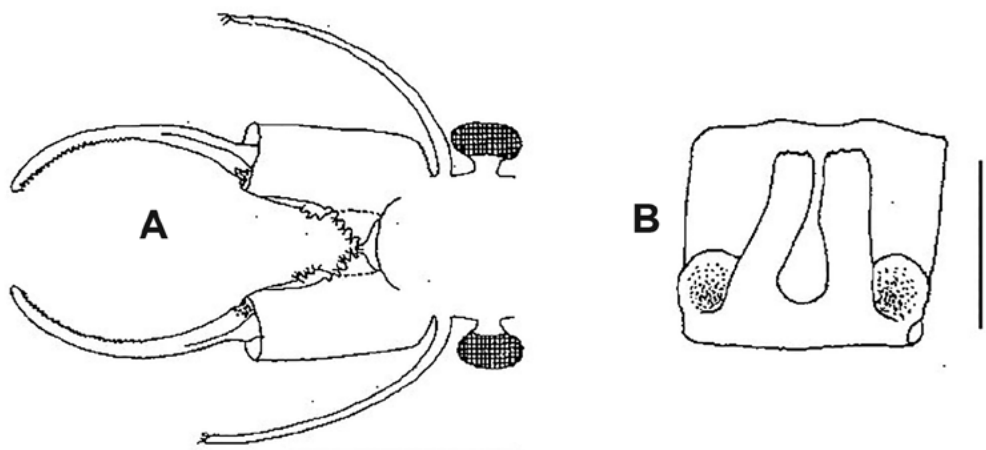

Fig 19 *B. papillata*. A, head; B, proximal portion of gonopods. Scale bars 1 mm.

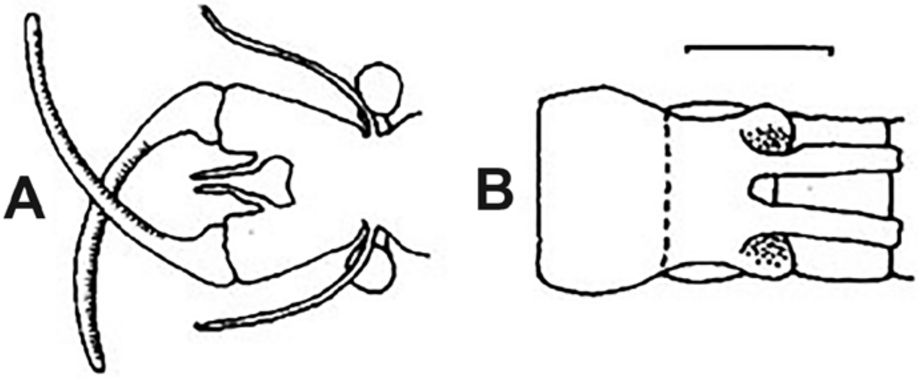

Fig 20. *B. vosperi* A, head; B, proximal portion of gonopods Scale bars 1 mm.

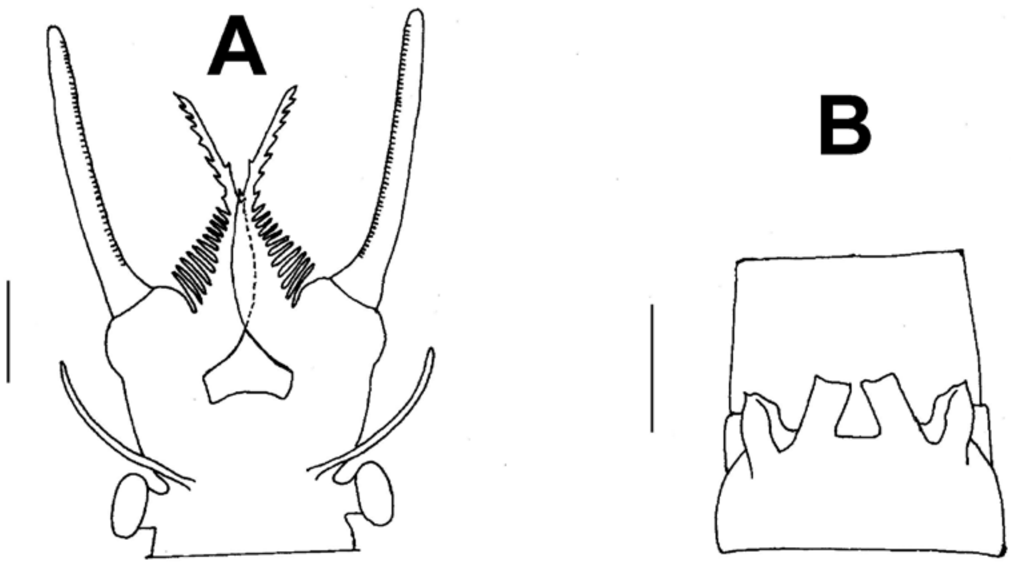

Fig 21. *B. buchananensis*. A,head; B, proximal portion of gonopods. Scale bars 1 mm.

5 (a) Antennal appendage on medial surface of proximal antennomere located mid length and a simple digit without ornamentation; male gonopods with lateral processes rounded (Fig 20) .... *.B. vosperi*

(b) Antennal appendage on medial surface of proximal antennomere located terminally, simple or complex and with ornamentation; male gonopods with lateral processes pointed (Fig 21) 6

6 (a) Proximal antennomere with a complex antennal appendage from distomedial corner bearing many long digitiform processes on basolateral surface and denticles distally; lateral processes on rigid basal portion of gonopods indistinctly tumid midway along their lengths (Fig. 21) .... *B. buchananensis*

(b) Proximal antennomere with a simple antennal appendage from distomedial corner of second antenna bearing denticles; lateral processes of gonopods not tumid medially (Fig. 22) 7

7 (a) Medial surface of fused basal part of proximal antennomere without an anterior projection; proximal segment of second antenna with a simple outgrowth from distomedial corner bearing many scattered long denticles, particularly on the medial surface; lateral processes of rigid portion of gonopods longer than the rigid portion, evenly arched laterally; no collar on gonopods (Fig. 22) .... *B. nichollsi*

(b)) Medial surface of fused basal part of proximal antennomere with medial outgrowth; proximal antennomere with outgrowth from distomedial corner bearing a few scattered short denticles; lateral process of gonopod shorter than rigid bases of gonopods and with a half collar on lateral surface of gonopods (Fig 23) .... *B hattahensis*

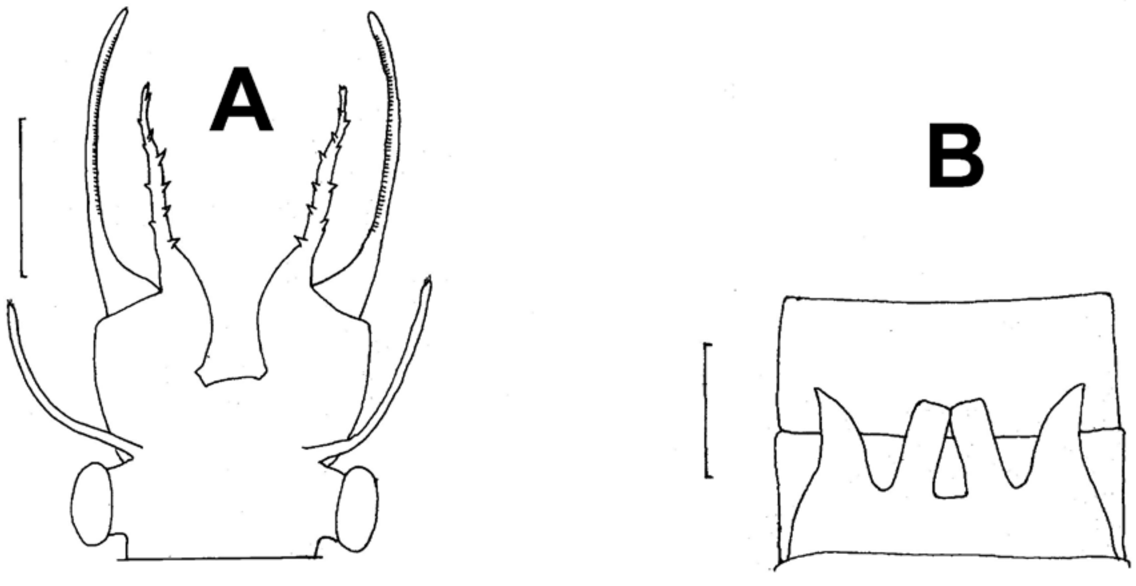

Fig 22. *B. nichollsi* A, head; B, proximal portion of gonopods. Scale bars 1 mm.

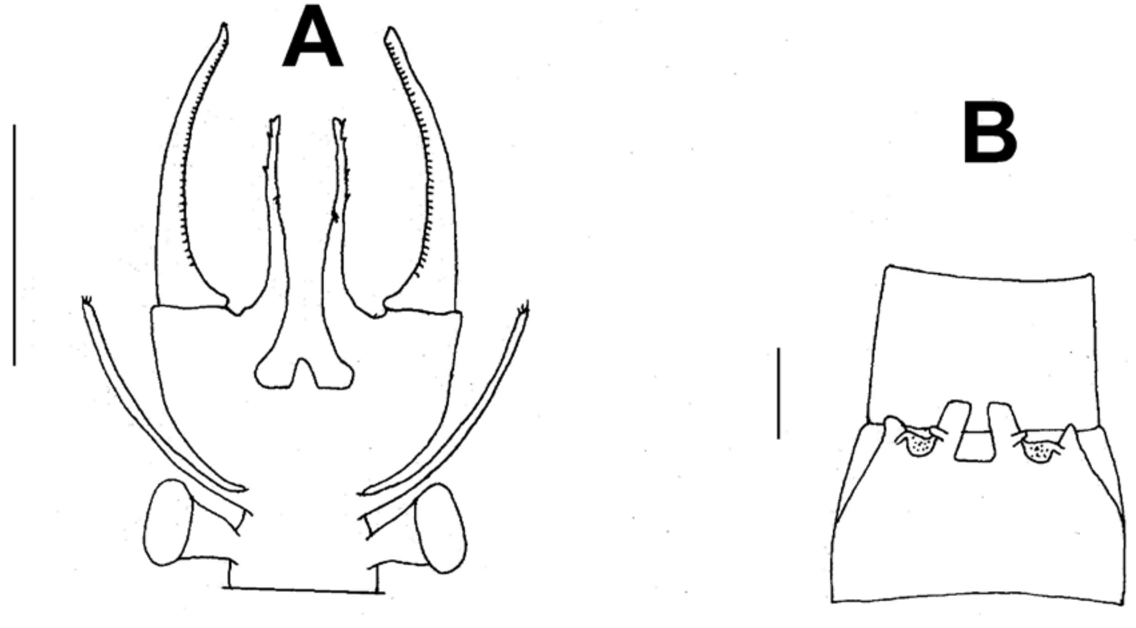

Fig 23. *B. hattahensis* A, head; B, proximal portion of gonopods. Scale bars 1 mm

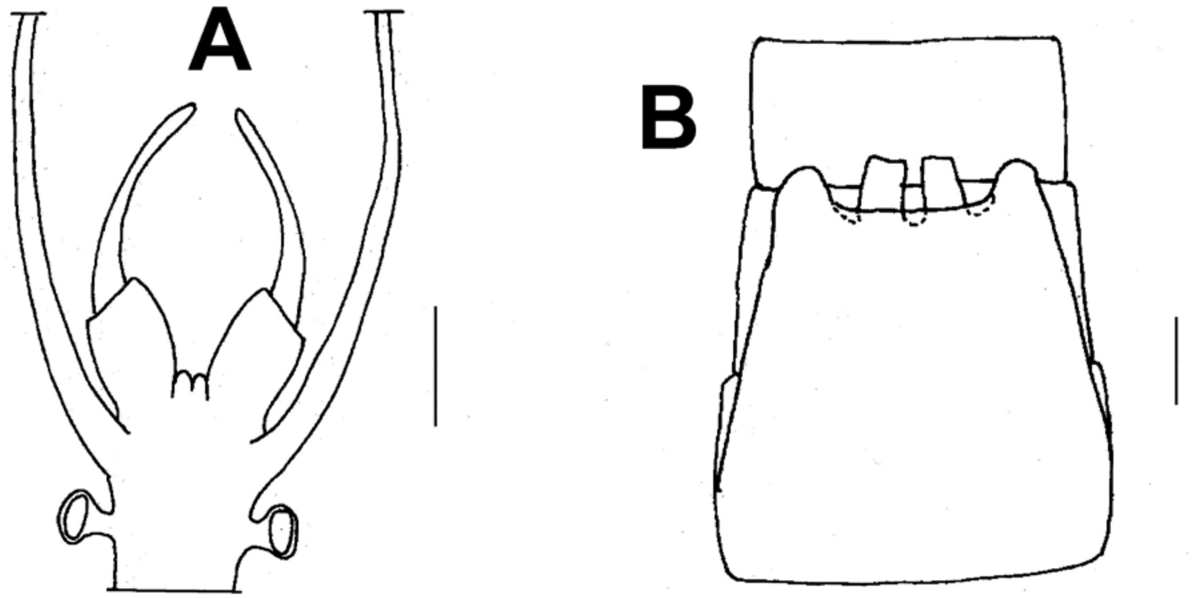

Fig 24. *B. occidentalis*. A, head; B proximal portion of gonopods . Scale bar 1 mm.

8 (a) First antenna much longer than second antenna and extending back to at least the 5th thoracic segment; base of each gonopod with a large basolateral projection adults usually > 30mm (Fig. 24) .... *B. occidentalis*

(b) First antenna shorter than second antenna; basolateral projections, if present, on gonopods not enlarged and generally smaller than proximal portion of gonopods; adults < 30 mm (Figs 25-27) 9

9 (a) Second antenna with distal antennomere with two small spines near its base; gonopods without basolateral projections; adults <10 mm (Fig. 25) .... *B. nana*

(b) Distal antennomere without spines; gonopods with basolateral projections; adults generally > 12 mm (Figs. 26,27) 10

10 (a) First antenna longer than proximal antennomere; space between rigid portion of gonopods and basolateral projections not in the form of a semicircular hollow; apex of distal segment antennomere usually turned laterally (Fig 4) .... *B. simplex*

(b) First antenna shorter than proximal antennomere; space between rigid portion of gonopods and basolateral projections in the form of a semicircular hollow; apex of distal antennomere not turned laterally (Fig. 42) .... *B. compacta*

(Note: *B. compacta* is similar to *B. hearnii* but *B. compacta* has a small rounded tumidity on the medial margin of the proximal antennomere, whereas *B. hearnii* has a distinct lamella in the same position. *B. hearnii* always has a small forked frontal appendage whereas *B. compacta* may have a minute forked frontal appendage, but usually not. Finally *B. compacta* occurs in southern Victoria and southern NSW whereas *B. hearnii* has only been found in southwest WA.)

11 (a) Proximal antennomeres with raised pad of small spines medially; gonopods with basolateral projections, no depression in these terminally (Figs. 28,29) 12

(b) Proximal antennomeres with a lobe mediobasally or medially, no basolateral projections to gonopods, but if present then a depression terminally (Figs. 30, 31) 13

12 (a) Second antenna with apex not markedly turned laterally; frontal appendage generally longer than 1/3 width of basal antennomere and ornamented; adults > 25 mm (Fig. 28) .... *B. australiensis*

(b) Apical antennomere with apex lyriform); frontal appendage < 1/3 width of basal antennomere and unornamented; adults < 20mm (Fig. 29) .... *B. lyrifera*

13 (a) Proximal antennomere with a raised pad mediobasally and remainder of medial surface covered in denticles; no basolateral projections of gonopod (Fig. 30) .... *B. halsei*

(b) Proximal antennomere with a lamella longer than high midway medially; no denticles on medial surface; basolateral projections of gonopod wswelling lateral to base of gonopods with a terminal depression (Fig 31) .... *B. hearnii*

(*B. hearnii* has the unusual feature a triangular swelling on the ventral side of the proximal antennomere (Fig 31B).

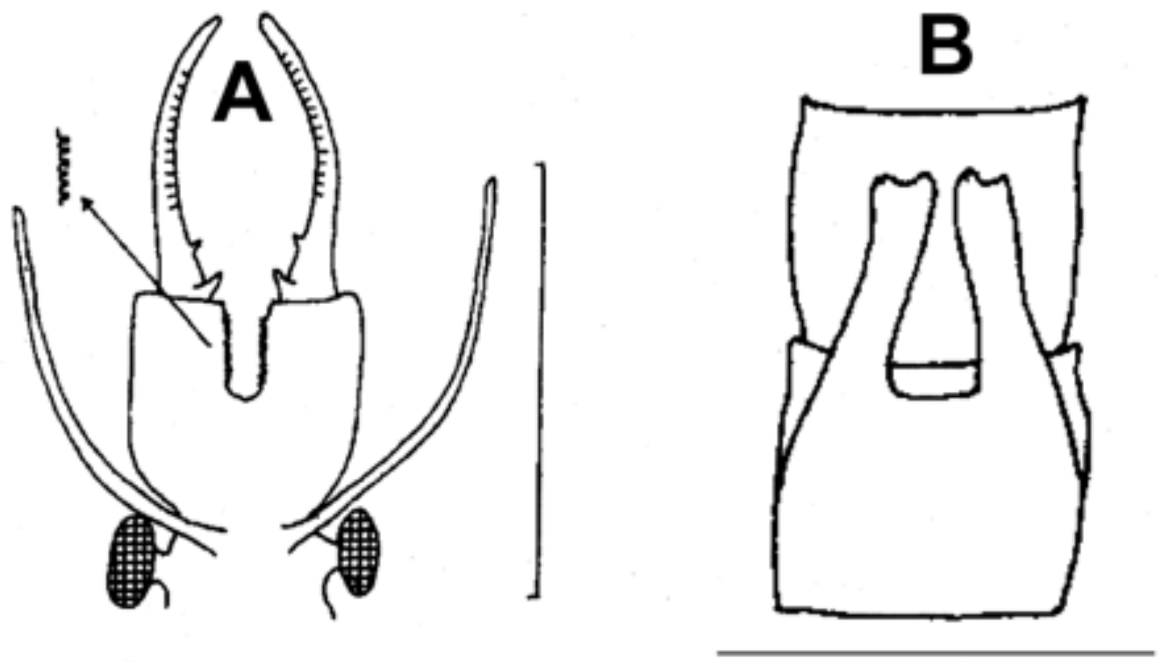

Fig 25. *B. nana* A, head; B, proximal portion of gonopods. Scale bars 1 mm.

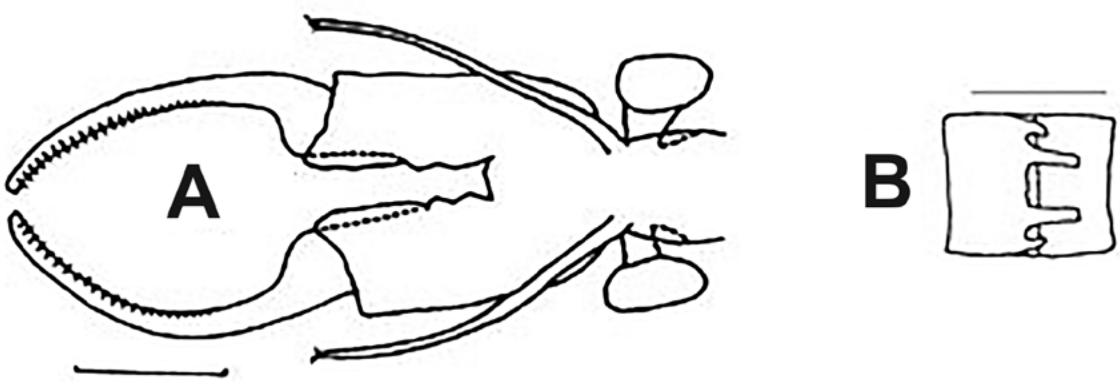

Fig 26. *B. simplex* A, head, B, proximal portion of gonopods. Scale bars 1 mm.

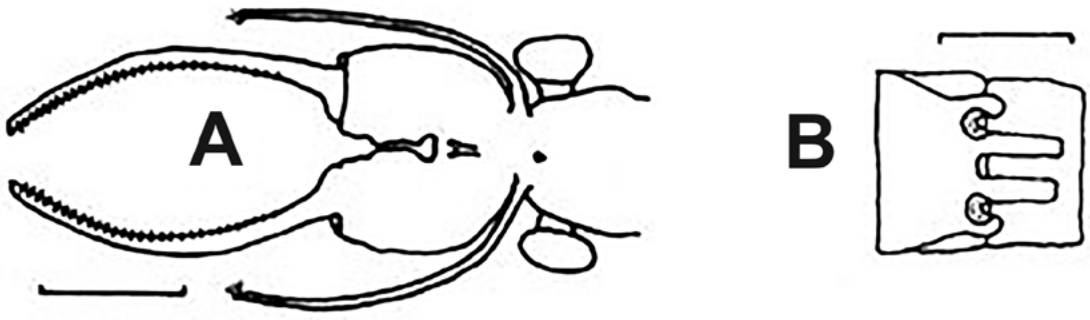

Fig 27 *B. compacta* A, head; B, proximal portion of gonopods. Scale bars 1 mm.

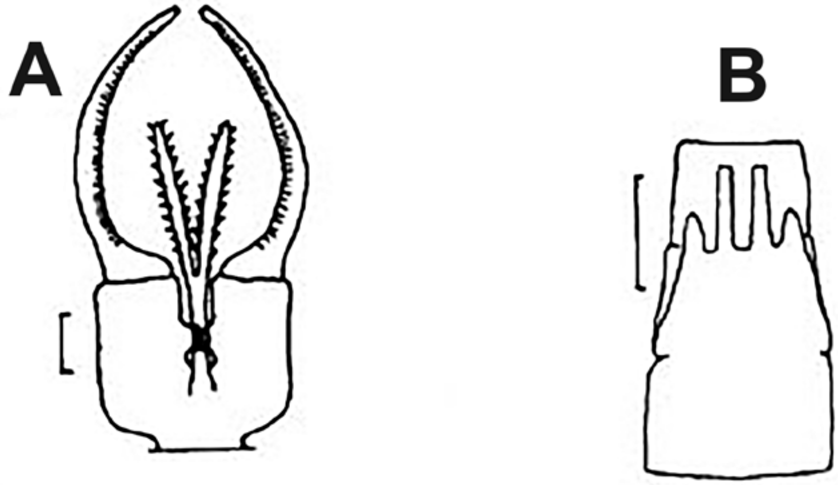

Fig 28. *B. australiensis* A, head; B, proximal portion of gonopods. Scale bars 1 mm.

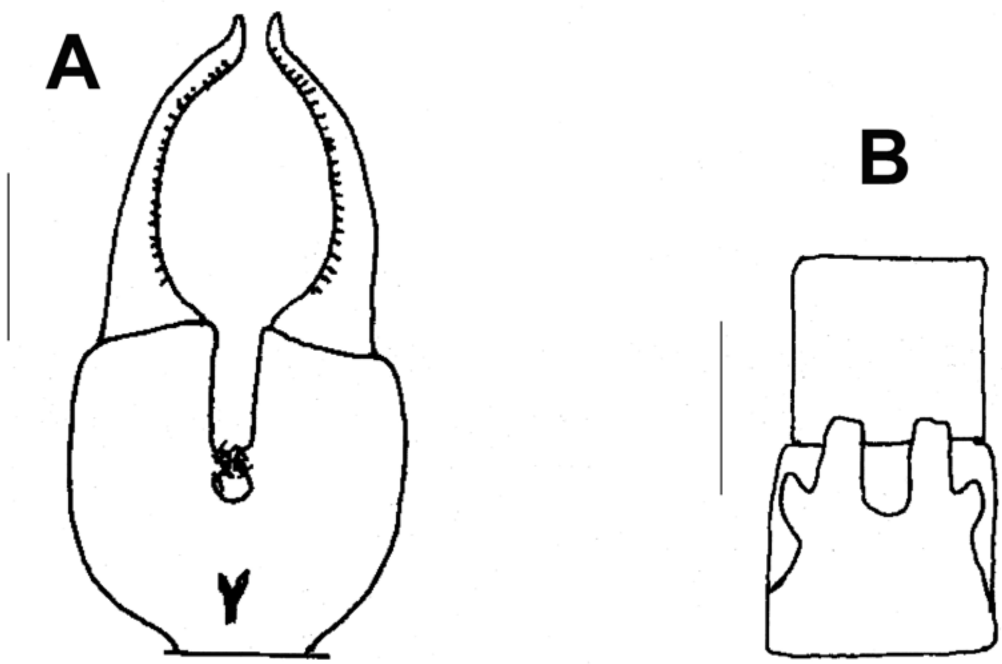

Fig. 29 B. *lyrifera* A, head; B, proximal portion of gonopods. Scale bars 1 mm.

14 (a) Frontal appendage consisting of a trunk without branches or forking into two simple branches with at most short spines and papillae (Figs 18D, 32) 15

(b) Frontal appendage consisting of a trunk bearing two complex branches which may be lamellate or tubular and with numerous digitiform processes (Figs 18E-G, 55) . 26

15 (a) Frontal appendage a simple trunk without branches or digitiform processes (Fig 32) .... *B. anatinorhychna*

(b) Frontal appendage forked into two simple branches both lacking digitiform processes (Fig 18D, 33) 16

16 (a) Distal segment of second antenna flattened and with 70-90° bend about halfway along its length; body length <10mm (Fig. 33) 17

(b) Distal segment of second antenna cylindrical or nearly so and evenly arched; body length variable (Fig. 36) 18

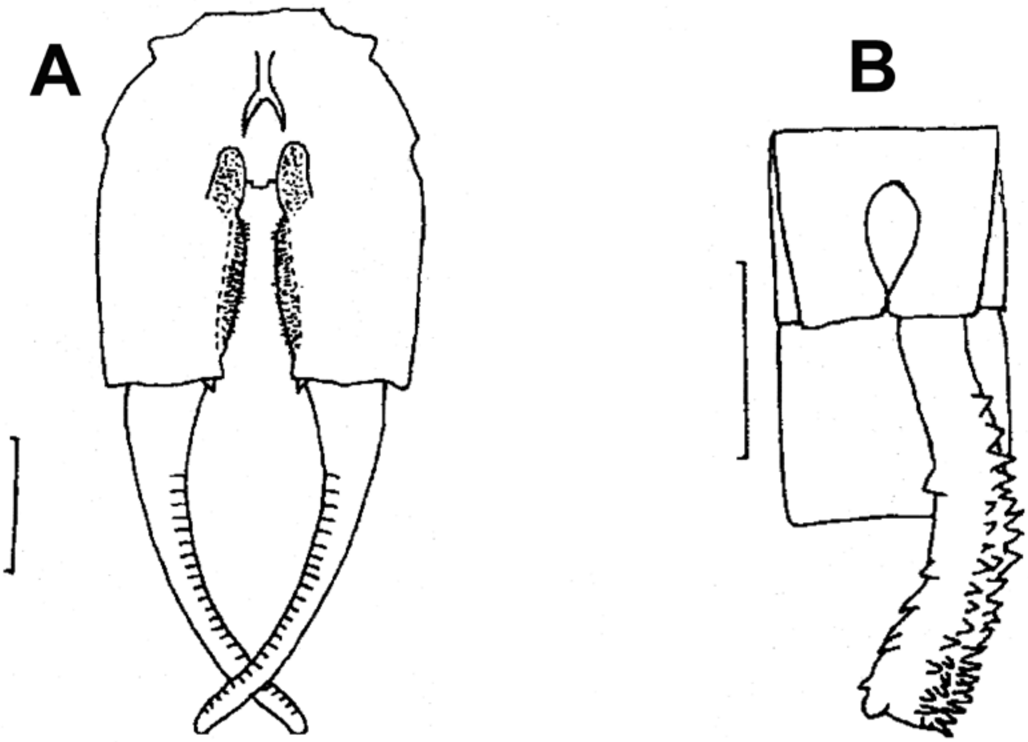

Fig. 30 B. halsei A, head; B, everted gonopod. Scale bars 1 mm.

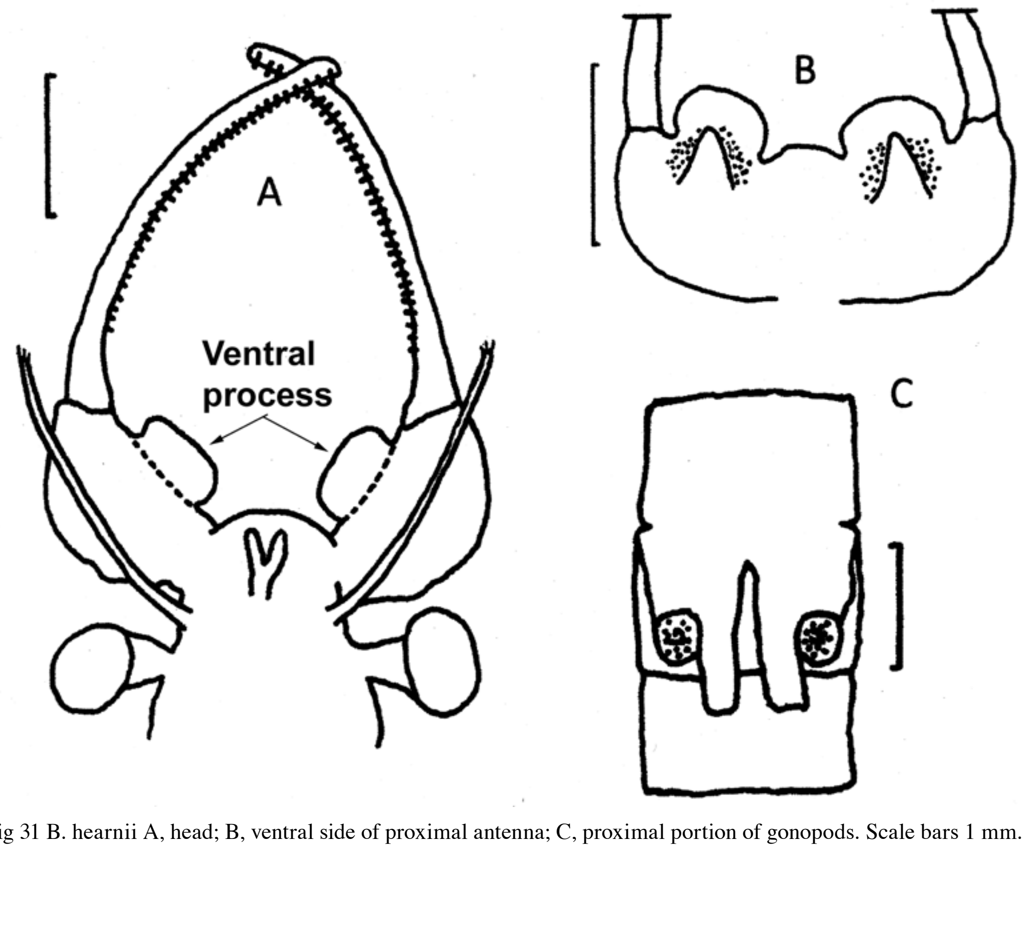

Fig 31 B. hearnii A, head; B, ventral side of proximal antenna; C, proximal portion of gonopods. Scale bars 1 mm.

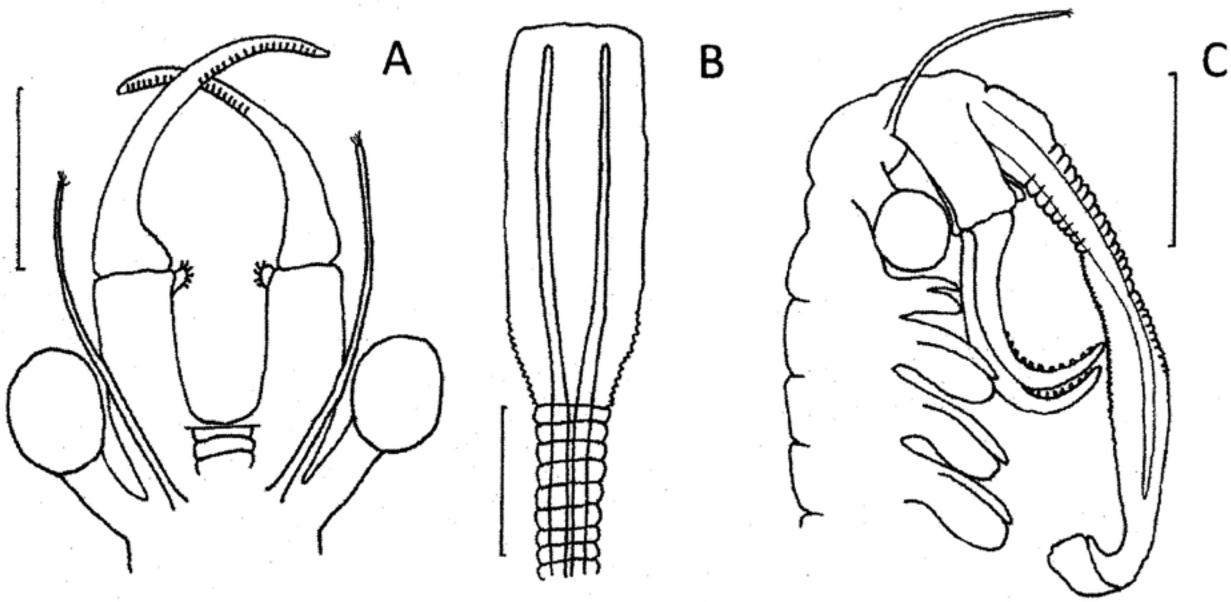

Fig 32. *B. anatinorhyncha* A, head dorsal view, frontal appendage removed; B, frontal appendage; C, anterior body lateral view. Scale bars 1 mm.

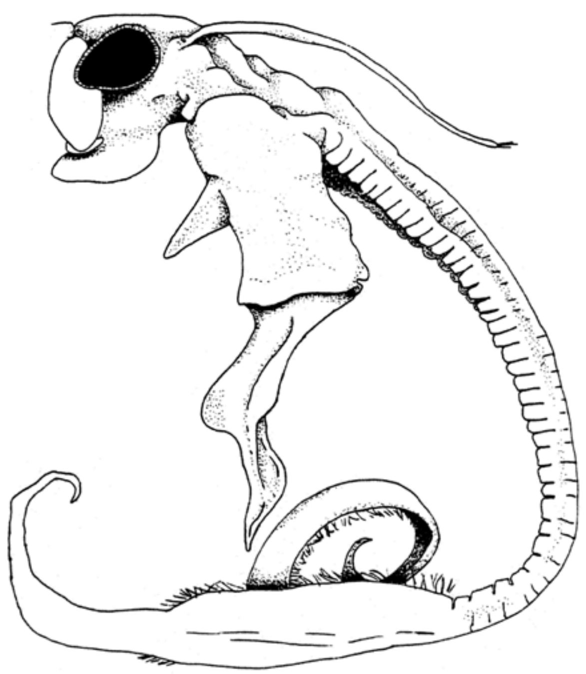

Fig 33. *B. apophysata* head, antennae and frontal appendage. This species is poorly known; it has not been seen since its description in 1941. Diagram courtesy of Christopher Rogers who has seen the types housed in the USA.

17 (a) Proximal antennomere with a large flap-like medial outgrowth (½ length of proximal segment); no filiform setae on this outgrowth; branches of frontal appendage with a fringe of fine setae apomedially on each branch of the frontal appendage (Fig. 33) .... *B. apophysata*

(b) Proximal antennomere with a small rounded outgrowth (< ¼ length of proximal segment) from medial surface; filiform setae on this outgrowth; frontal appendage with basolateral edge of branches with a fringe of fine setae (Fig. 34) .... *B. proboscida*

18 (a) Proximal antennomere apically with a large triangular outgrowth, about half the length of the distal segment; basolateral projections of gonopod without a distinct gap between gonopods and the projections (Fig. 35A,B) 19

(b) Proximal antennomere without an apical outgrowth; basolateral projections, if present, separated by a distinct gap from gonopod base (Fig. 35C,D) 20

19 (a) Distal antennomere with apex expanded into a knob; trunk and the two branches of frontal appendage subequal in length and with an uneven lateral fringe; proximal antennomere with a large lobe occupying most of the medial surface (Fig. 36) .... *B. insularis*

(b) Distal antennomere with apex not expanded into a knob; two branches of frontal appendage about half as long as the trunk and lateral fringe even; small insignificant lobe and some denticles on distomedial surface of proximal antennomere (Fig. 37) .... *B. denticulata*

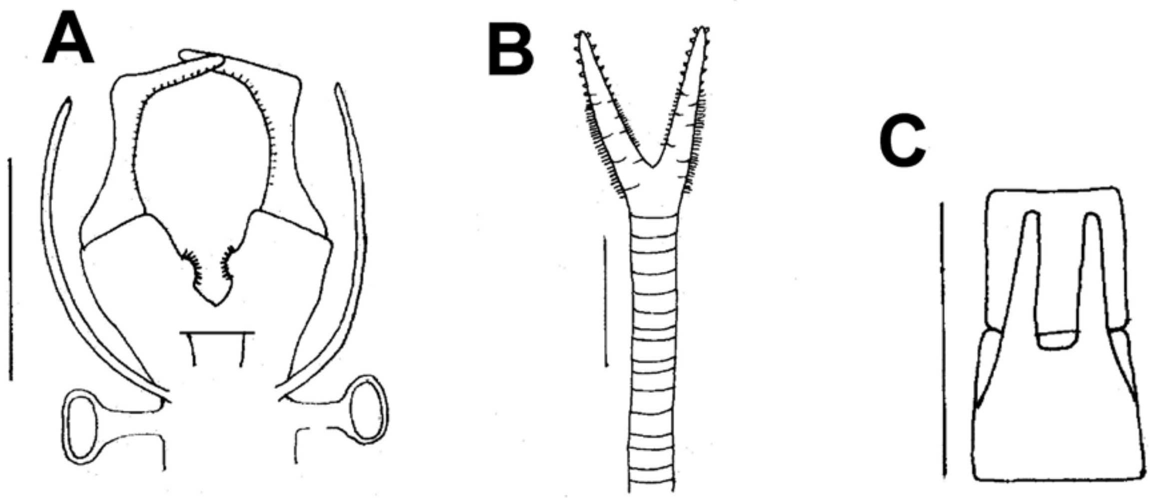

Fig 34. *B. proboscida* A, head; B, frontal appendage; C, proximal portion of gonopods. Scale bars 1 mm.

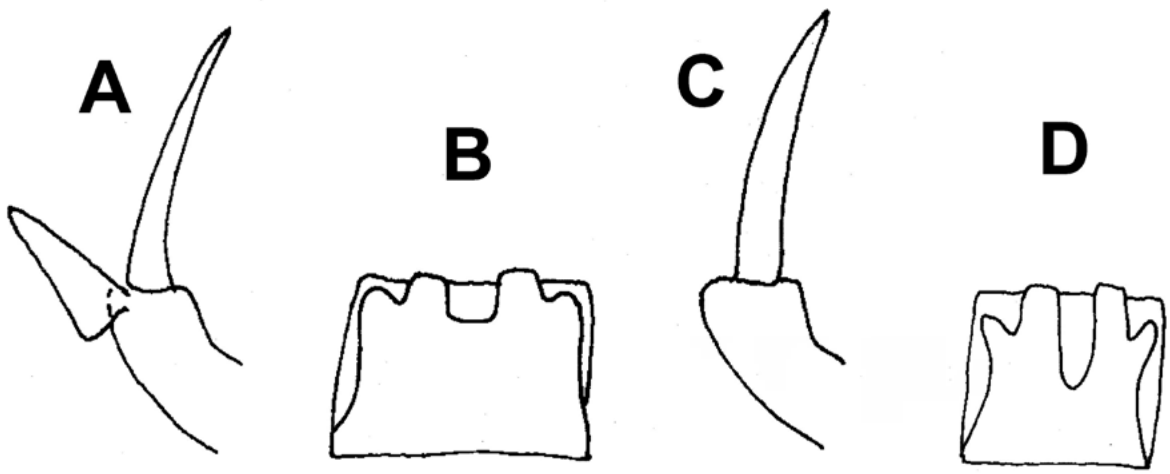

Fig 35. Various *Branchinella* spp. A & C, antenna with and without a triangular process at distolateral corner; B & D, lateral projections at bases of gonopods verses lateral projections midway along the gonopods.

20 (a) Frontal appendage with one or more spines at base of the two branches; trunk of frontal appendage expanded proximal to the insertion of lateral spines; apex of distal antennomere expanded; medial surface of base of each gonopod with a stout spine (Fig. 38) .... *B. longirostris*

(b) Frontal appendage without spines and not expanded mid length; apex of distal segment of second antenna evenly narrowing; gonopod base lack spines 21

(Note: *B. longirostris* is a variable species in keeping with its isolation on granite outcrops in southern WA. Spines proximal to the bifurcation of the trunk vary from 1 to 4 and are inserted on various extrusions, singly or grouped. Also the two branches of the trunk are variable in shape as are the distribution of digitiform processes. The species is virtually restricted to pan gnammas and is almost always the only anostracan in such habitats.

21 (a) The two branches of the trunk less than half its total length, bulbous with a distinct digitiform apex; no basolateral projections on gonopod base (Fig.40) . *B. latzi*

(b) Branches of the trunk not bulbous and evenly narrowing apically; base of gonopod with or without a basolateral projections on each side (Fig 41) 22

22 (a) Frontal appendage variable in length, but almost always shorter than second antenna and not rolled in life; adults > 25 mm, often red/pink in life .... *B. australiensis*

(b) Frontal appendage longer than second antenna and rolled in life and usually also in death; adults <20 mm, rarely red/pink in life (Fig. 41) .... *B. affinis* group 23

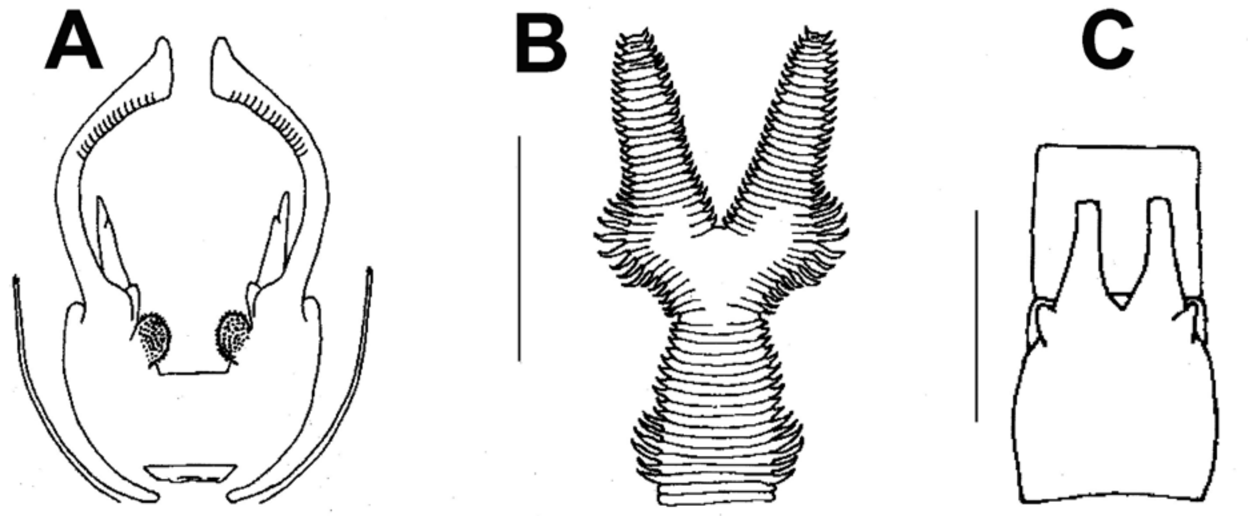

Fig 36. *B. insularis* A, antennae; B frontal appendage; C, proximal portion of gonopods. Scale bars 1mm.

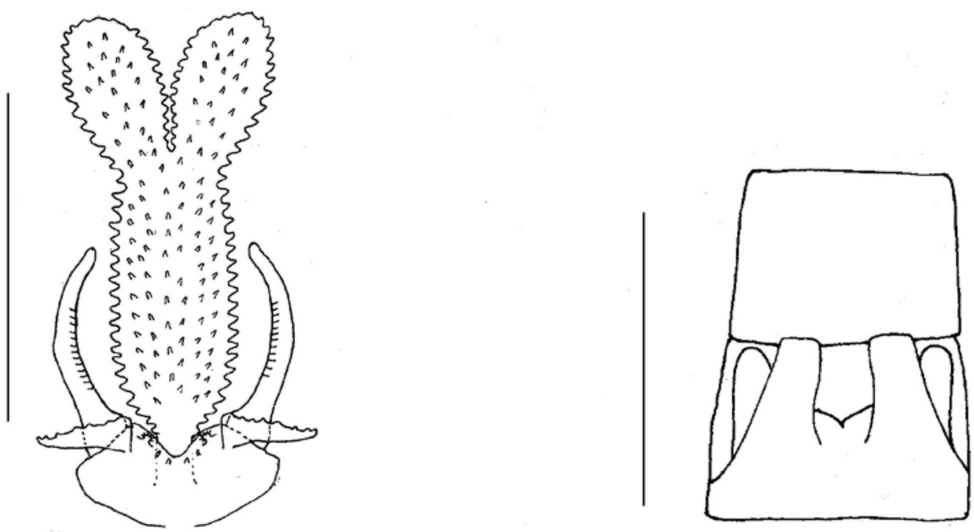

Fig 37. *B. denticulata* A, second antenna with frontal appendage; B, proximal portion of gonopods. Scale bars 1 mm.

23 (a) Frontal appendage widest midway long the stem; the two branches of the stem tubular; small or large tumidity with setae on medial surface of proximal antennomere (Fig. 42) 24

(b) Frontal appendage widest at junction with the two branches; these branches elongated triangles; no tumidities on medial surface of proximal antennomeres (Fig. 43) 25

24 (a) Trunk of frontal appendage narrow (width ca 0.15 to 0.25 of length); mid median tumidity of proximal antennomere small, symmetrical; branches of frontal appendage stem long (0.5 to 0.8 of stem length)(Fig.41) .... *B. affinis*

(b) Trunk of frontal appendage relatively broad (width ca 0.3-0.4 of length); proximal antennomere with an asymmetrical tumidity near its apex; branches of frontal appendage shorter (<0.3 of stem length)(Fig. 42) .... *B. erosa*

(Note: these two species are very similar, but their females are easily distinguished—see female key. An additional character, again variable, is the relative length of the basolateral projections of the gonopod base. They are almost as long as the gonopod base in *B. affinis*, but about half the length in *B. erosa*).

25 (a) No basolateral projections on gonopod base; fringe of denticles on medial and lateral surfaces of stem branches,

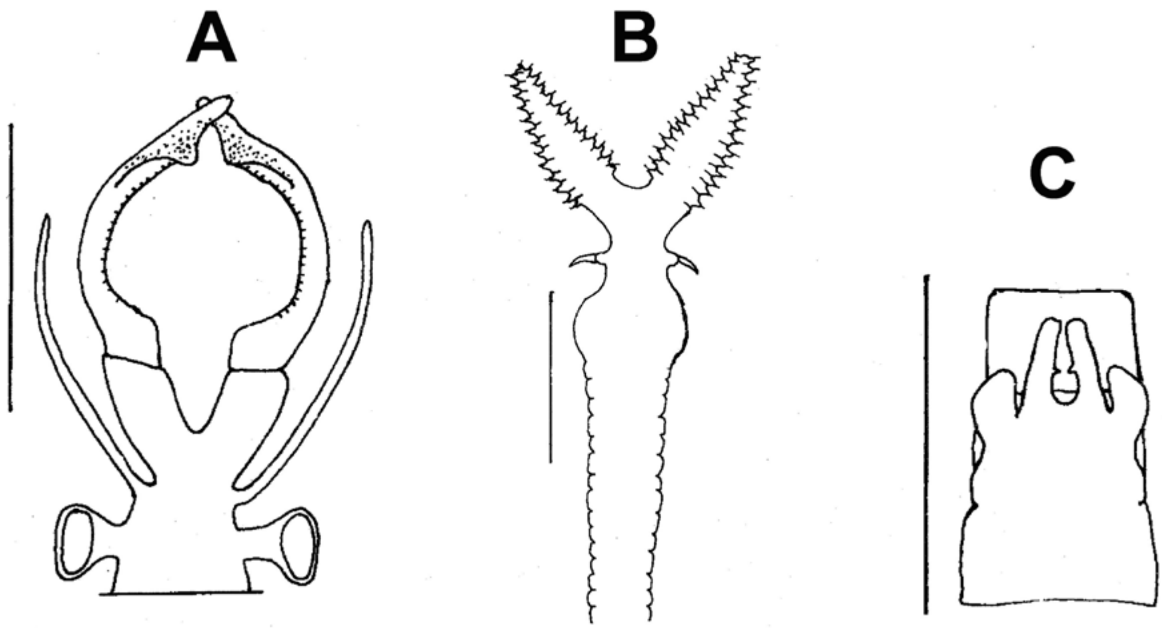

Fig 38. *B. longirostris* A, head; B, frontal appendage; C, proximal portion of gonopods. Scale bars 1 mm.

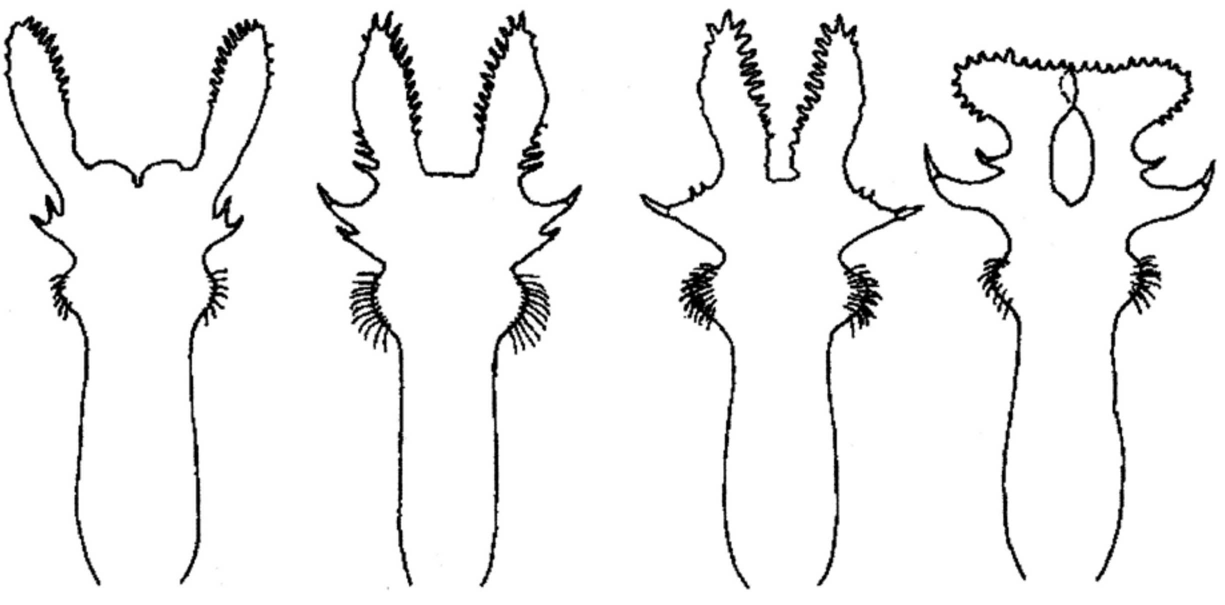

Fig 39. *B. longirostris* Variations in the frontal appendage

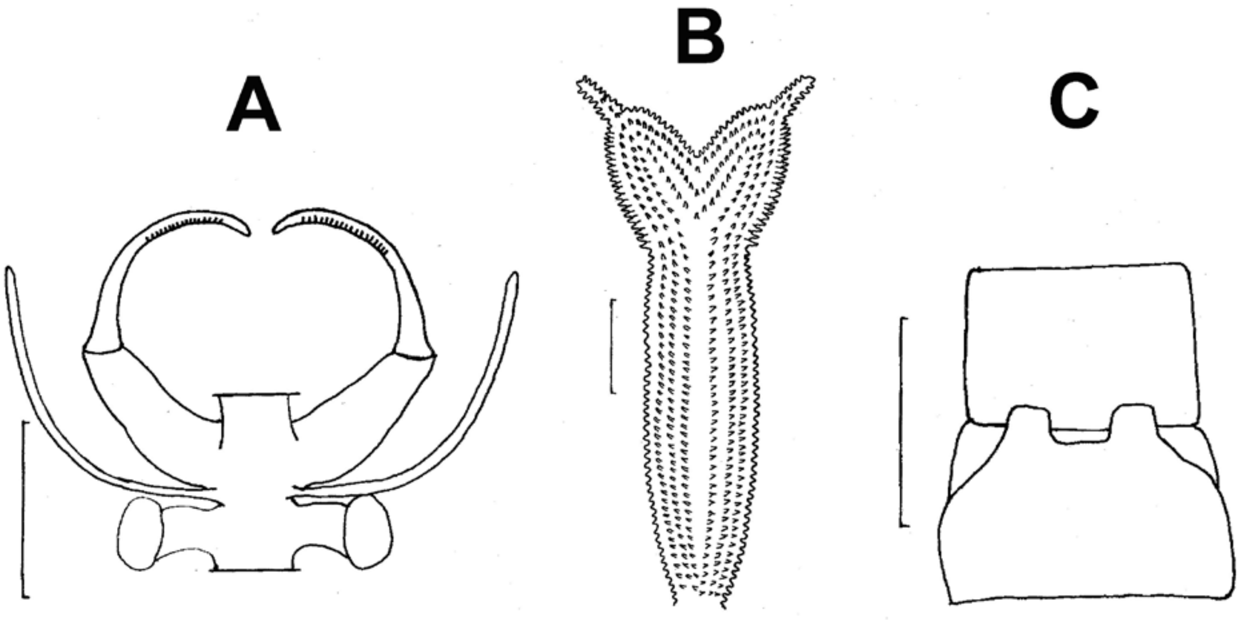

Fig 40. *B. latzi* A, head: B, frontal appendage; C, proximal portion of gonopods. Scale bars 1 mm.

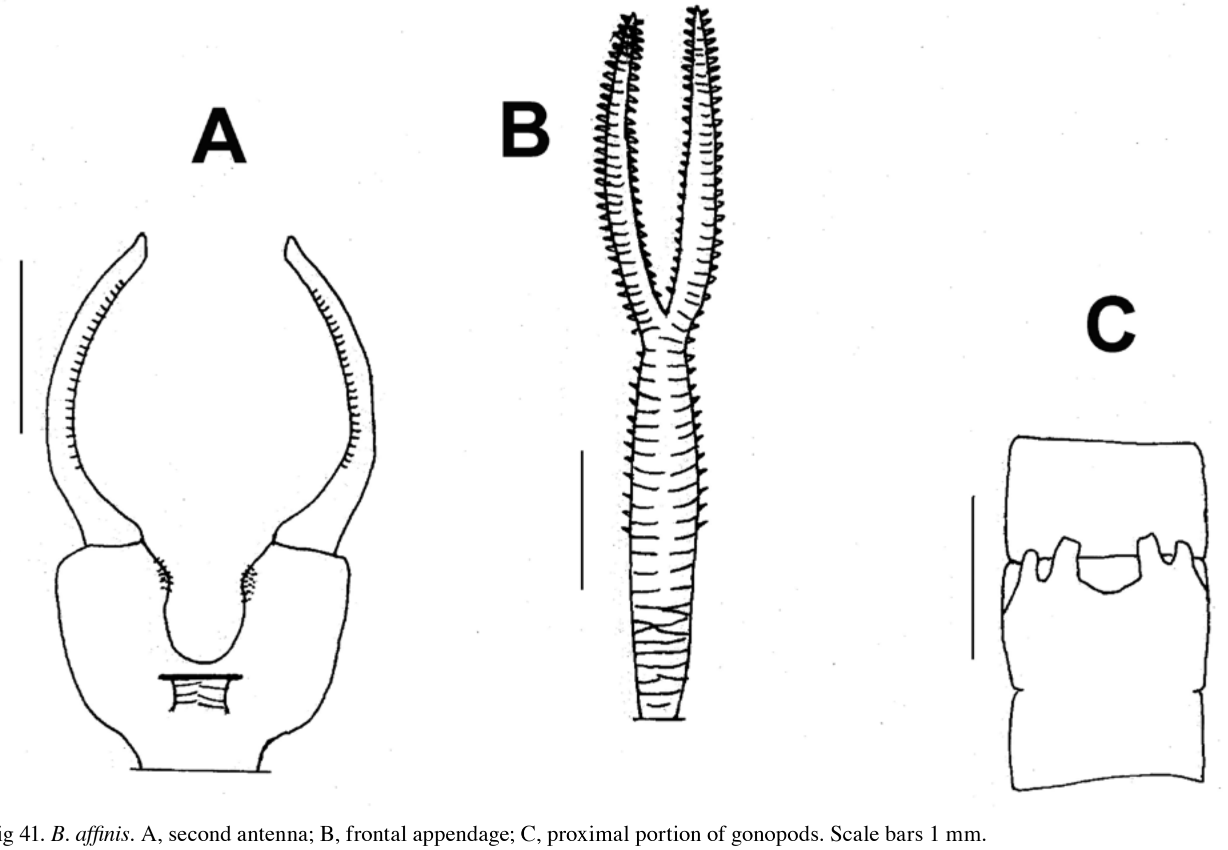

Fig 41. *B. affinis*. A, second antenna; B, frontal appendage; C, proximal portion of gonopods. Scale bars 1 mm.

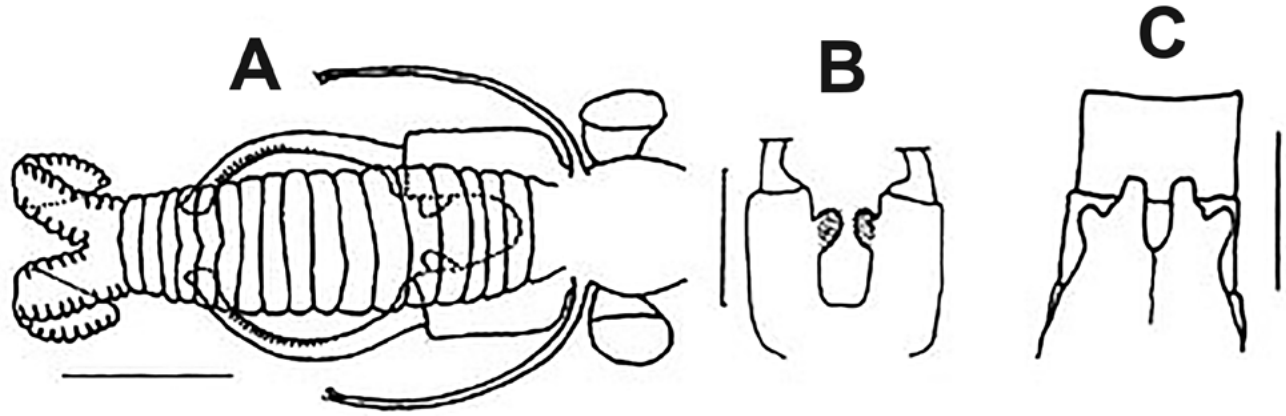

Fig 42. *B.erosa*. A, head; B, proximal segment of second antenna; C, proximal portion of gonopods.Scale bars 1 mm.

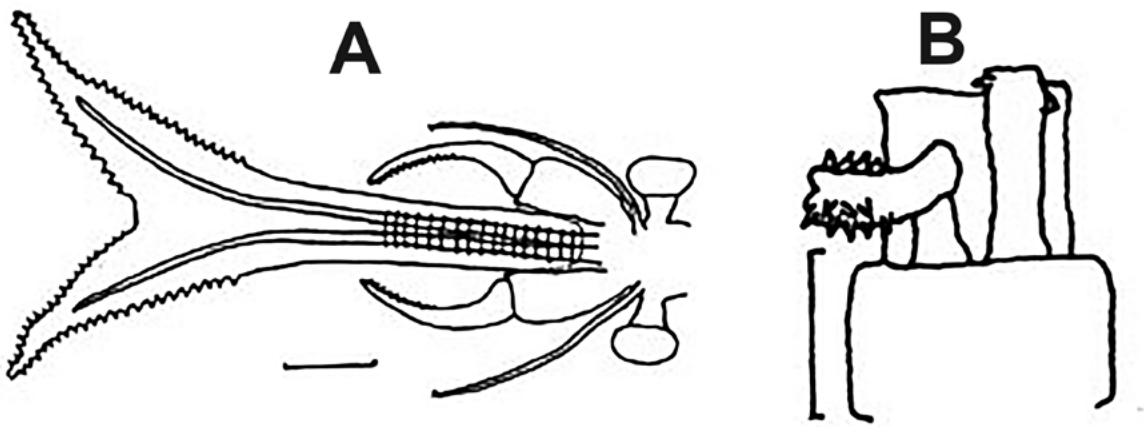

Fig 43. *B. minmina* A, head; B, proximal portion of gonopods. Scale bars 1 mm.

usually no denticles/short setae on medial surface of medial surface proximal segment of antenna, though there may be a few apically (Fig. 43) .... *B. minmina*

(b) Triangular basolateral projections on gonopod base; denticles/short digitiform processes only on lateral surface of stem branches; denticles on medial surface of proximal antennomere (Fig. 44) .... *B. macraeae*

(Note. Again another difficult pair to separate. Another useful character is the increase in width of the stem distally is much greater in *B. minmina* than in *B. macareae* (by about a factor of 2). Also note *B. minmina* occurs in northwestern Qld and *B. macareae* in the Pilbara WA).

26 (a) Frontal appendage consisting of a stem bearing two approximately tubular branches which in turn may bear a few to many (<15) elongate tubular sub-branches which in turn may bear papillae of fairly uniform structure (Figs.18E,F, 45) 27

(b) Frontal appendage with a trunk bearing two lamellate branches with numerous (>20), short, digitiform processes usually terminating in spines and usually differentiated (Figs.18G, 55) 36

27 (a) Bilobed flat outgrowth between the two main branches of the frontal appendage (Figs. 18F, 45) 28

(b) No flat outgrowth between the two main branches of the frontal appendage (Figs. 18E, 47) 30

28 (a) Frontal appendage with sub-branches of main branches equal on both sides; proximal antennomere with no small setae on medial surface; first antenna distinctly longer than proximal antennomere of second antenna (Fig. 45) .... *B. wellardi*

(b) Frontal appendage with sub-branches of main branches mostly on lateral edge with just a few on the distomedial surface; proximal antennomere with small setae on medial surface; first antenna subequal in length to proximal antennomere of second antenna (Figs. 46, 47) 29

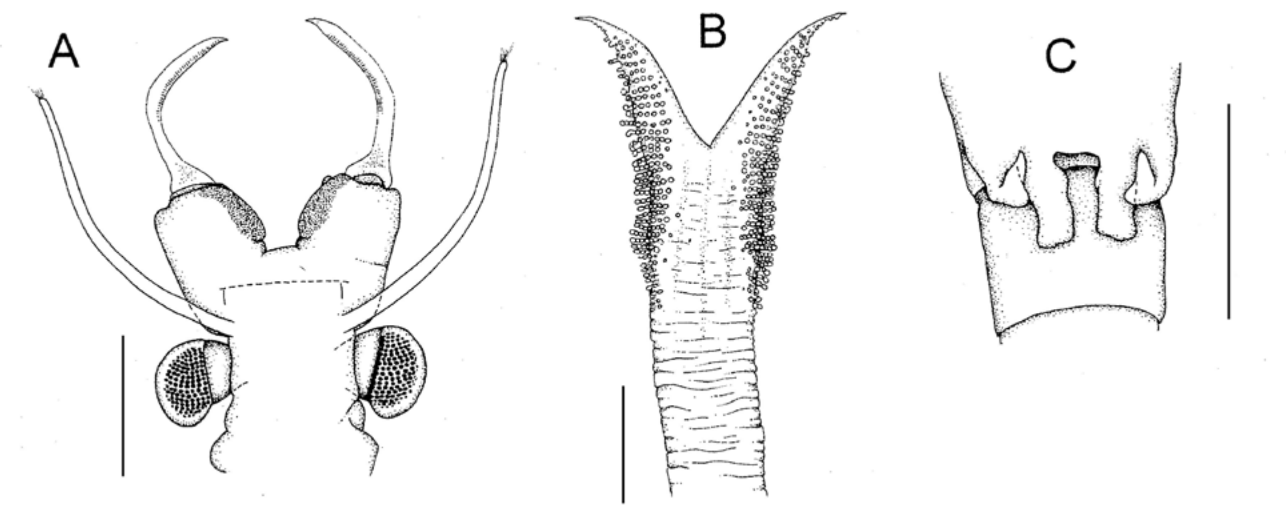

Fig. 44. *B. macraeae* A,head; B, frontal appendage; C, proximal portion of gonopods. Scale bars 1 mm.

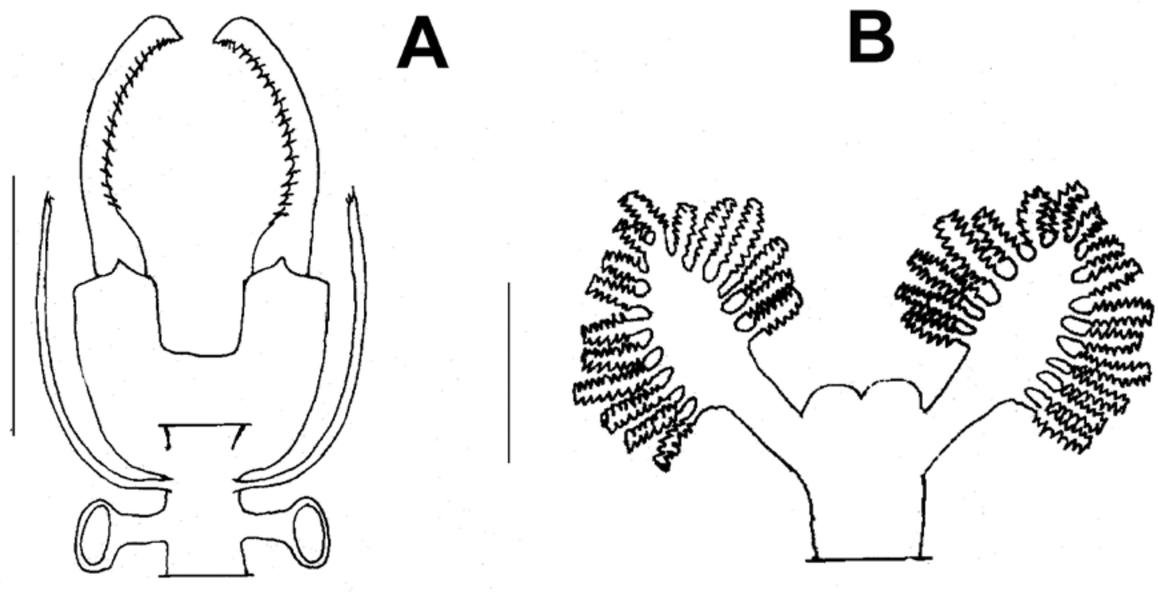

Fig 45. *B. wellardi* A, head; B, frontal appendage Scale bars 1 mm.

29 (a) Frontal appendage with sub-branches of main branches bearing papillae, but not further ramified; each main branch of frontal appendage terminating in an apical knob covered with denticles; medial surface of proximal segment antennomere with filiform setae concentrated basially; adults < 11 mm (Fig. 46) .... *B. tyleri*

(b) Frontal appendages with sub-branches of main branches ramified into further branches; each main branch of frontal appendage lacking a knob apically; medial surface of proximal segment of second antenna with filiform setae concentrated apically; adults >12m (Fig. 47) .... *B. arborea*

30 (a) Stout spine at junction between proximal and distal antennomere (Fig. 48,49) 31

(b) No such spine present (Fig. 50) 32

31 (a). Frontal appendage with sub-branches of each main branch on basal half of lateral margin only and decreasing markedly in size from the base; spine at apex of proximal antennomere almost on distolateral corner (Fig. 48) .... *B. dubia*

(b). Frontal appendage with sub-branches inserted laterally from base to apex of each main branch and a few on medial margin near the apex, no consistent variation in size of the sub-branches; spine at apex of proximal antennomere placed medially (Fig. 49) .... *B. pinnata*

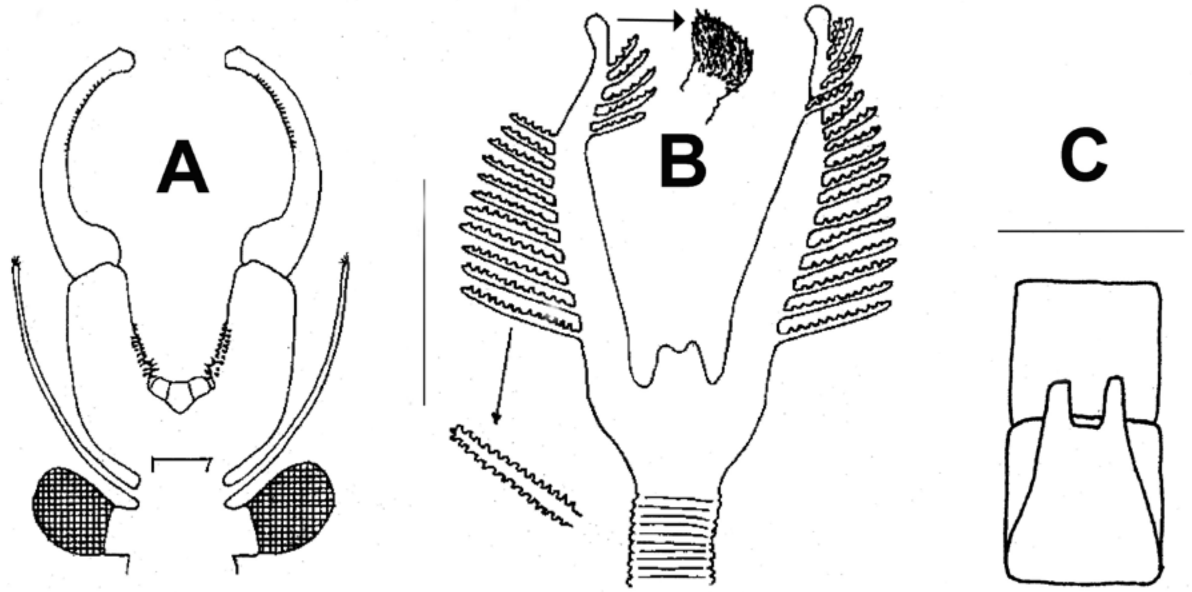

Fig 46. *B. tyleri*. A, head; B, frontal appendage; C, proximal portion of gonopods Scale bars 1mm.

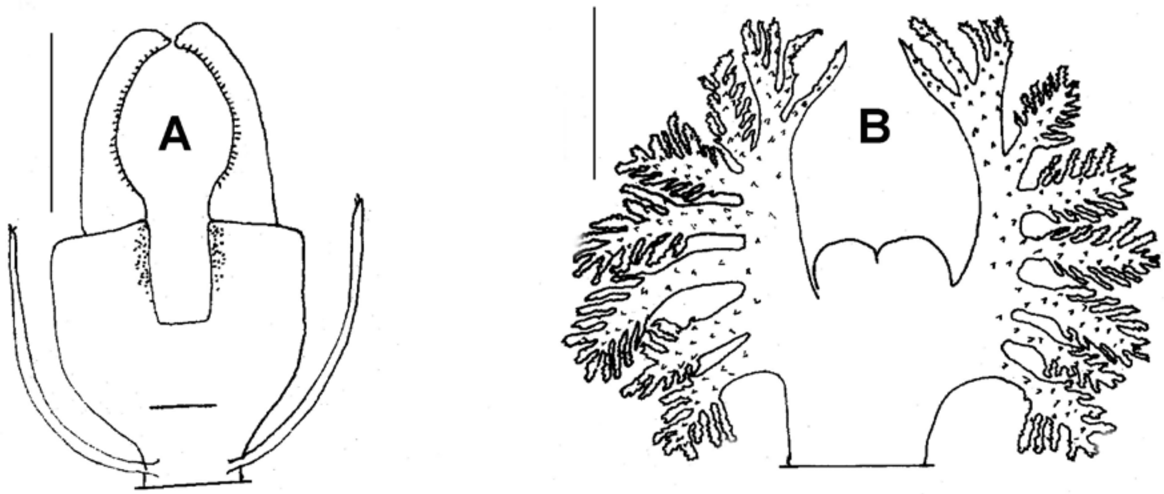

Fig 47. *B. arborea*. A, first and second antenna; B, frontal appendage. Scale bars 1 mm.

32 (a) Frontal appendage with 2 – 6 basal digitiform processes on each side of the trunk near its base; branches of frontal appendage with simple digitiform processes/sub-branches, largely without denticles (Figs.50,51,52) 33

(b) Frontal appendage without lateral digitiform processes on its basal trunk; branches of frontal appendage more complex, either some ramified into sub-branches or with two types of processes, digitiform processes as in 32(a) plus a large laminar process medially; all digitiform processes/sub-branches with numerous denticles (Fig. 60) 35

33 (a) The two sub-branches of the frontal appendage widest medially and with about 20 digitiform processes laterally and about 12 medially; eye reduced < half diameter of basal frontal appendage stem; digitiform processes of basal stem with a spiny sub-terminal bulb supporting a large spine terminally (Fig 50) .... *B. pinderi*

(b) The two sub-branches of the frontal appendage of even width or decreasing terminally and with <10 digitiform processes laterally and medially; eye or normal size, subequal in diameter to that of basal frontal appendage stem; basal digitiform processes lacking subterminal bulb and large terminal spine 34

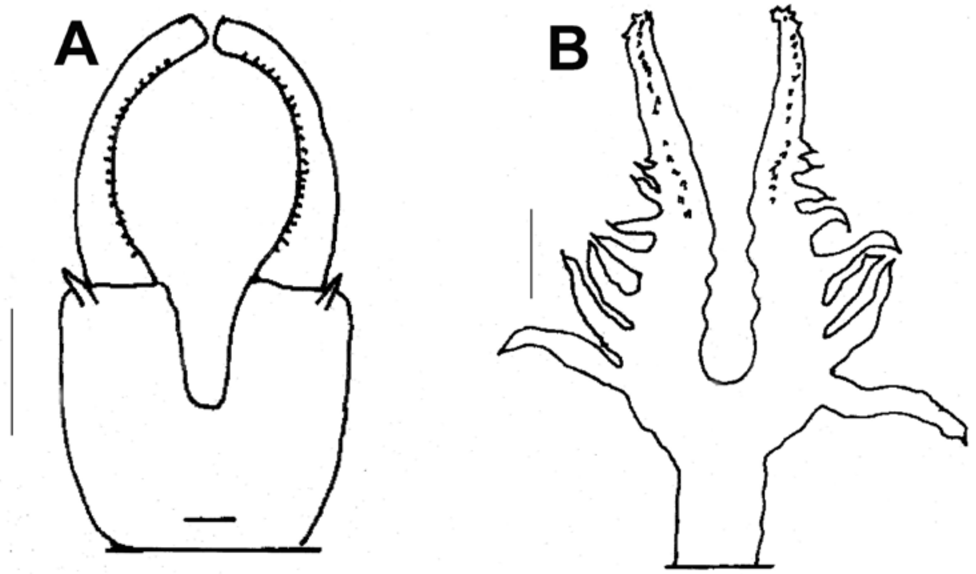

Fig 48. *B. dubia*. A second antennae; B, frontal appendage. Scale bars 1mm.

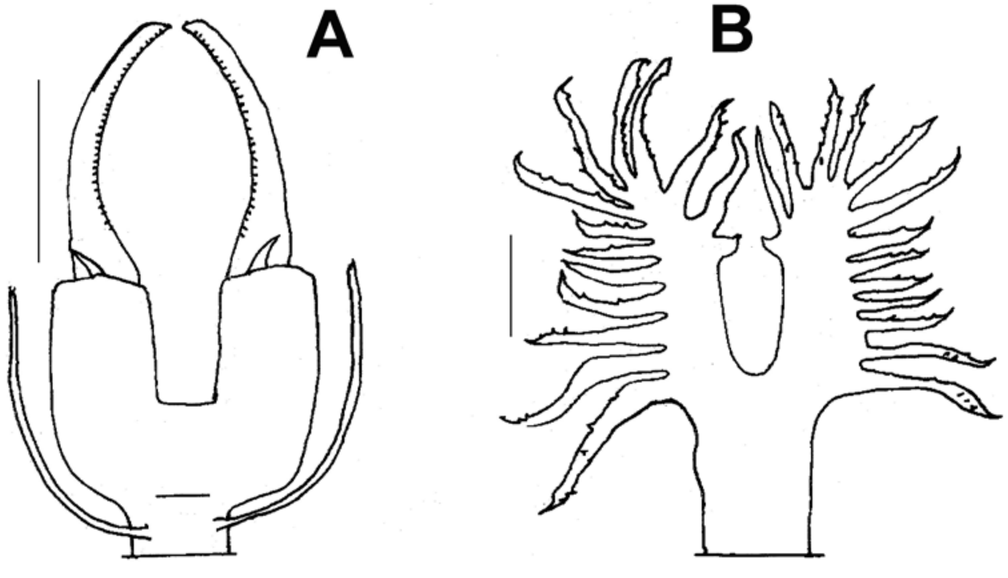

Fig 49. *B. pinnata*. A, first and second antennae; B, frontal appendage. Scale bars 1 mm.

34 (a) About 6-8 smooth digitiform processes both laterally and medially on the two branches of the frontal appendage; no proliferation of digitiform processes terminally on these branches; stem base with two (rarely 3 or 4) digitiform processes laterally; proximal antennomere with a raised pad on mid anteriolateral surface (Fig 51) .... *B. basispina*

(b) Two branches of frontal appendage with about 6 digitiform processes laterally and 3-5 smaller such processes medially each with stout setae laterally; generally 3 (maybe 2-4) terminal digitiform processes also with stout setae laterally; stem base with about 6 small digitiform processes laterally; proximal antennomere without a raised pad (Fig 52) .... *B. multidigitata*

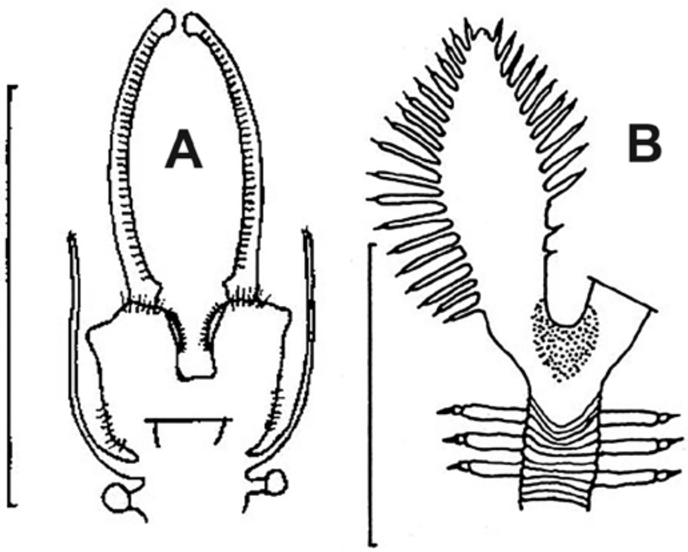

Fig 50. *B. pinderi*. A, head; B, frontal appendage; C, enlarged basal spine. Scale bars 1 mm.

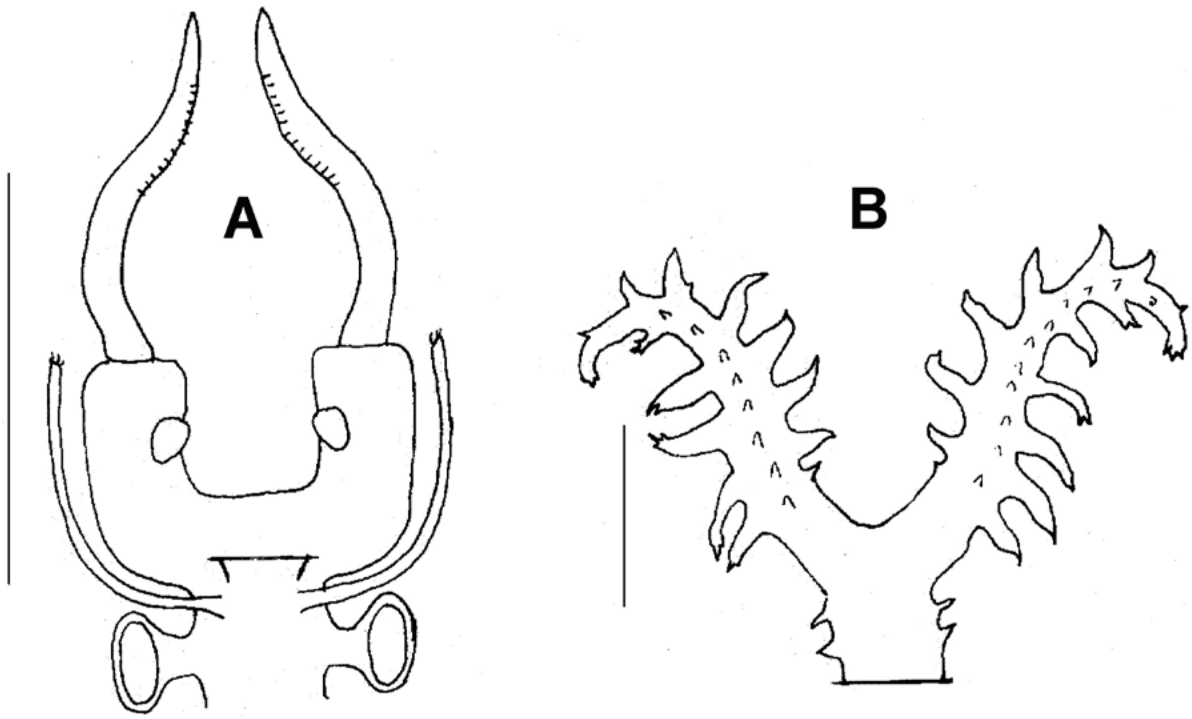

Fig 51. *B. basispina* A, head; B, frontal appendage. Scale bars 1 mm.

35 (a) Frontal appendage with the two branches ramified into 3-4 sub-branches laterally; no sub-branches or laminar extrusions medially; 4-6 terminal sub-branches, but these not further ramified (Fig 53) .... *B. frondosa*

(b) Frontal appendage with two branches bearing about 10 simple sub-branches laterally and about 5 medially, but all of these on apical half; medial basal half of each branch with a bent naked laminar process (Fig 54) .... *B. herrodi*

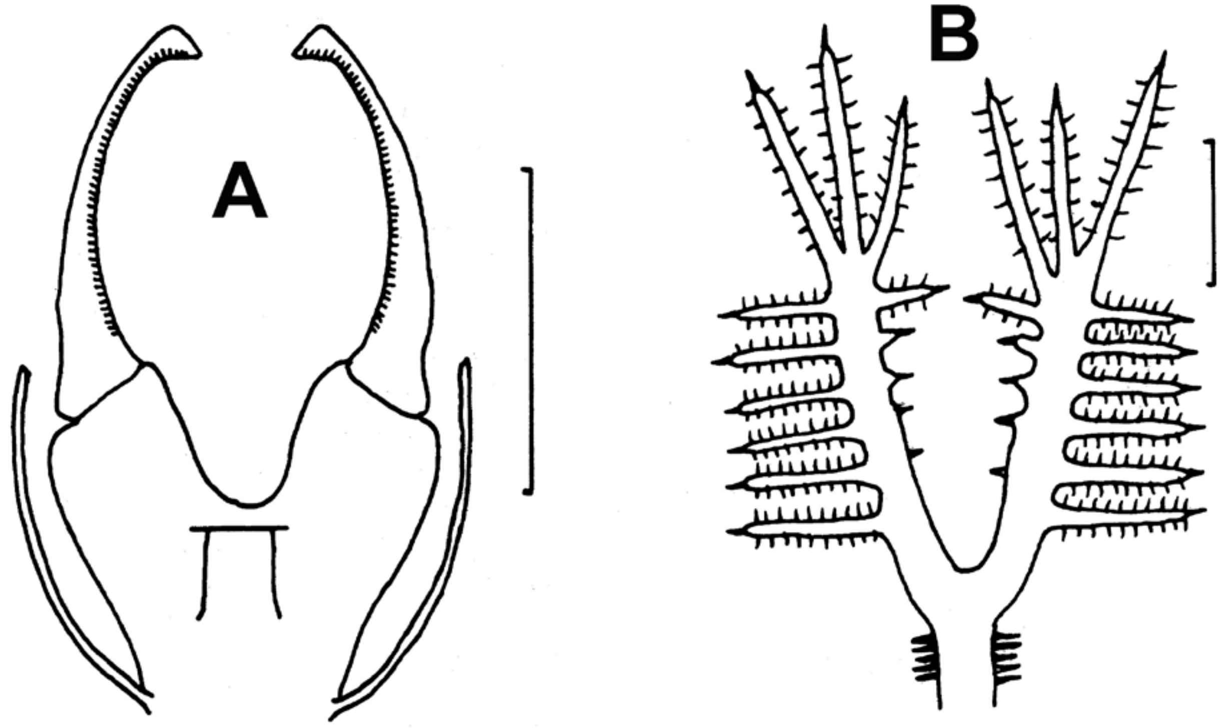

Fig 52. *B. multidigitata* A, first and second antennae; B, frontal appendage. Scale bars 1 mm.

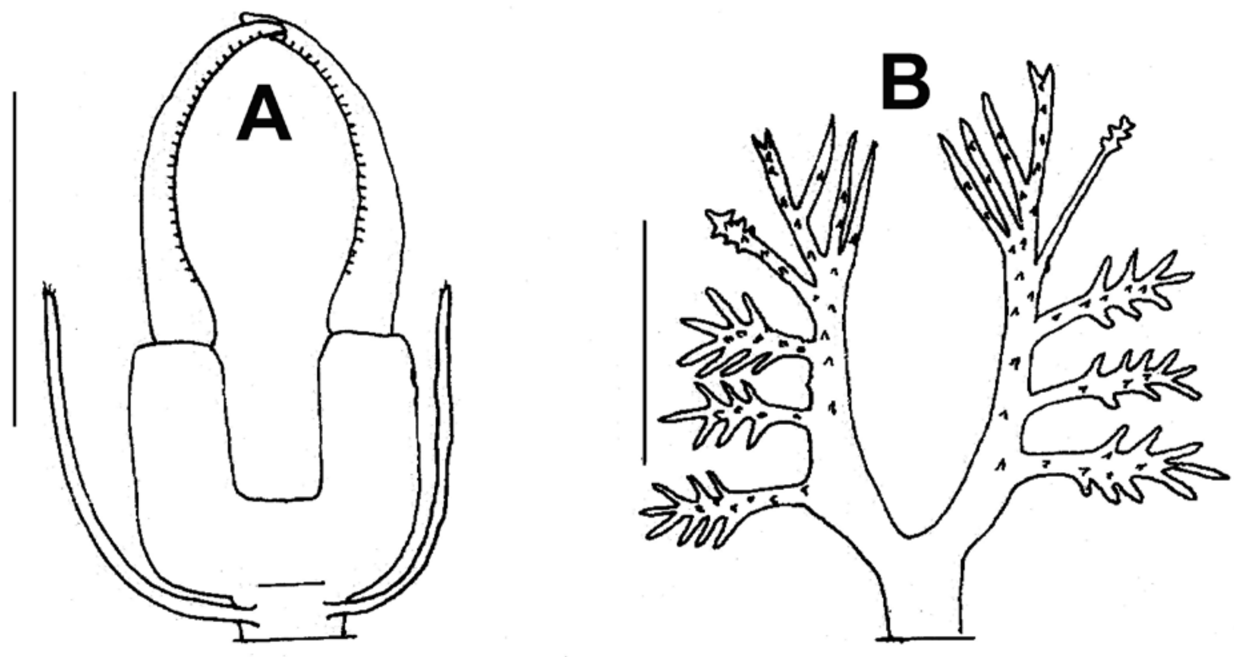

Fig 53. *B. frondosa*. A first and second antennae; B, frontal appendage. Scale bars 1 mm

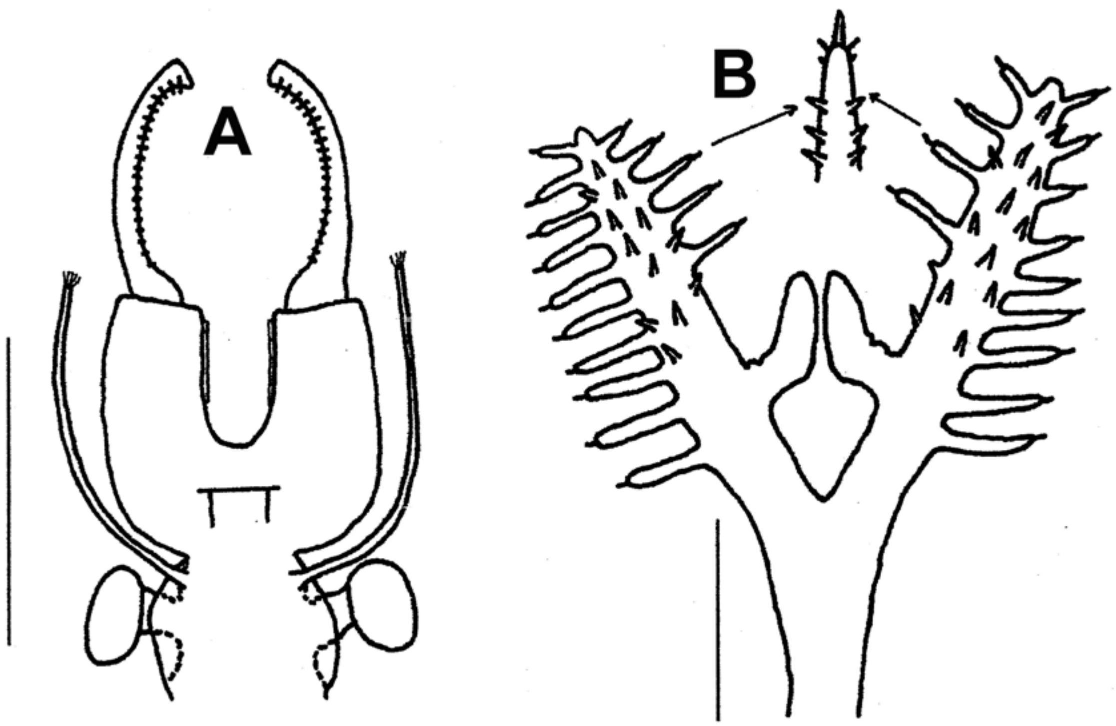

Fig 54. *B. herrodi*. A,head; B, frontal appendage. Scale bars 1 mm.

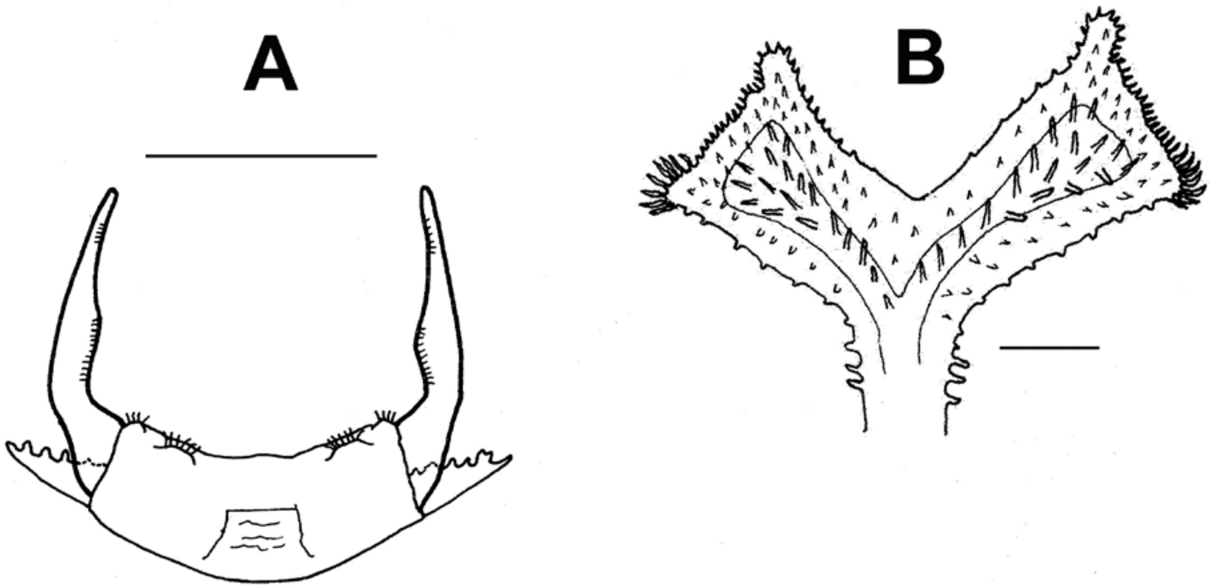

Fig 55. *B. budjiti*. A second antenna; B, frontal appendage. Scale bars 1 mm.

36 (a) Junction of proximal and distal antennomeres with a triangular antennal appendage; medial distal surface of each branch of the frontal appendage without a lamellate outgrowth; proximal antennomere with no outgrowths or two small ones on medial margin (Fig. 55) 37

(b) Junction of proximal and distal antennomeres without a triangular antennal appendage; lamellate outgrowth on medial distal surface of each branch of the frontal appendage; proximal antennomere with a large outgrowth on each medial margin (Fig. 57) 38

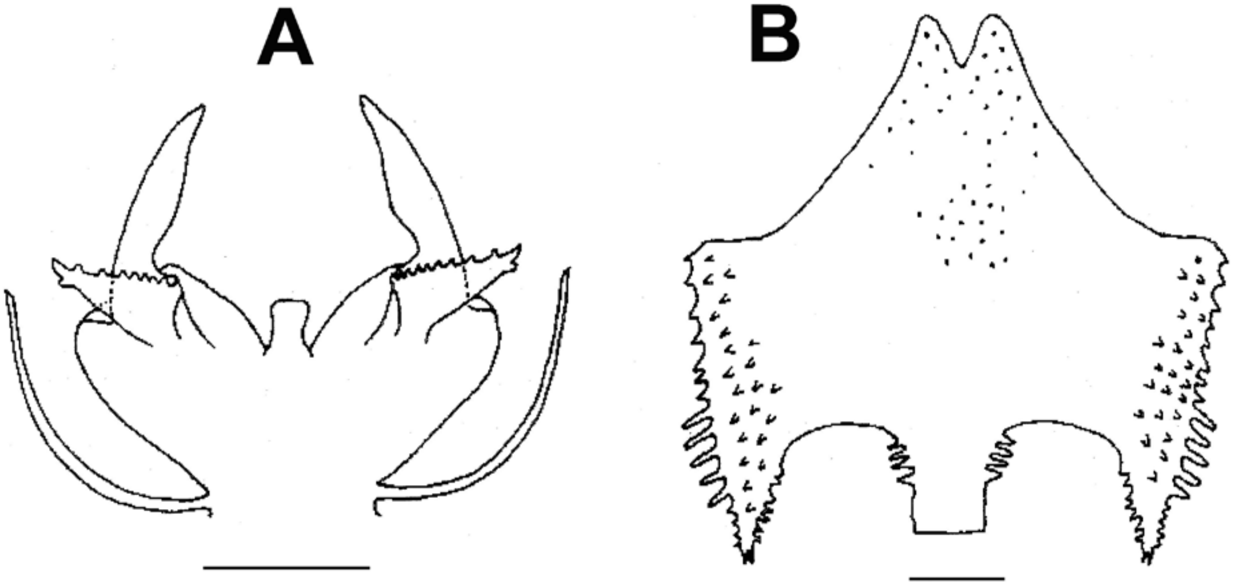

Fig 56. *B. lamellata*. A, first and second antennae; B, frontal appendage. Scale bars 1 mm.

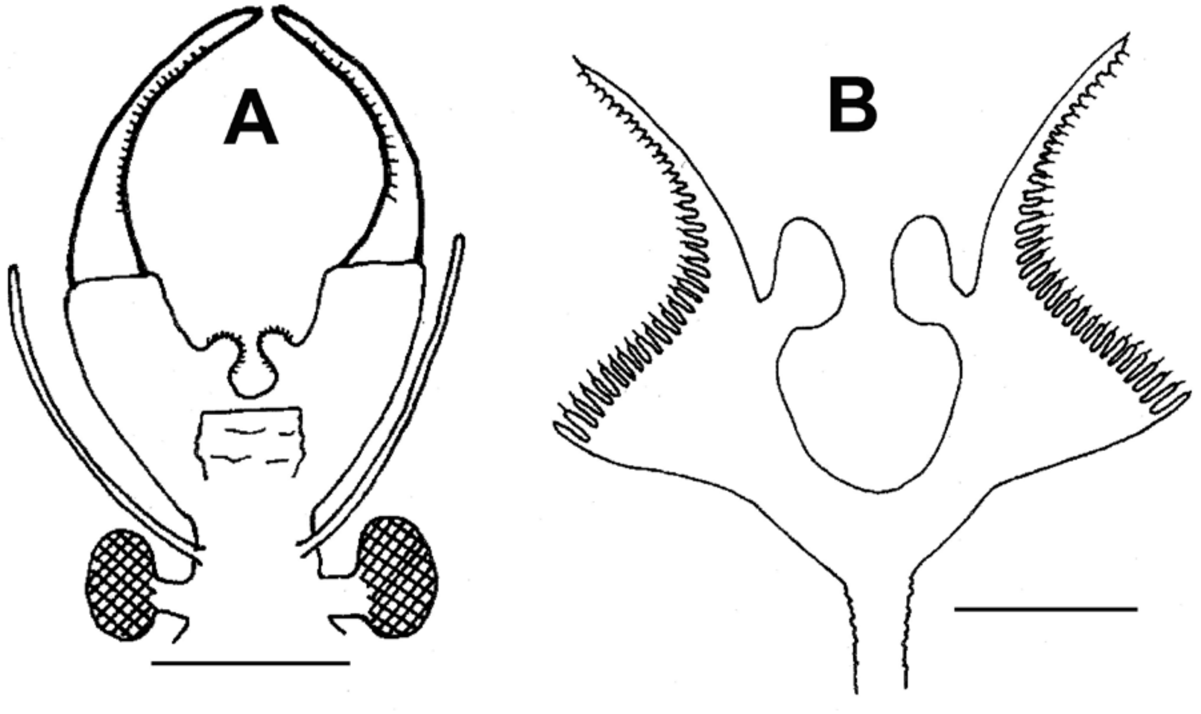

Fig.57. *B. campbelli*. A, head; B, frontal appendage. Scale bars 1 mm.

37 (a) Frontal appendage with a large concave embayment on lamellar plate between the extremities of the two branches of the frontal appendage; medial margin of partly fused proximal antennomeres without any outgrowth but two small raised areas distally (Fig. 55) .... *B. budjiti*

(b) Large convex outgrowth (but with a small central embayment at its extremity) on lamellar plate between the extremities of the two branches of the frontal appendage; medial margin of partly fused proximal segment of antennomere with a rectangular outgrowth medially and no outgrowths or raised areas distally (Fig 56) .... *B. lamellata*

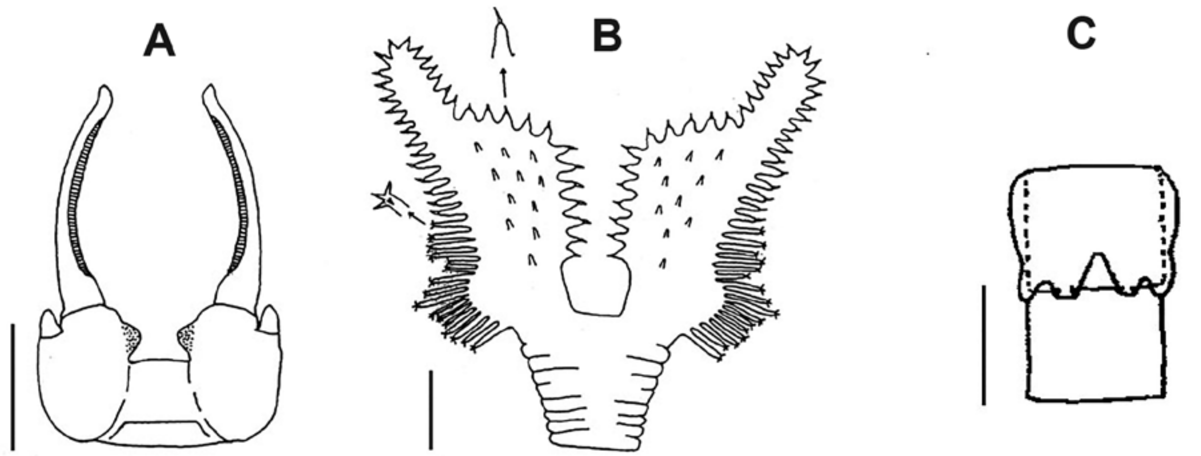

Fig 58. *B. kadjikadji*. A, second antenna; B, frontal appendage; C, proximal portion of gonopods. Scale bars 1 mm.

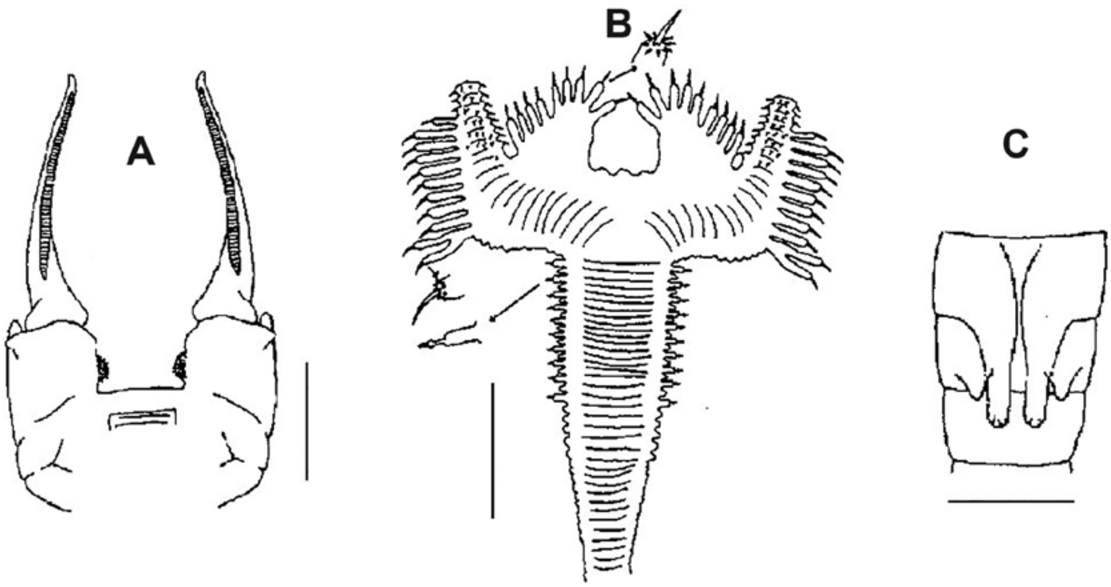

Fig 59. *B. complexidigitata*. A, second antenna; B, frontal appendage; C, proximal portion of gonopods. Scale bars 1 mm.

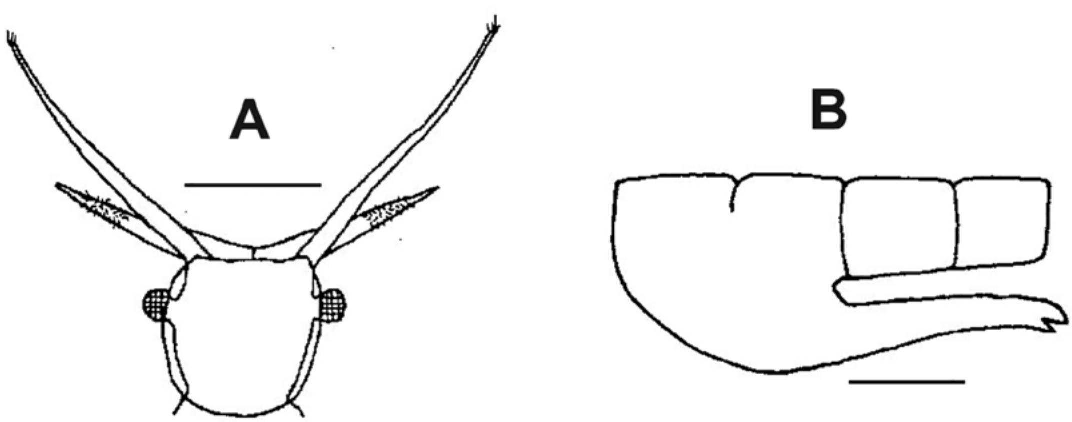

Fig 60. *B. pinderi* female. A, head; B genital and associated segments. Scale bars 1 mm.

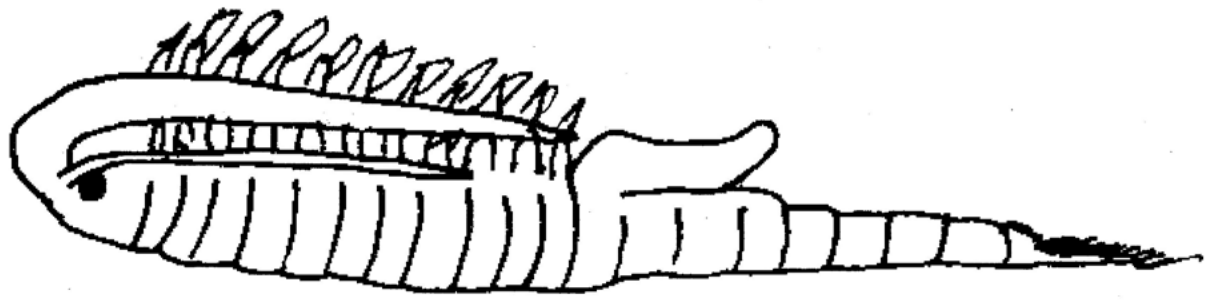

Fig 61. Female *B. occidentalis*

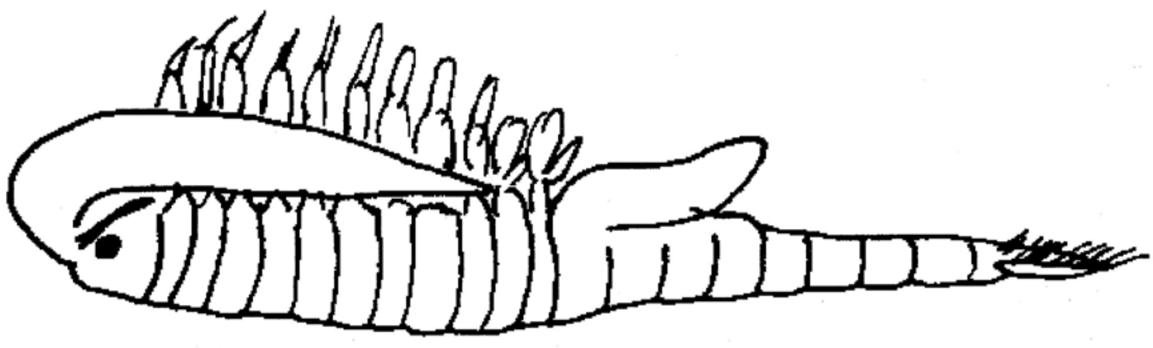

Fig 62. Female *B. australiensis*

38 (a) The two branches of the frontal appendage without digitiform processes on medial surface; terminal spines on digitiform processes simple; medial edge of lateral branch of frontal appendage with a lamellate outgrowth distinctly oval in plan (Fig. 57) .... *B. campbelli*

(b) Two branches of the frontal appendage with digitiform processes on medial surface; many digitiform processes terminate in a complex arrangement of spines; medial edge of lateral branch of frontal appendage with a lamellate outgrowth broadly merging with the lateral branch (Figs 58, 59) 39

39 (a) Frontal appendage with a short stem (*ca* ¼ of total length) and two branches at an acute angle and with all digitiform processes separate; gonopod base with basolateral projections of subequal length to the stiff base of the gonopods (Fig. 58) .... *B. kadjikadji*

(b) Frontal appendage with a long stem (> ½ its total length) with two short branches with at least some of their length at right angles to the trunk and bearing many digitiform processes, two of which on the distolateral corner are partly fused; gonopod base with basolateral projections distinctly shorter than stiff base of gonopods (Fig. 59) .... *B. complexidigitata*

Key to some female fairy shrimps in Australia (for mature *Australobranchipus, Branchinella* and *Streptocephalus*)

1 (a) First antenna almost twice as long as second antenna; latter narrow lanceolate (length >5x width), apex evenly narrowing and sharp; eyes reduced, about same diameter as first antenna (Fig 60) .... *B. pinderi*.

(b) First antenna subequal in length to second antenna or shorter; later relatively wide (length 2-4x width) apex often blunt, but there may be an narrow appendix apically; eyes normal, with diameter much wider than that of first antenna 2

2 (a) Second antenna fasciaform, reaching at least to the sixth thoracic segment, often more; elongate > 6x longer than wide, often more (Fig 61) 3

(b) Second antenna of various shapes such as lanceolate, ovate, roundish (and including fasciaform in a few species) but not reaching fourth thoracic segment; rarely elongate, usually <4x longer than wide (Fig 63,64) 4

3 (a) First antenna very long, reaching at least the eight thoracic segment; second antenna reaching to 8-10th thoracic segments and sometimes to the genital segments and beyond (in old specimens)(Fig 61) .... *B. occidentalis*

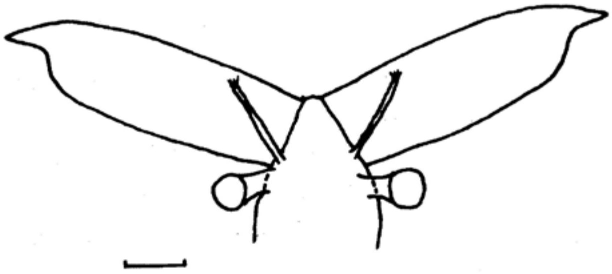

Fig 63 *B. compacta* female head

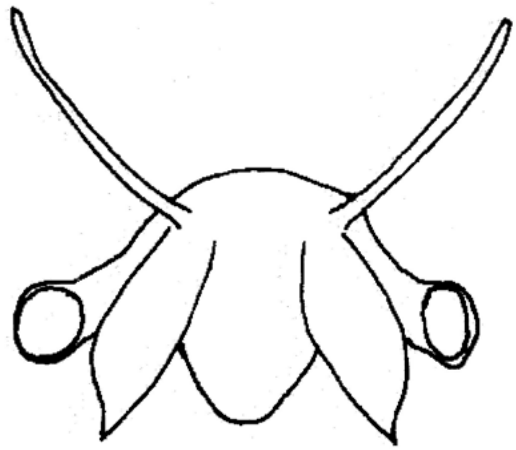

Fig 64 *B. nana* female head

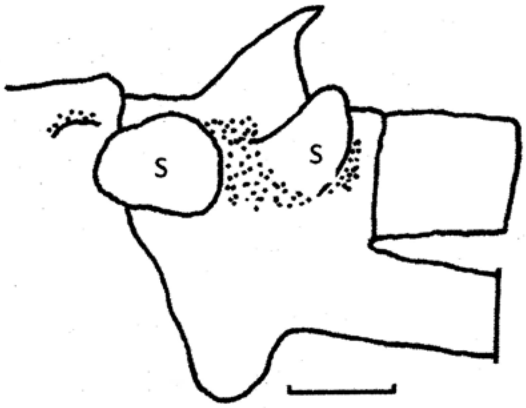

Fig 65 *B. hearnii* genital segments.

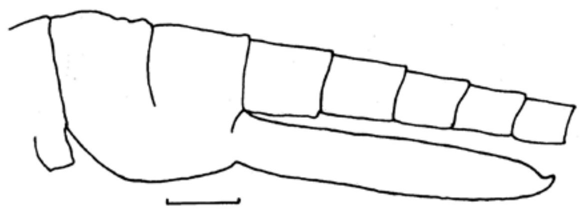

Fig 66 *B. papillata* brood pouch and associated segments

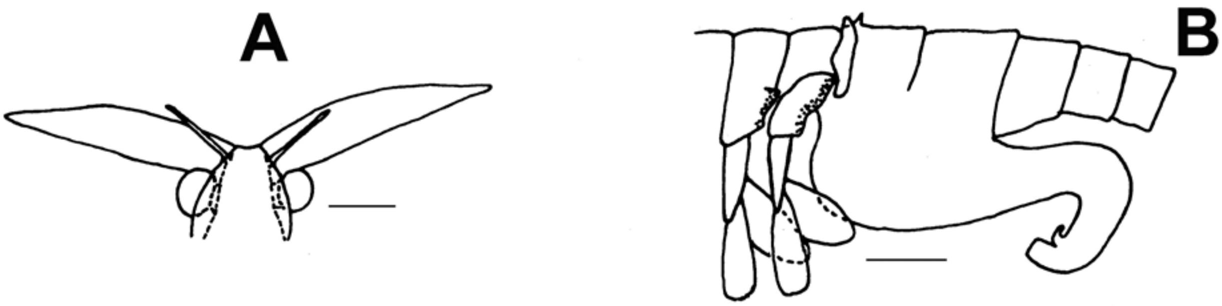

Fig 67. Female *B. vosperi*. A, head: B, Thorax 10 – Abdomen 3. Scale bars 1 mm.

(b) First antenna short, not reaching fourth thoracic segment; second antenna of variable length (according to age?) often reaching only to 6th thoracic segment, but it can reach to even the genital segments in large (=old?) specimens (Fig 62) .... *B. australiensis*

4 (a) Second antenna held at 90º to 120º to the head.and fasciaform (Fig 63) 5

(b) Second antenna held anteriorly or ventrally in same axis as head and lanceolate, oval or roundish (Fig 64) 9

5 (a) Genital segments with lateral tumidities and/or dorsal spines (Fig 65) 6

(b) Genital segments smooth (Fig 66) 8

6 (a) 10th and 11th thoracic segments with ridges at about 90º to body axis (Fig 67) .... *B. vosperi*

(b) 10th and 11th thoracic segments smooth surfaced (Fig 66) 7

7 (a) Genital segments with 2 prominent lateral swellings and 2 dorsal spines; occurs in southwest WA (Fig. 68) .... *B. hearnii*

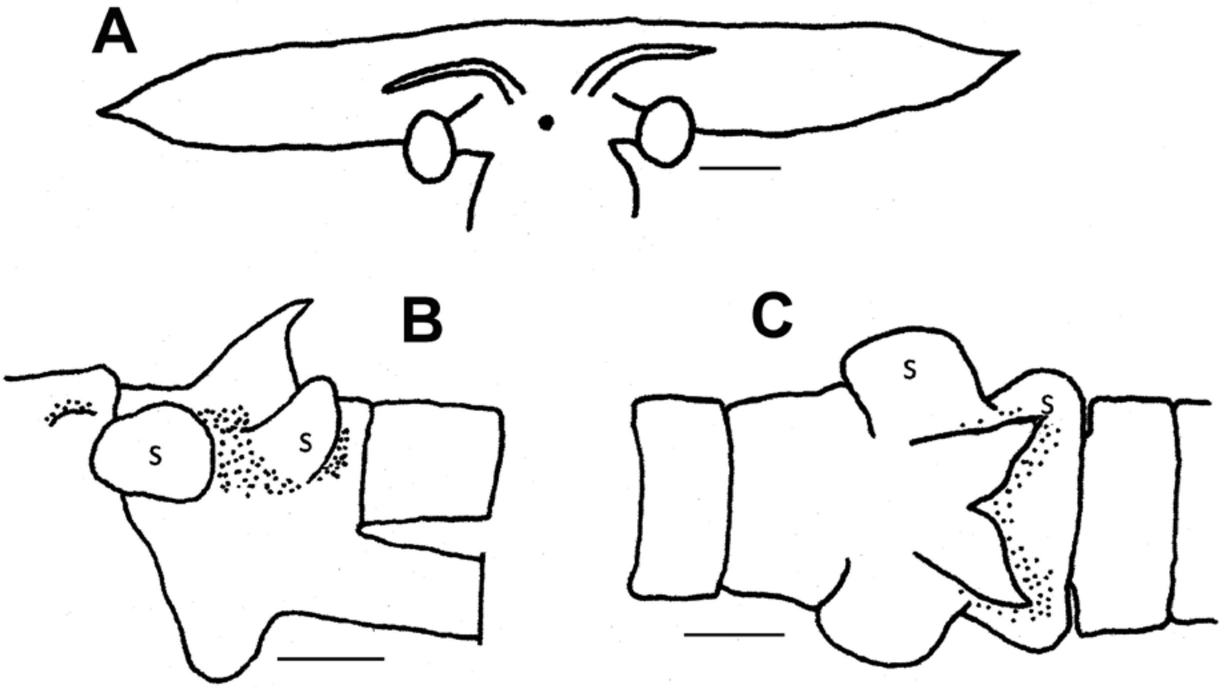

Fig 68. *B. hearnii* female. A, head; B lateral view of genital and nearby segments; C, dorsal view of genital and nearby segments.

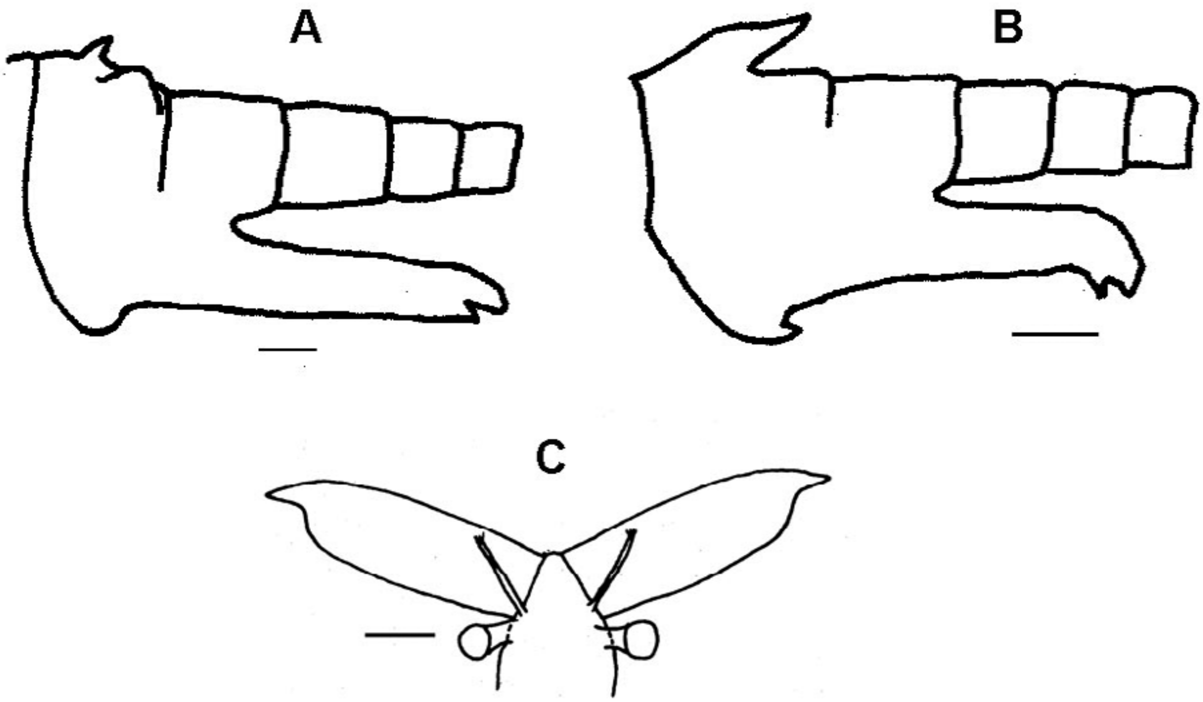

Fig 69. *B. compacta* female. A & B, lateral view of genital and nearby abdominal segments; C, head. Scale bars 1 mm.

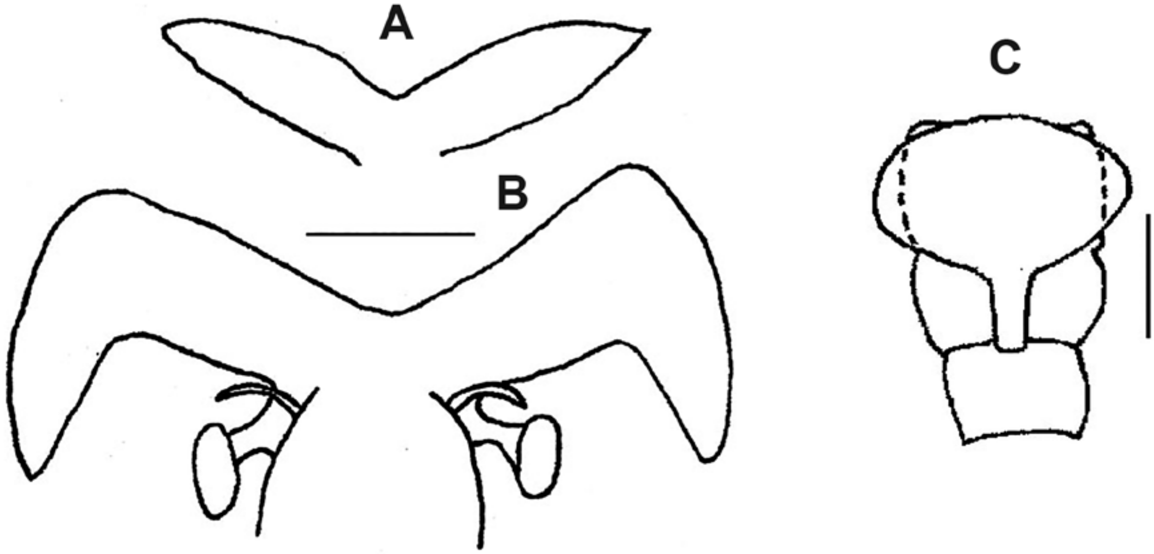

Fig 70. *B. simplex* female. A, immature second antenna; B, mature head; C, brood pouch. Scale bars 1 mm.

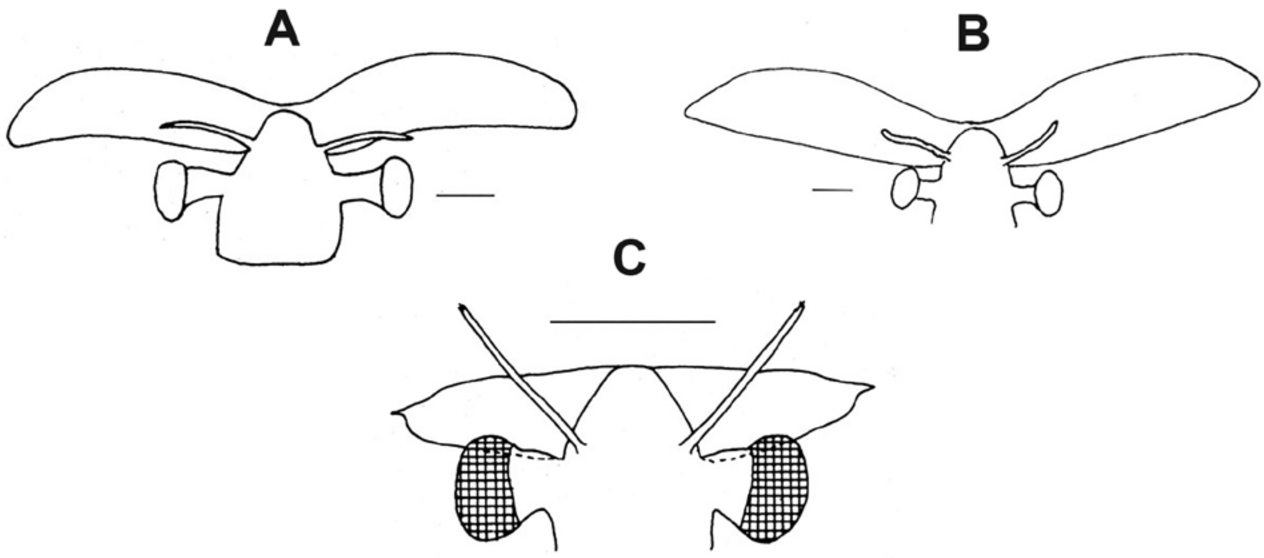

Fig 71 Female heads. A, *B. buchananensis*; B, *B. hattahensis*; C, *B. papillata*. Scale bars 1mm.

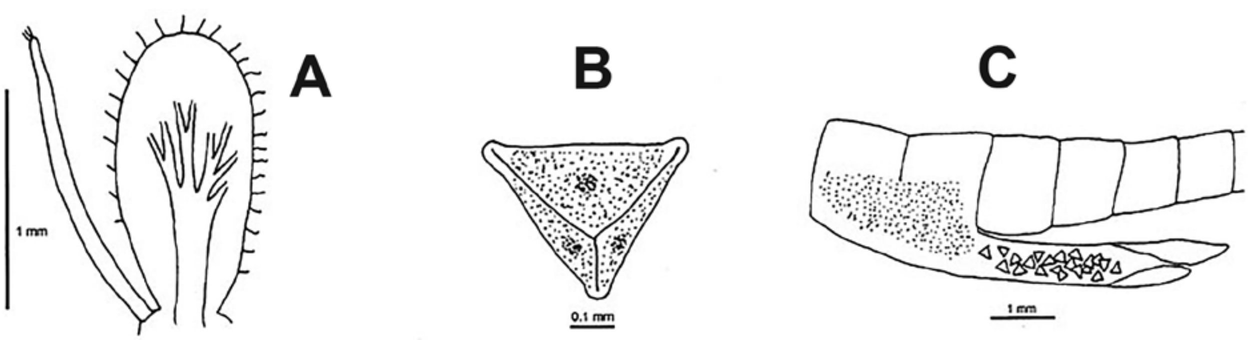

Fig 72. *Streptocephalus archeri*. A, antennae; B, egg; C, brood pouch.

Fig 73. *B. longirostris* second antenna

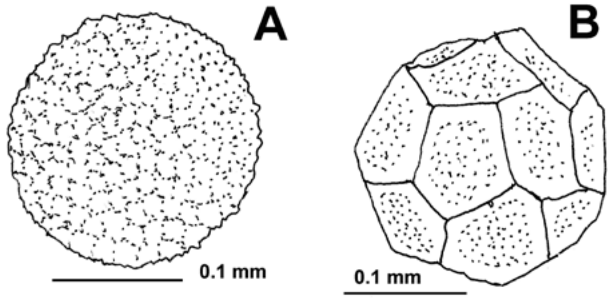

Fig 74. Eggs of A, *B. lyrifera* and B, *B. arborea*

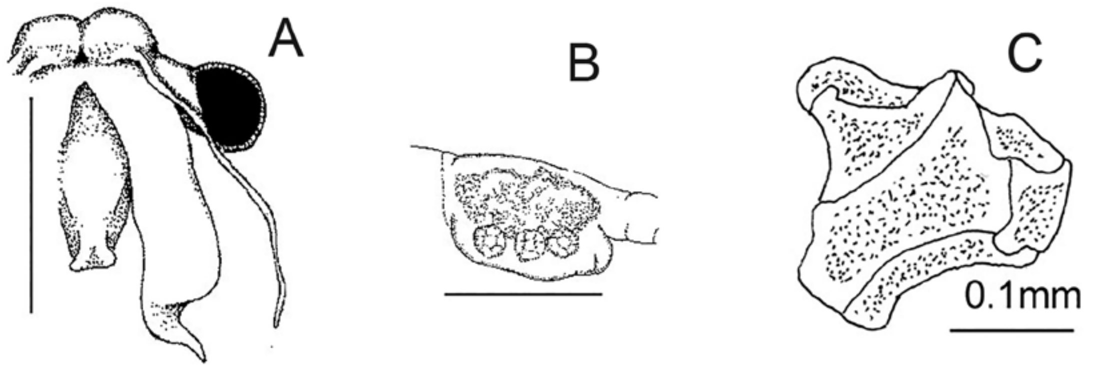

Fig 75. *Australobranchipus gilgaiphila*. A, head; B. brood pouch; C, egg.

(b) Genital segments with 2 weak swellings or none and one weak dorsal spine; occurs in southern Victoria and southeast NSW (Fig 69) .... *B. compacta*

8 (a) Mature females with a distinct bend in its second antenna so that antennae apices point backwards (Fig. 70) .... *B. simplex*

(b) Mature and immature females with straight second antennae (Figs. 68,69,71) .... *B.buchananensis, B. compacta, B. hattahensis, B. nichollsi, B. papillata, B. simplex*.

(Note: *B. simplex* can be usually be differentiated by the structure of its brood pouch — it is rounded-ovate instead of being long and reaching to the 3rd or more abdominal segment)

9 (a) Eggs tetrahedral; second antenna broadly ovate and without any appendix apically (Fig 72) .... *Streptocephalus archeri*

(b) Eggs not tetrahedral, usually spherical or perhaps campanuliform, often with ridges; second antenna usually lanceolate with a sharp apex, occasionally rounded but still with a sharp apex and rarely narrowly ovate without any appendix apically (Fig 74,75) 10

10 (a) Second antenna roundish with a small sharp appendix apically (Fig 73) .... *B. longirostris*

(b) Second antenna not as above. (Fig. 63,75,76) 11

(Note: Really it would be rare to want to key out *B. longirostris*, as to know the specimen came from a gnamma (rock-hole) in southern Western Australia would be enough to know its identity, such is the fidelity of this species to pan gnammas to the exclusion of all others, except rarely for *B. affinis* in rock pools at the edge of an outcrop. Another exception would be granitic gnammas on the western fringe of the Nullarbor which contain *B. basispina*. This species is also known westwards to the Norseman area, but in pit gnammas).

11 (a) Eggs not spherical, almost bell-shaped with one pole much bigger than the other; egg strongly ridged; oval brood pouch; second antenna ovate-lanceolate but with a distinct shoulder and apical appendix on medial side; adults very small< 10 mm (Fig 75) .... *Australobranchipus*

(b) eggs spherical or almost so; egg smooth (but often with minute outgrowths, visible only under high magnification), ridges if any weak; brood pouch elongated; second antenna approximately lanceolate usually, but not always (see couplet 12) narrowing apically to a approximately symmetrical sharp apex; adults of various sizes, usually >10 mm (Fig. 71,74, 76,77) 12

12 (a) Second antenna narrowly ovate without any appendix apically (Fig 76) .... *B. minmina; B. multidigitata*

(b) Second antenna lanceolate narrowing apically with an appendix of various sizes and proportions (Fig 77) .... other *Branchinella* species

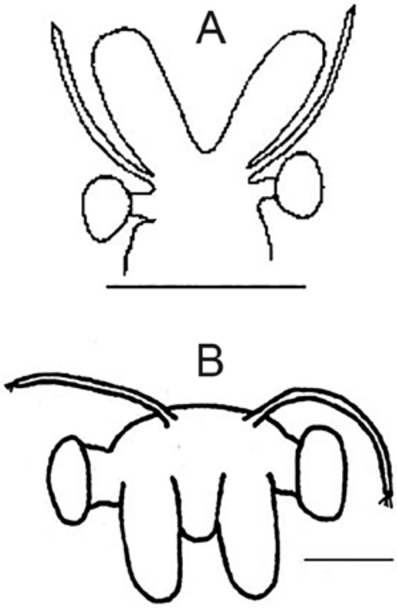

Fig 76. A, *B. multidigitata* head dorsal view; B, *B. minmina* head frontal view. Scale bars 1 mm.

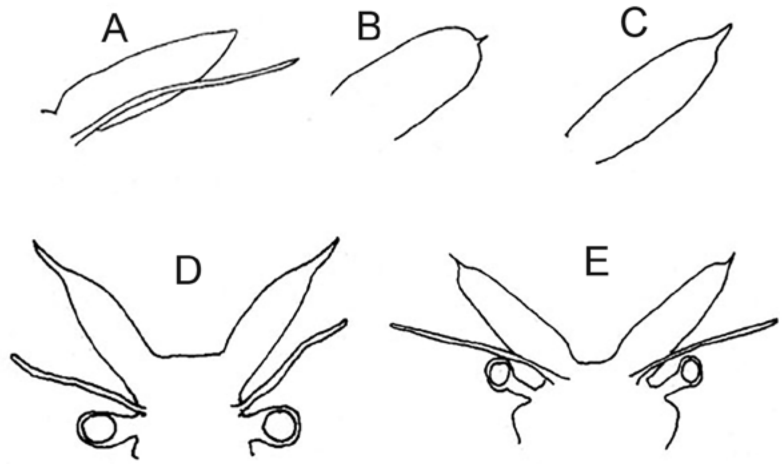

Fig 77. Second antennae of various species: A, *B.lyrifera*; B, *B. affinis*; C, *B. proboscida*; D, *B. kadjikadji*; E, *B.halsei*

Note: Trying to separate females of the numerous species of *Branchinella* is very difficult. They display a continuous and variable series from a long narrow appendix on the second antenna (Fig. 77D)(*B. kadjikadji, B. tyleri*) to a reasonably distinct appendix (Fig. 77E)(*B. budjiti, B. halsei*) to a slightly differentiated appendix (Fig. 77C) (*B. arborea, denticulata, frondosa, pinnata, probiscida, wellardi*) to one which is minute and so approaches the condition in *B. lyrifera*) (Figs 77A)(e.g. *B. nana, B. complexidigitata, B. campbelli*). There is enough variation in this sequence, maybe added to by unequal preservation, not to try to construct a binding key, but nevertheless this knowledge helps to narrow the options. *B. nana* is perhaps distinct by having the appendix distinctly mediolateral on the apex, compared to a central position for all the other species (Fig. 77). If a species is not mentioned above, then the structure of its second antenna is unknown or very variable.

Size may help a little in narrowing options. (Be warned, however, to only use adults and to remember that exceptional nutritional conditions may affect size.) Large species (> 22 mm) include *B. australiensis, B. buchananensis, B. compacta, B. halsei, B. hattahensis, B. hearnii* and *B. occidentalis*. Larger medium sized (14-22 mm) taxa include *B. complexidigitata, B. dubia, B. erosa, B. frondosa, B. lyrifera, B. minmina, B. nichollsi*, *B. pinnata* and *B. vosperi*. Smaller medium species (10-16 mm) number *B. affinis, B. anatinorhyncha, B. arborea, B. basispina, B. budjiti, B. campbelli, B. compacta, B. kadjikadji, B. insularis, B. lamellata, B. latzi, B. longirostris, B. multidigitta* and *B. simplex*. Small species (<10 mm) include *B. denticulata, B. nana, B. pinderi, B. proboscida, B. tyleri* and *B. wellardi.*

Fairy Shrimps in Saline Waters

Australia is a land of numerous saline waters, these being exploited largely by the endemic *Parartemia* and to a much lesser extent, mainly in southern Western Australia by the introduced *Artemia* (Reubhart et al, 2008; Timms, 2009a). A key is provided for these in Timms (2012a). While *Australobranchipus* and *Streptocephalus* have never been found in our saline wetlands, the same cannot be said for the *Branchinella*. Ten of the presently known 39 species of *Branchinella* have been recorded so far in waters > 3g/L. While many of these records are in low salinity waters, a few are from mesosaline conditions and even greater (Table 1). Two of these species, *B. australiensis* and *B.compacta*, are known to be osmoconfomers (Geddes, 1973) and presumably most of the rest are too, but it would be amazing if such was the case for the most salt-tolerant species, *B. simplex*, which lives in waters as saline as 62 g/L.

These salt-tolerant *Branchinella* are hardly called brine shrimps and hence not keyed out in that key. Almost all are known from fresh waters as well, so that their presence in saline waters is an anomaly. They belong with their congeners, so have been keyed out in the previous pages.

Table 2. Species of *Branchinella* known from saline waters*

Species	Known salinity range (g/L)
B. affinis	0.01 – 6.7
B. australiensis	0.02 – 8.6
B. buchananensis	1.9 – 42.6
B. compacta	0.6 – 15.9
B. erosa	0.2 – 12
B. frondosa	0.02 – 4.2
B. hearnii	0.5 – 12
B. nana	2 – 13
B. papillata	13-14
B. simplex	12.8 – 62

*Data from Timms (2009, 2012b and unpublished)

It should be realised that some species of *Branchinella* sometimes occur in lakes that are normally saline, but due to a major episodic filling are momentarily fresh. Such is the case with *B. nichollsi* which was once thought to be a saline species due to its one time occurrence in saline Hannah Lake near Kalgoorlie (Timms, 2002). Another example is *B. affinis* in a saline lake near Grass Patch, WA ---when this lake holds water it is normally saline and the haunt of *P. acidiphila*, but in January 2007 after a downpour of 200mm in a couple of days the lake became fresh and *B. affinis* prevailed (Timms, 2009b). What is amazing about both of these examples is the presence of an egg source in the lake catchment so that there is an appropriate shrimp to exploit such unusual conditions.

Glossary

abdomen third division of the body, with 6 segments and a telson bearing two cercopods. Segments without appendages.

antenna sensory appendages of head. First antenna (=antennule) small, thin and one segment. Second antenna (=antenna) larger, particularly in males, one or two antennomeres. Plural antennae.

antennomeres 'segments' of the antenna

antennal appendage a comparatively large outgrowth from apex of basal segment of antenna; most obvious in male *Streptocephalus*. Some *Branchinella* have a smaller appendages, generally on distomedial corner of basal segment.

apex tip

appendix refers to long narrow pointed extension on the apex of the second antenna of many *Branchinella* females.

apical refers to the tip

apophyses a bulbous tumidity ('swelling') or protruding process, usually from the basal antennomere of the antenna.

appendage in crustaceans, any of the paired, articulated structures attached to each segment, e.g. antennae, thoracopods. Also the frontal appendages and antennal appendages.

basal segment proximal part of antenna that is attached to the head.

basolateral projections of gonopods male gonopods consist of two parts, a basal tube and an extension tube which is usually inverted within the base. In many species there are also lateral projections at the base to the central tubes.

bifurcated divided into two

bilobed with two lobes

biramous having two branches

brood pouch external pouch carried on the lower and perhaps lateral surfaces of the genital segments of females to store fertilized resting eggs until deposition or death. The term 'ovisac' should not be used as the eggs are fertilized.

bulbous swollen or bulb-like

campanuliform bell-shaped

carapace hard cuticular covering of the segments.

cercopods a pair of terminal appendages that articulate with the telson.

cheliform having a pincer-like shape

chitinized chitinous integument hardened by the deposition of proteins

denticulate bearing small teeth-like structures

dichotomous division in two more or less equal parts

digitiform shaped like a finger, i.e. elongated, tubular.

distal the part of the structure furthest from the point of attachment (opposite = proximal or basal)

dorsal process protuberance on the upper surface of the 'clypeus'

endites Medially directed expansion of the basal part of the thoracopod (= phyllopodous limb). Usually 6 in number with the distal one the endopod.

endopod distal medially directed expansion of thoracopod.

epipodite a laterally directed expansion of the thoracopod between the preepipodite and exopodite. Normally sausage-shaped.

exopodite flattened laterally directed most distal expansion of the thoracopod. Also called an exopod.

fasciaform	Like a flat strip (ie a band) of thin material
fecundity	fertility, usually expressed as numbers of cysts produced during the life of a female.
filaform	thread-like
foliaceous	leaf-like
frontal appendage	median outgrowth from the front of the head in some male anostracans (mainly in *Branchinella*). It is formed during embryonic development by the fusion of right and left antennal appendages. It consists of a stem and generally two branches, which may be further divided (=ramified) and/or bear papillae and/or digitiform processes. Rarely called a frontal process and should not be termed a frontal organ.
frontal process	usually this is a lamellar outgrowth from the anterior of the fused basal segment of the second antenna. Rarely it is equated with the frontal appendage, but not in these keys.
genital segments	the two fused segments between the thoracopod-bearing segments of the thorax and the abdomen. They are part of the thorax, not the abdomen. In males these segments bear the gonopods and in females the brood pouch.
genitalia	external structures involved in reproduction.
gilgai	small clear temporary pools formed by the expansion and contraction of clay-rich soils, particularly common in the greater Moonie area of inner southwest Queensland
gnamma	a pool on a rock outcrop. Usually found on granite rocks, and are of two basic types: pan gnammas which are shallow hollows in the surface laminations and pit gnammas which are deep and occur at junctions of vertical joints.
gonopod	refers to male or female sexual apparatus. They are made of modified limbs of the two genital segments
gonopore	hole at the distal end of the brood pouch for insertion of the male gonopod and for expulsion of eggs.
hand	this refers to the hand-like structure of the second antenna of male *Streptocephalus*.
head	anterior most region of the body. It is formed by the coalescence of 5 segment and bears the stalked compound eyes and 5 pairs of appendages: antennules, antennae, mandibles, maxillules and maxillae
integument	outer layer of body (=carapace)
lamellar	flat and thin; sheet-like
lanceolate	shaped like a spear head, tapering at each end.
lateral process	refers to outgrowths on the outer (lateral) surface of the base of the penes.
limb (leg)	an appendage, usually one used in locomotion. Better termed thoracopod.
mandible	first pair of mouthparts; hardened jaws used for crushing or biting food.
maxilla	Second and third pair of mouthparts. Plural maxillae
medial process	refers to the protuberance (usually finger-like) in the middle of the anterior surface of the 'clypeus'.
mesial/medial	towards the mid-line.
outgrowth	a small definitive protrusion
papillae	a small single lobe or nipple
parthenogenesis	asexual reproduction in which the egg develops without fertilization
phyllopod	one of a pair of flattened or leaf-like swimming appendages on the ventral surface of the thoracic segments. Synonym thoracopod.
praeepipodite	basolateral lobe of the thoracopod (or phyllopod)
proximal	towards the point of attachment (opposite of distal)
ramified	Branching
resting egg	In anostracans the fertilized egg is stored temporarily in the brood pouch. It should not be called a cyst as the wall is produced by the female, not the embryo in the egg.
seta	a chitinous hair or bristle. Plural setae
setose	bearing many setae
segment	a single element or article in a jointed appendage, or one of the units making up the body
somite	An alternate term for a body segment
sympatric	occurring together
sub-apical	just below the apex or tip of a structure
telson	the terminal part of the body behind the last abdominal segment
tetrahedral	A three-dimensional four-sided pyramid
thorax	the middle grouping of segments of an anostracan body. Typically consists of 8 segments bearing thoracopods followed by two fused genital segments
thoracopod	any of the paired appendages of the thorax. Syn: thoracic leg, phyllopod.
trapozoid	quadrilateral shape

truncate top cut off any object
tumidity a swelling
vestigal much reduced

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Bibliography

(This list is meant to be a bibliography of papers which are useful in the study of Australian Anostracans as well as papers referred to in the text.)

Bayly, I.A.E., 1982. Invertebrates of temporary waters on granite outcrops in Southern Western Australia. Australian Journal of Marine and Freshwater Research 33: 599-606.

Bayly, I.A.E., 1997. Invertebrates of temporary waters in gnammas on granite outcrops in Western Australia. Journal of the Royal Society of Western Australia 80: 167-172.

Bayly, I.A.E., 2001. Invertebrate occurrence and succession after episodic flooding of a central Australian rock hole. Journal of the Royal Society of Western Australia 84: 29-32.

Belk, D. & J. Brtek, 1995. Checklist of the Anostraca. Hydrobiologia 298: 315-353. Comment: useful for an overall view of the diversity of fairy shrimps

Brendonck, L., 1997. The anostracan genus *Branchinella* (Crustacea: Branchiopoda), in need of a taxonomic revision; evidence form penile morphology. Zoology Journal of the Linnean Society 119: 447-455.

Brtek, J. & G. Mura, 2000. Revised key to families and genera of the Anostraca with notes on their geographical distribution. Crustaceana 73(9): 1037-1088.

Conte F.P. & M.C. Geddes, 1988. Acid brine shrimp: metabolic strategies in osmotic and ionic adaptation. Hydrobiologia 158: 191-200.

Dumont, H.J. & S.V. Negrea, 2002. Branchiopoda. Guides to the Identification of the Microinvertebrates of the Continental Waters of the World. Ed H.J.F. Dumont. Backhuys Publishers, Leiden. 398pp.

Eriksen C. & D. Belk, 1999. Fairy shrimps of California's puddles, pools and playas. Mad River Press, Eureka, California. 196pp.

Geddes, M.C., 1973. Studies on Australian anostracans (Crustacea: Branchiopoda). Ph. D Thesis, Monash University.

Geddes, M.C., 1973. A new species of *Parartemia* (Anostraca) from Australia. Crustaceana 25: 5-12.

Geddes, M.C. 1973. Salinity tolerance and osmotic and ionic regulation in *Branchinella australiensis* and *B. compacta* (Crustacea: Anostraca). Comparative Biochemistry and Physiology 45A: 559-569.

Geddes, M.C., 1975a. Studies on the Australian brine shrimp *Parartemia zietziana* Sayce (Crustacea: Anostraca). I. Salinity tolerance. Comparative Biochemisty and Physiology 51A: 553-559.

Geddes, M.C., 1975b. Studies on the Australian brine shrimp *Parartemia zietziana* Sayce (Crustacea: Anostraca). II. Osmotic and ionic regulation. Comparative Biochemistry and Physiology 51A: 561-571.

Geddes, M.C., 1975b. Studies on the Australian brine shrimp *Parartemia zietziana* Sayce (Crustacea: Anostraca). III. The mechanisms of osmotic and ionic regulation. Comparative Biochemistry and Physiology 51A: 561-571.

Geddes, M.C., 1976. Seasonal fauna of some ephemeral saline waters in western Victoria with particular reference to *Parartemia zietziana* Sayce (Crustacea: Anostraca). Australian Journal of Marine and Freshwater Research 27: 1-22.

Geddes, M. 1979. The brine shrimps *Artemia* and *Parartemia* in Australia pp57-65 in: The Brine Shrimp *Artemia* Vol 3. Ecology, Culturing, Use in Aquaculture. Edit G.Persoone, P. Sorgeloos, O. Roels & E. Jaspers. Universa Press, Wetteren, Belgium 456pp.

Geddes, M.C., 1981a. Revision of Australian species of *Branchinella* (Crustacea: Anostraca). Australian Journal of Marine and Freshwater Research 32: 253-295.

Geddes, M.C., 1981b. The brine shrimps *Artemia* and *Parartemia*. Comparative physiology and distribution in Australia. Hydrobiologia 81: 169-179.

Geddes, M.C., 1983. Biogeography and ecology of Australian Anostraca (Crustacea: Branchiopoda). Australian Museum Memoirs 18: 155-163.

Geddes, M.C. & W.D. Williams, 1987. Comments on *Artemia* introductions and the need for conservation pp 19-26 in: Artemia Research and its Applications *Artemia* Vol 3. Ecology, Culturing, Use in Aquaculture. Edit P. Sorgeloos, D.A. Bengston, W. Decleir & E. Jaspers Universa Press, Wetteren, Belgium 556pp.

Heatwole, H, 1987. Major components and distributions of the terrestrial fauna. In: Dyne, G.R., & Walton, D.W. Eds Fauna of Australia Vol 1A. Australian Government Publishing Service, Canberra. pp101-135.

Hebert, P.D., E.A. Remigio, J.K. Colbourne, D.J. Taylor & C.C. Wilson. 2002. Accelerated molecular evolution in halophilic crustaceans. Evolution 56: 909-926.

Henry, M., 1924. A monograph of the freshwater Entomostraca of New South Wales. IV Phyllopoda. Proceedings of the Linnean Society of New South Wales 49: 120-137.

Herbert, B., & B.V.Timms, 2000. A new species of *Streptocephalus (Parastreptocephalus)* (Crustacea: Anostraca: Streptocephalidae) from North Queensland, Australia. Memoirs Queensland Museum. 45: 385-390

Linder, F., 1941. Contributions to the morphology and taxonomy of the Branchiopoda Anostraca. Zoologiska Bidrag Från Uppsala 20: 101-303.

Manwell, C. 1978. Haemoglobin in the Australian anostracan *Parartemia zietziana*: evolutionary strategies of conformity vs regulation. Comparative Biochemistry and Physiology 59A: 37.

McMaster, K, A. Savage, T. Finston, M.S.Johnson, & B. Knott. 2002. Has *Artemia parthenogenetica* been introduced into Western Australia through human agency? Paper present at the 8th International Conference on Salt Lakes, Zhemehuzhny, Russia, 23-26 July, 2002.

Marchant, R., 1978. The energy balance of the Australian brine shrimp *Parartemia zietziana* (Crustacea,: Anostraca). Freshwater Biology 8: 481-489.

Marchant, R., & W.D.Williams, 1977a. Field estimates of oxygen consumption for the brine shrimp *Parartemia zietziana* Sayce (Crustacea: Anostraca) in two salt lakes in Victoria, Australia. Freshwater Biology 7: 535 – 544.

Marchant, R., & W.D.Williams, 1977b. Population dynamics and production of a brine shrimp *Parartemia zietziana* Sayce (Crustacea: Anostraca) in two salt lakes in western Victoria. Australian Journal of Marine and Freshwater Research 28: 417-438.

Marchant, R., & W.D.Williams, 1977c. Field measurements of ingestion and assimilation for the Australian brine shrimp *Parartemia zietziana* Sayce (Crustacea: Anostraca). Australian Journal of Ecology 2: 379-390.

Milner, D.F., 1929. A description of two new species of Anostraca Phyllopoda from Western Australia. Journal of the Royal Society of Western Australia. 15: 25-35.

Mitchell, B.D. & M.C. Geddes. 1977. Distribution of the brine shrimp *Pararatemia zietziana* Sayce and *Artemia salina* (L) along a salinity and oxygen gradient in a South Australian saltfield. Freshwater Biology 7: 461-467.

Pinceel, T., L. Brendonck, M.H.D. Larmuseau, M.P.M. Vanhove, B.V.Timms & B. Vanschoenwinkel, 2013a. Environmental change as a driver of diversification in temporary aquatic habitats: does the genetic structure of extant fairy shrimp populations reflect historic acidification? Freshwater Biology 58: 1556-1572.

Pinceel,T., B. Vanschoenwinkel, A. Waterkeyn, M. P.M. Vanhove, A. Pinder, B.V. Timms & L. Brendonck, 2013b. Fairy shrimps in distress: a molecular taxonomic review of the diverse fairy shrimp genus *Branchinella* (Anostraca: Thamnocephalidae) in Australia in the light of ongoing environmental change. Hydrobiologia 700: 313-327.

Pinder, A.A., S.A.Halse, R.J.Shiel, & J.M.McRae, 2000. Granite outcrop pools in south-western Australia: foci of diversification and refugia for aquatic invertebrates. Journal of the Royal Society of Western Australia 83: 149-161.

Remigio, E.A., P.D.N. Hebert & A. Savage, 2001. Phylogenetic relationships and remarkable radiation in *Parartemia* (Crustacea: Anostraca), the endemic brine shrimp of Australia: evidence from mitochondrial DNA sequences. Biol. J. Linnean Society74: 59-71.

Remigio, E.A., B.V. Timms. & P.D.N. Hebert. (2003) Phylogenetic systematics of the Australian fairy shrimp genus *Branchinella* (Crustacea: Anostraca) based on mitochondrial DNA sequences. Journal of Crustacean Biology 23: 436-442.

Rogers, D.C., 2006. A genus level revision of the Thamnocephalidae (Crustacea: Branchiopoda: Anostraca). Zootaxa 1260: 1-25.

Rogers, D.C. & B.V. Timms, 2014. Anostracan (Crustacea: Branchipoda) zoogeography III. Australian bioregions Zootaxa 3881: 453-487.

Rogers, D.C., B.V.Timms, M Jocqué & L. Brendonck, 2007. A new genus and species of branchiopod fairy shrimp (Crustacea: Branchiopoda: Anostraca) from Australia. Zootaxa 1551: 49-59.

Sanders, P.R., 1999. Biogeography of fairy shrimps (Crustacea: Anostraca) in the Paroo, northwestern Murray-Darling basin. B. Sc Honours Thesis, University of Newcastle, 87pp.

Sars, G. O., 1896. Description of two new Phyllopoda from North Australia. Archiv for Mathematik og Naturvidenskab. Kristiania 18(8): 1-34.

Timms, B.V., 2001. Two new species of *Branchinella* Sayce 1903 (Crustacea: Anostraca: Thamnocephalidae) from the Paroo, inland Australia. Records of the Australian Museum 53: 247-254.

Timms, B.V., 2002. The Fairy Shrimp Genus *Branchinella* Sayce 1903 (Crustacea: Anostraca: Thamnocephalidae) in Western Australia, including a description of four new species. Hydrobiologia 486: 71-89

Timms, B.V., 2004. An Identification Guide to the Fairy Shrimps (Crustacea: Anostraca) of Australia. Identification and Ecology Guide No 47, Cooperative Centre for Freshwater Research, Albury, NSW.

Timms, B.V., 2005. Two new species of *Branchiniella* (Anostraca: Thamnocephalidae) and a reappraisal of the *B. nichollsi* group. Memoirs of the Queensland Museum 50: 441-452.

Timms, B.V., 2008. Further studies on the fairy shrimp genus *Branchinella* (Crustacea, Anostraca, Thamnocephalidae) in Western Australia, with a description of new species. Records of the Western Australian Museum 24: 289-306.

Timms, B.V., 2009a. Biodiversity of large branchiopods of Australian saline lakes. Current Science 96: 74-80.

Timms, B.V., 2009b. A study of the salt lakes inland of Esperance, Western Australia, with special reference to the role of ground water acidity and episodicity. In: Oren, A, Natfz, D, Palacois, P. & Wurstburgh, W.A. (eds) Saline Lakes Around the World; Unique Systems with Unique Values, Natural Resources and Environmental Issues, Volume XV. S.J. and Jessie E Quincey Natural Resource Research Library. Logan, Utah, USA, pp 215-224.

Timms, B.V., 2012a. An Identification Guide to the Brine Shrimps (Crustacea: Anostraca: Artemiina) of Australia. Museum Victoria Science Reports 16: 1-36.

Timms, B, V, 2012b. Further studies on the fairy shrimp genus *Branchinella* (Crustacea: Anostraca: Thamnocephalidae) in Australia, with descriptions of five new species. Zootaxa 3595: 35-60.

Timms, B.V., B. Datson & M. Coleman., 2006. The wetlands of the Lake Carey catchment, northeast Goldfields of Western Australia, with special reference to large branchiopods. Journal of the Royal Society of Western Australia. 89: 175-183.

Timms, B.V. & M.C. Geddes, 2003. The fairy shrimp genus *Branchinella* Sayce, 1903 (Crustacea: Anostraca: Thamnocephalidae) in South Australia and the Northern Territory, including a description of three new species. Transactions of the Royal Society of South Australia 127: 53-68.

Timms, B.V. & S. Lindsay. 2011. Morphometrics of the resting eggs of the fairy shrimp *Branchinella* in Australia (Anostraca: Thamnocephalidae). Proceedings of the Linnean Society of New South Wales 133: 51-68.

Timms, B.V. & P.R.Sanders, 2002. Biogeography and ecology of fairy shrimps (Crustacea: Anostraca) in the middle Paroo catchment of arid-zone Australia. Hydrobiologia 486: 225-238.

Timms, B.V., W. D. Shepard & R.E. Hill. 2004. Cyst shell morphology of the fairy shrimps (Crustacea: Anostraca) of Australia. Proceedings of the Linnean Society of New South Wales. 125: 73-95.

Weekers, P.H.H., G. Murugan, J.R. Vanfleteren, D. Belk & H.J. Dumont. 2002. Phylogenetic analysis of anostracans (Branchiopoda: Anostraca) inferred from nuclear 18S ribosomal DNA. Molecular Phylogenetics and Evolution 25: 535-544.

Williams, W.D., 1981. The Crustacea of Australian inland waters pp 1101 – 1138 in: Ecological Biogeography of Australia (ed) A Keast. Junk, The Hague 2142pp

Williams, W.D., P. De Deckker & R.J. Shiel, 1988. The limnology of Lake Torrens, an episodic salt lake of central Australia, with particular reference to unique events in 1989. Hydrobiologia 384: 101-110.

Williams, W.D. & M.C. Geddes, 1991. Anostracans of Australian salt lakes, with particular reference to a comparison of *Parartemia* and *Artemia*. pp351-367 in: *Artemia* Biology edit R.A. Browns, P. Sorgeloos & C.N.A.Trotman CRC Press, Boston.

Zofkova, M. & B.V. Timms, 2009. A conflict of morphological and genetic patterns in the Australian anostracan *Branchinella longirostris*. Hydrobiologia 635: 67-80.