ON THE ORIGIN OF *DANIELOPOLINA BALTANASI* SP. N. (OSTRACODA, THAUMATOCYPRIDOIDEA) FROM THREE ANCHIALINE CAVES ON CHRISTMAS ISLAND, A SEAMOUNT IN THE INDIAN OCEAN

BY

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ABSTRACT

The morphology and systematic affinities of *Danielopolina* sp. cf. *D. kornickeri* from Christmas Island, an isolated seamount in the Indian Ocean, are reassessed with the aid of new material including a juvenile male. The species is formally described as *Danielopolina* (*Humphreysella*) *baltanasi* sp. n., which places the species in a separate subgenus to *Danielopolina* (*Danielopolina*) *kornickeri* from northwest Australia, the only other member of the genus in the Indian Ocean. In addition, the only deep-sea member of the genus, *D. carolynae* from the mid-Atlantic, a putative colonizer of seamounts, belongs to the subgenus *Danielopolina*. These findings compound theories on the distribution and dispersal of anchialine faunas. A coherent programme of molecular phylogenetic research and historical biogeographical analysis is needed to further enquiry into the enigmatic distribution of the anchialine faunas of both isolated sea mounts and epicontinental waters. Owing to the scarcity of anchialine fauna and the difficulty of access of their habitat, a global effort will be required to assemble the required specimens.

RÉSUMÉ

La morphologie et les affinités systématiques de *Danielopolina* sp. cf. *D. kornickeri* de l'île Christmas, un mont sous-marin isolé de l'océan Indien, sont re-évaluées grâce à du matériel nouveau dont un mâle juvénile. L'espèce est officiellement décrite comme *Danielopolina* (*Humphreysella*) *baltanasi* sp. n., qui la place dans un sous-genre distinct de *Danielopolina* (*Danielopolina*) *kornickeri* du nord-ouest de l'Australie, le seul autre membre du genre dans l'océan Indien. De plus, le seul autre

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membre profond du genre, *D. carolynae* de la zone médio-Atlantique, que l'on suppose coloniser les monts-marins, appartient au sous-genre *Danielopolina*. Ces découvertes compliquent les théories sur la répartition et la dispersion des faunes anchihalines. Un programme cohérent de recherche sur la phylogénie moléculaire et l'analyse biogéographique historique sera nécessaire pour éclaircir ultérieurement la répartition énigmatique des faunes anchihalines à la fois des monts sous-marins isolés et des eaux épicontinentales. En raison de la rareté de la faune anchihaline et de la difficulté d'accès à son habitat, un effort global sera nécessaire afin de rassembler les spécimens requis.

INTRODUCTION

The thirteen extant species of *Danielopolina* Kornicker & Sohn, 1976 belong to the subgenera *Danielopolina* Kornicker & Sohn, 1976 and *Humphreysella* Kornicker & Danielopol, 2006 (table I). The Galapagos Islands and the islands of the Caribbean, including the exceptionally diverse anchialine fauna of the Bahamas Banks, has only the subgenus *Humphreysella*. The rich anchialine fauna of Yucatan has only the subgenus *Danielopolina* despite being geographically central to the previous locations (fig. 1). Conversely, both subgenera are present in the Canary Islands where they are found in sympatry, and in the Indian Ocean but where they occur in allopatry in the different types of anchialine systems on seamounts and/or epicontinental areas (Humphreys & Danielopol, 2006).

Danielopolina (*Humphreysella*) *baltanasi* sp. n. is the second representative of the genus known from the Indian Ocean, the other being *D.* (*D.*) *kornickeri* Danielopol, Baltanás & Humphreys, 2000 from northwestern Australia, 1560 km to the south-east across deep (abyssal) ocean. Humphreys & Danielopol (2006) emphasized that the presence of *Danielopolina* on Christmas Island, an isolated seamount, was atypical as it is associated there with a *Procaris*-type anchialine fauna typical of isolated seamounts (a type also known from Ascension Island, Hawaii, and Bermuda), whereas elsewhere *Danielopolina* is associated with Remipede-type anchialine systems found in epicontinental regions, save for the single case in the mid-Atlantic abyssal (*D. carolynae* Kornicker & Sohn, 1976 at 3459 m depth).

Recent papers dealing with the origin of anchialine faunas on isolated seamount islands provide the background literature (Humphreys & Danielopol, 2006; Hunter et al., 2008). Shallow water ocean dispersal of anchialine fauna has been supported (Kano & Kase, 2004) but Bermuda, like Christmas Island, is surrounded by abyssal ocean more than 4000 m deep (Vogt & Jung, 2007) and the presence there of certain lineages of anchialine fauna has been attributed to ocean dispersal on the Gulf Stream from the Caribbean (Hunter et al., 2008). Given the occurrence of *D. kornickeri* in Western Australia, dispersal was considered a potential source for the Christmas Island population, but this is negated herein by the designation of the two Indian Ocean *Danielopolina* to different subgenera. Although colonization of anchialine systems from the deep sea has been proposed (Fuchs, 1894; Hart

TABLE I

Species of *Danielopolina* partitioned amongst the two subgenera and arranged quasi-geographically

Humphreysella Kornicker & Danielopol in Kornicker et al., 2006		*Danielopolina* Kornicker et al., 2006	
D. styx Kornicker & Iliffe, 1989	Galapagos		
		D. Mexicana Kornicker & Iliffe, 1989	Yucatan
D. bahamensis Kornicker & Iliffe, 1989	Bahamas		
D. exuma Kornicker & Iliffe, 1998	Bahamas		
D. kakuki Kornicker & Iliffe, 2000	Bahamas		
D. palmeri Kornicker, Iliffe & Harrison-Nelson, 2007	Bahamas		
D. orghidani (Danielopol, 1972)	Cuba		
D. elizabethae Kornicker & Iliffe, 1992	Jamaica		
		D. carolynae Kornicker & Sohn, 1976	Mid-Atlantic deep
D. wilkensi Hartmann, 1985	Canary Islands	*D. phalanx* Kornicker & Iliffe, 1995	Canary Islands
D. baltanasi sp. n.	Christmas Island, Indian Ocean	*D. kornickeri* Danielopol, Baltanás & Humphreys, 2000	North-west Australia, Indian Ocean

et al., 1985; Boxshall, 1989) and challenged (e.g., Stock, 1986; Danielopol, 1990; Baltanás & Danielopol, 1995; Danielopol et al., 1996; Boxshall & Jaume,
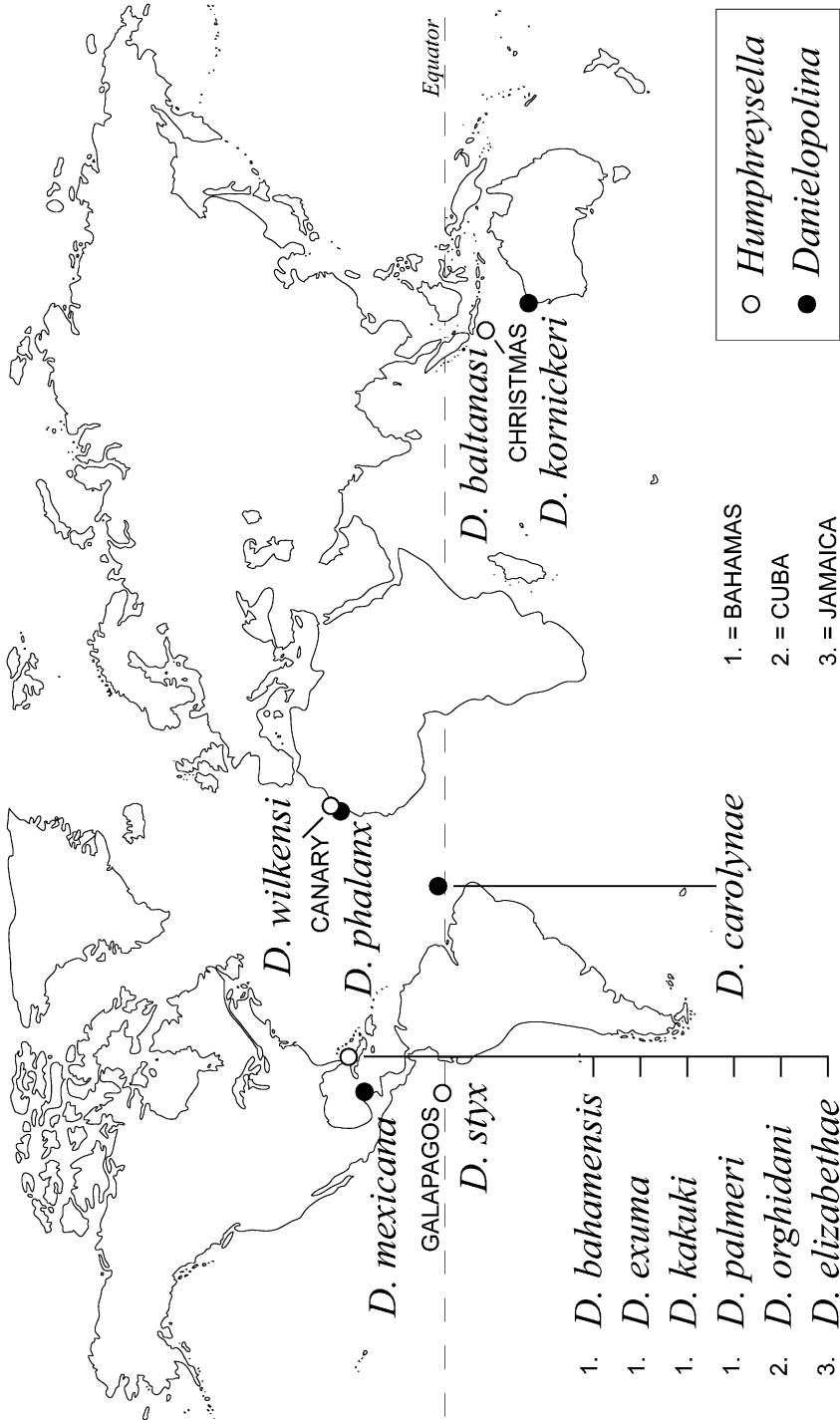
Fig. 1. Distribution of species of the subgenera *Danielopolina* (*Danielopolina*) and *Danielopolina* (*Humphreysella*).

1999), the only deep ocean species, *Danielopolina carolynae* from the mid-Atlantic, a putative colonizer of anchialine habitat from the deep sea, also belongs to a different subgenus from *D. baltanasi* sp. n. (see Taxonomy section and Discussion).

Ancestors of *Danielopolina* inhabited shelf waters since the Permian (Sohn & Kornicker, 1998; Danielopol et al., 2000) and crevicular systems in carbonate rocks of a marine shelf platform (probably marine caves) in the Western Tethys in the Late Jurassic (Aubrecht & Kozur, 1995). The distribution of the genus *Danielopolina*, and the anchialine fauna with which it characteristically occurs, has been related to the former extent of Tethys (the 'Full Tethyan Track': Stock, 1993; Danielopol et al., 1996; Jaume et al., 2001). Even Christmas Island, unusual for an isolated seamount, has a fauna also associated with Tethys, such as the presence of *Danielopolina* (cf. Humphreys & Danielopol, 2006) and *Microceratina* Swanson, 1980 (cf. Namiotko et al., 2004).

Within this framework there are competing hypotheses concerning the origin of anchialine faunas. Firstly, because a diverse suite of crustaceans representing basal lineages is restricted to anchialine systems (Boxshall & Jaume, 1999), they have been there for geological eras and their current distribution arose by vicariance (Manning et al., 1986) resulting from the fragmentation of Pangaea ('plate rafting'), and so the extant species represent relict populations. Secondly, if crevicular faunas are widespread (Maciolek, 1983), then anchialine faunas may merely represent the accessible part of this broader crevicular fauna. The thesis that there has been a crevicular system in spatio-temporal continuity from shore to abyssal depth and around the globe for eons, has recently been revitalized as the 'Ophel' in which these various chemoautotrophic ecosystems became globally linked during deep time (Por, 2007, 2008).

The hypothesis that anchialine faunas widely inhabit shallow crevicular habitats is supported by the genetic similarity of populations found in separate surface expressions of anchialine systems (Humphreys, 2001; Santos, 2006; Page et al., 2008) and by their presence in wells (*Danielopolina* spp. on Canary Islands; Wilkens et al., 1986: Cape Range; W. F. Humphreys, unpubl.), and so, potentially, in the crevicular systems in the floor of the continental shelf. Their presence in wells led Kornicker & Iliffe (2000) to deduce that they could migrate through crevicular spaces of volcanic rock lending support for the hypothesis of deep crevicular dispersal down and along slope of seamount islands, as proposed by Hart et al. (1985). This proposition has been further supported by the presence of anchialine fauna in oceanic blue holes and offshore submarine caves (Kornicker et al., 2007). Although ocean blue holes on the Bahamas contained anchialine Myodocopa (cf. Kornicker et al., 2007), there was slight species overlap between inland and ocean blue holes (2%) and none between the inland blue holes and

the open ocean, whereas there was 24% overlap between the open ocean and ocean blue holes (calculated from table 1 in Kornicker et al., 2007). Similarly, on Exuma Island, only one of 24 species (4%) of myodocopid was sampled from both oceanic and inland blue holes (Kornicker et al., 2008). However, at Conch Sound Blue Hole, Andros Island, a cave leading from this oceanic blue hole contained various higher taxa typically associated with inland anchialine systems (remipedes, thermosbaenaceans, blind cave fish, and halocyprid ostracodes (B. Kakuk, pers. comm. 2002, cited in Kornicker et al., 2007).

The presence of a number of Tethyan species on Christmas Island suggests dispersal is one factor in this distribution (Humphreys & Danielopol, 2006). Else, as suggested by Boxshall & Jaume (2000: 13), modern anchialine assemblages may be "a composite of taxa with varying origins. . .built up over several episodes of colonization". Taking in consideration the fossil documentation of closely related taxa of *Danielopolina* (viz., the distribution of the genus *Pokornyopsis* Kozur, 1974 during the first part of the Mesozoic, cf. Danielopol et al., 1996, 2000) in the thermospheric environment of the Tethys Ocean (cf. inter alia for this latter aspect and the dispersal of ostracode taxa at various depths, Benson, 1984; Boomer et al., 1995) one could accept the hypothesis that thaumatocypridids like *Danielopolina* could colonize subsurface systems either in the incipient stage of the development of sea-mounts, like Christmas Island, or later on from both shallow or even bathyal marine systems (for this latter alternative model, see arguments in Kornicker & Iliffe, 1985). Evidence for the colonization of coastal caves by bathyal fauna, representing Mesozoic relicts, was documented with various sponge taxa by Vacelet (1996), and with amphipod Crustacea by Boutin (1994). The latter argued that crustaceans had already colonized the oceanic island of Fuerteventura (Canary Islands) by the Mesozoic.

Molecular phylogenetic research, which has been effective in resolving questions about anchialine Atyidae (cf. Page et al., 2008; Hunter et al., 2008), needs to be applied across the breadth of higher taxa characteristic of anchialine systems in order to determine whether the common biogeographic pattern seen in modern anchialine faunas at a global scale is reflected in a common historical biogeography. However, given the apparent rarity of many species, it will be a considerable challenge to assemble appropriate collections. Meanwhile, molecular evidence is consistent with the Tethyan origin of the anchialine fauna of Bundera Sinkhole in north-western Australia. Namely, *Stygiocaris* (Atyidae) is the sister taxon (Page et al., 2008) to the amphi-Atlantic anchialine genus *Typhlatya*. *Danielopolina* (*D.*) *kornickeri* is part of the Bundera fauna but its DNA has not been examined.
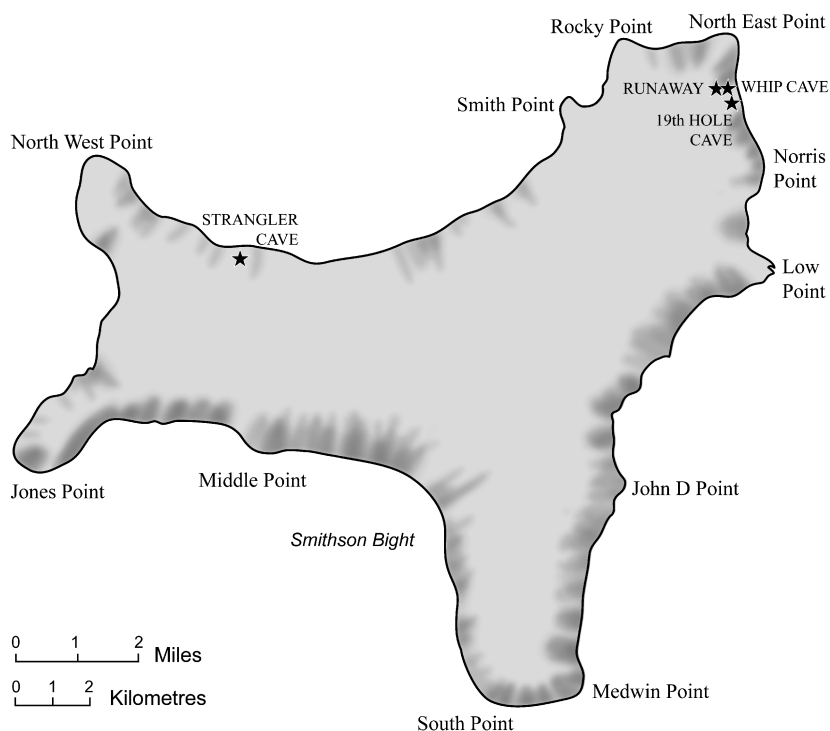
Fig. 2. Christmas Island showing localities of caves with *Danielopolina baltanasi* sp. n. (species not collected in Runaway Cave).

ANCHIALINE CAVES OF CHRISTMAS ISLAND

Christmas Island (fig. 2) is a limestone covered basaltic volcano rising 4.5 km from the sea floor adjacent to the Java Trench and, at its present stage of development, Christmas Island is a carbonate cover island (sensu Mylroie et al., 2001; Jensen et al., 2002). Owing to the steady uplift of the island (Grimes, 2001) the limestone forms a series of emergent marine terraces and the anchialine waters are accessed through the lower two of these terraces. Saltwater interface caves such as those found in the Bahamas (Mylroie et al., 1991) and those on Christmas Island, are sites of vigorous karst development resulting from mixing corrosion at the freshwater saltwater interface (Ford & Williams, 1989). Owing to the mode of development of these caves (Grimes, 2001; for the Bahamas see Mylroie et al., 1991), and the predominantly much lower sea level stands during the Pleistocene (Chappell & Thom, 1977), these saltwater interface caves are likely to extend to at least 80 m below the present sea level, notwithstanding an uplift of the island by 12-30 m in the last 124 000 years (Woodroffe, 1988). Evidence of lower sea level is seen in speleothems, formed subaerially, now drowned to depths of up to 6 m in coastal caves on Christmas Island (Humphreys & Eberhard, 1998). SCUBA
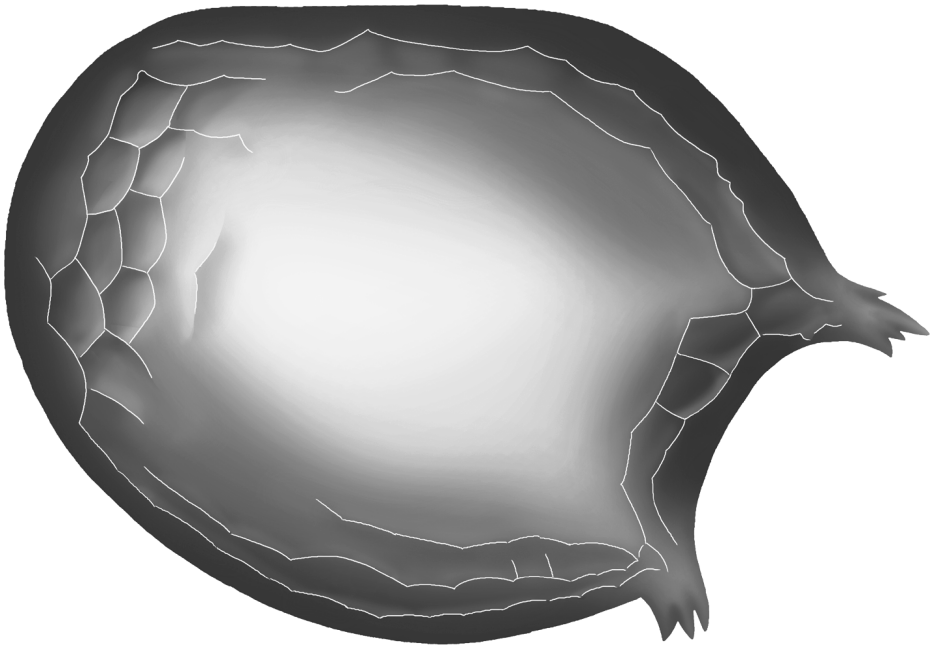
Fig. 3. Carapace of instar I of *Danielopolina baltanasi* sp. n. from The 19th Hole. Length excluding upper anterior process 0.28 mm. Drawing based on specimen WAM C35470 and fig. 1 in Humphreys & Danielopol (2006). Carapace is preserved in alcohol. Illustration previously appeared in Kornicker et al. (2006, fig. 2).

divers have reported caves and freshwater outflows up to 55 m depth off shore, whilst submarine springs (vruljas) have been reported at 200 m depth in Flying Fish Cove (Pettifer & Polak, 1979). The evidence indicates that there is a broad band of caverns, and associated crevicular habitat, from above the ocean to a depth of at least 100 m (Humphreys & Eberhard, 1998, 2001; Grimes, 2001; Namiotko et al., 2004; Humphreys & Danielopol, 2006) that could have, and may currently support, anchialine fauna on Christmas Island, and that this cavernous/crevicular collar would have provided continuous anchialine habitat during eustatic change.

Danielopolina baltanasi sp. n. (fig. 3) were collected in three caves beneath rainforest in anchialine pools at a distance of 90-150 m from the shore. Whip Cave (length 114 m, depth 14.3 m) is 40 m from Runaway Cave (length 145 m, depth 18.5 m) and 250 m from The 19th Hole on the lower of the raised marine terraces that skirt Christmas Island. Each contains anchialine pools and, although underground connection between the caves has not been traversed by cavers, the caves are likely to be linked by a continuous anchialine system owing to the phreatic karst development characteristic of this area. This area contains, in addition to *Danielopolina baltanasi* sp. n., a range of stygofauna, most notably the ostracode *Microceratina martensi* Namiotko, Wouters, Danielopol & Humphreys,

2004, a Podocopida, the decapod *Procaris noelensis* Bruce & Davie, 2006, and a wide variety of other decapods that are listed in Namiotko et al. (2004).

Runaway Cave is immediately inland of Whip Cave (fig. 2) and the water level is affected by marine tides, but the temporal and amplitude damping of the tide with distance inland has not been measured. Water quality data for Runaway Cave are included as they provide the deepest available profile of the Christmas Island anchialine system. The water quality profile was strongly stratified, typical of anchialine systems (Sket, 1996; Humphreys, 1999; Iliffe, 2000) with fresh water overlying near full seawater (c. 80%) at a depth of 4.5 m. This salinity stratification was mirrored by marked gradients in dissolved oxygen, pH, redox, and increasing temperature (fig. 4A). Whip Cave could be profiled to a depth of about 2 m and the physicochemical structure was also consistent with that of an anchialine system (fig. 4B).

Strangler Cave to the north-west of the island (fig. 2) about 14 km from Whip Cave, is entered inland from jumble karst leading to a tidally influenced aquatic habitat. The cave, which contains tree roots and terrestrial subterranean fauna, is difficult to locate and not well known. In 1998, the lower parts of Strangler Cave had water saturated air at 25.6°C containing 0.5% CO_2 and the water had DO 7.46 mg l^{-1} at 27.1°C, conductivity 29.2 mS cm^{-1} at pH 7.40 (Humphreys & Eberhard, 1998). A profile of the water column to a depth of 3.2 m, made when *Danielopolina baltanasi* sp. n. was collected (fig. 4C), showed that salinity increased with depth from about 60% to 85% seawater and there was marked stratification of temperature, DO, and redox values typical of anchialine systems. No other obligate subterranean fauna elements are known from Strangler Cave, but a polychaete and harpacticoid copepods were present, including *Nitokra* sp. (Ameiridae) and *Monocletodes* sp. (Cletodidae), the latter being active mud burrowers in shallow marine habitats (T. Karanovic, pers. comm. 2006).

In north-western Australia, the location of *Danielopolina kornickeri*, morphological and molecular evidence indicates that considerable differentiation has occurred within a distance of 70 km between populations of other species inhabiting the anchialine system fringing Cape Range (Humphreys, 2001; Page et al., 2008). However, as discussed in the section on habitat, our present knowledge of Christmas Island karst (Grimes, 2001; Humphreys & Eberhard, 2001) suggests that the anchialine fringe on Christmas Island is likely to be continuous and so the presence of *D. baltanasi* sp. n. far apart on the island is not unexpected.

MATERIAL AND METHODS

Anchialine fauna was intensively sampled using small baited funnel traps and by plankton nets (125 and 250 μm mesh, up to 400 mm diameter) variously swept
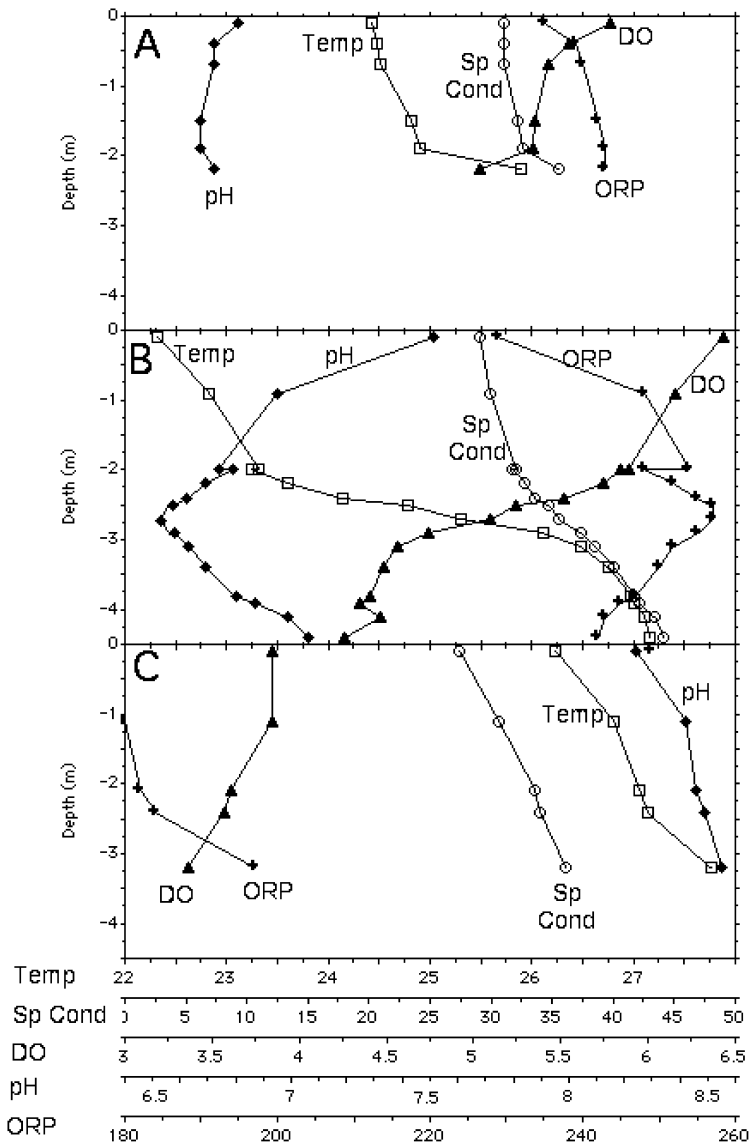
Fig. 4. Depth profiles of water quality in: A, Whip Cave; B, Runaway Cave; C, Strangler Cave; all on Christmas Island. Temperature (°C), specific conductance (mS cm^{-1}), dissolved oxygen (DO mg l^{-1}), pH, redox (ORP, mV); (pH is relative, not absolute, see Methods).

through the water by hand, pushed by swimmer, or cast and hauled through the water by line. Although access for netting was limited to shallow water (less than 4 m deep), the caves continued to deeper water down finer conduits and amongst breakdown mounds; given the geological history of the island, extensive karst development at depth may be expected (Humphreys & Eberhard, 2001).

Whip Cave (CI-54; karst index number from Humphreys & Eberhard, 2001), The 19th Hole cave (CI-19) and Runaway Cave (CI-2) were sampled on 20, 20, and 15 days, respectively (Brooks, 2007) in April-May, 2006, yielding one specimen of *Danielopolina baltanasi* sp. n. from Whip Cave and no *Procaris* (Procarididae), the prime target. A single juvenile from The 19th Hole had been collected in 2004 (Humphreys & Danielopol, 2006; Kornicker et al., 2006). Strangler Cave (CI-16) was visited twice and was only sampled using a 400 mm diameter cast haul net, which yielded a single specimen of *Danielopolina*, two copepods, a polychaete, and no other stygofauna.

Samples were returned to the laboratory and sorted live in a Petri dish under a dissecting microscope, using intense lateral illumination, and preserved in 75% ethanol, 100% ethanol, or propylene glycol.

Depth profiles were determined using a Quanta-G water quality monitoring system (Hydrolab Corporation, Austin, Texas) attached to a 50 m cable, which permitted the measurement of various physico-chemical water quality parameters (temperature, specific conductance, pH, dissolved oxygen, oxidation reduction potential, and depth) to locate any vertical stratification of the water column. The instrument was calibrated against the standards recommended for the instrument, both before and after the measurements. On recalibration, the pH was found to have drifted +1.18 pH at pH 7 and +1.20 pH at pH 10, consequently, the pH value recorded is uncertain and the pH data prior to recalibration are included here to show the depth at which changes in pH occurred relative to other parameters.

Dissections: camera lucida drawings of visible appendages were drawn while they were attached to the body; then each specimen was dissected and the parts mounted on a slide so that they could be examined and drawn at higher magnifications. The appendages were separated from the body of the specimen from Stranglers Cave, whereas only a few appendages were separated from the body of the specimen from Whip Cave. Separated valves of each specimen were examined while in a drop of glycerine on a slide. The specimen from The 19th Hole was not dissected when it was described by Kornicker et al. (2007).

The prefix CI- denotes the number of the karst feature in the Christmas Island Karst Index (Humphreys & Eberhard, 1998).

SYSTEMATICS

The description is under the authority of L. S. Kornicker only.

Superorder HALOCYPRIDA G. O. Sars, 1866

Order HALOCYPRIDA Dana, 1853

Suborder HALOCYPRIDINA Dana, 1853

Superfamily THAUMATOCYPRIDOIDEA Müller, 1906

Family THAUMATOCYPRIDIDAE Müller, 1906

Genus **Danielopolina** Kornicker & Sohn, 1976

Type species. — *Danielopolina carolynae* Kornicker & Sohn, 1976.

Subgenus **Humphreysella** Kornicker & Danielopol, 2006

Type species. — *Danielopolina orghidani* (Danielopol, 1972).

Danielopolina baltanasi sp. n.[1]
(figs. 5-11)

Danielopolina sp. (cf. *D. kornickeri* Danielopol, Baltanás & Humphreys, 2000) in Humphreys &
Danielopol, 2006: 1340, fig. 1.
Danielopolina sp. cf. *D. (D.) kornickeri* in Kornicker et al., 2006: 83, fig. 4.

Material examined. — Holotype BES 13669, juvenile male, appendages on slide, carapace in
alcohol. Western Australian Museum registration number C40048; for type localities see below.
Paratypes: Christmas Island, Indian Ocean, Whip Cave, karst # CI-54, 10°25′22.0″S 105°42′04″E;
BES 13649,1 juvenile ?female (appendages on slide, carapace in alcohol); Western Australian
Museum registration number C40049, collected 3 May 2006, R. D. Brooks. Christmas Island, Indian
Ocean, The 19th Hole, karst # CI-19, 10°25′30.0″S 105°42′04.2″E; BES 11687, karst # CI-19,
1 juvenile instar I in alcohol, Western Australian Museum registration number C35470, collected 21
June 2004, R. D. Brooks.
Type locality. — Christmas Island, Indian Ocean, Strangler Cave, karst # CI-16, 10°27′48.3″S
105°35′05.8″S; collected 5 May 2006, W. F. Humphreys.

Etymology. — The species is named for Dr. Angel Baltanás, for his contribution
to knowledge of the phylogentic relationships of the Thaumatocyprididae.

Age and sex of specimens. — The specimen from The 19th Hole is interpreted to
be an instar I (sex unknown) because the basis of the mandible bears only 4 ventral
teeth. The specimen from Whip Cave is interpreted to be older than instar III
because of the presence of a 7th limb with bristles. The specimen lacks ventral
bristles on the 4th segment of the 1st antenna, which suggests that it is female. The
specimen from Strangler Cave is without a 7th limb suggesting that it is younger

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[1]) Thus henceforth to be cited as: *Danielopolina baltanasi* Kornicker, 2009.

TABLE II

Comparison of morphology of specimens of *D. baltanasi* sp. n. from Christmas Island; D, dorsal; L, long; na, not applicable; No., number; S, short; V, ventral; +, present; −, absent; carapace length and height determined without including anterior processes

Character	The 19th Hole	Strangler Cave	Whip Cave
	Instar I	Juv. male	Juv. ?female
Carapace length (mm)	0.28	55	0.70
Carapace height (mm)	0.20	39	0.54
1st antenna			
Article 1	0	1L	1L
Article 2	0	1D	1D
Article 4	0	1-2V	0
Article 5	1V	2V	2V
Article 7	1V-1D	2V-1D	2V-1D
Article 8	2	3	3
2nd antenna (endopod bristles)			
Article 1	0V-0D	0V-1, 2D	0V-2D
Article 2	1V-1D	3V-1D	3V-1D
Article 3	1L-1S	0L- 2S	0L-1S
Mandible (No. basis teeth)	4	5	5
6th Limb			
Limb present (+), absent (−)	−	+	+
Limb extends past 5th limb	na	+	+
Limb bristles present (+)	na	+	+
7th Limb			
Limb present (+), absent (−)	−	?	+
Limb bristles (No.)	na	?	2
Furcal claws (No.)	3	5-6	5

than instar IV; however, it has a well developed 6th limb and undeveloped male copulatory lobes, which suggests that it is older than an instar III. The specimen is tentatively interpreted to be older than an instar III. Possibly its 7th limbs were lost during dissection. The absence of a terminal hook on the endopod of its 2nd antenna shows that it is not an adult male. Some pertinent morphological characters possessed by the three juveniles are compared in table II.

Descriptions. — Juvenile male (Strangler Cave). Carapace shape (fig. 5A). An elongate oval in lateral view with upper and lower anterior processes. Dorsal, ventral, and posterior margins convex; anterior margin between upper and lower processes straight. Upper and lower anterior processes with 3 terminal prongs.

Carapace ornamentation (fig. 5A). Dorsal and ventral anterior processes with proximal surface reticulations and 3 distal parallel ribs, each terminating in a small projection. Anterior surface of valve between processes with narrow ridge parallel and just posterior to anterior edge. Lateral surface with continuous
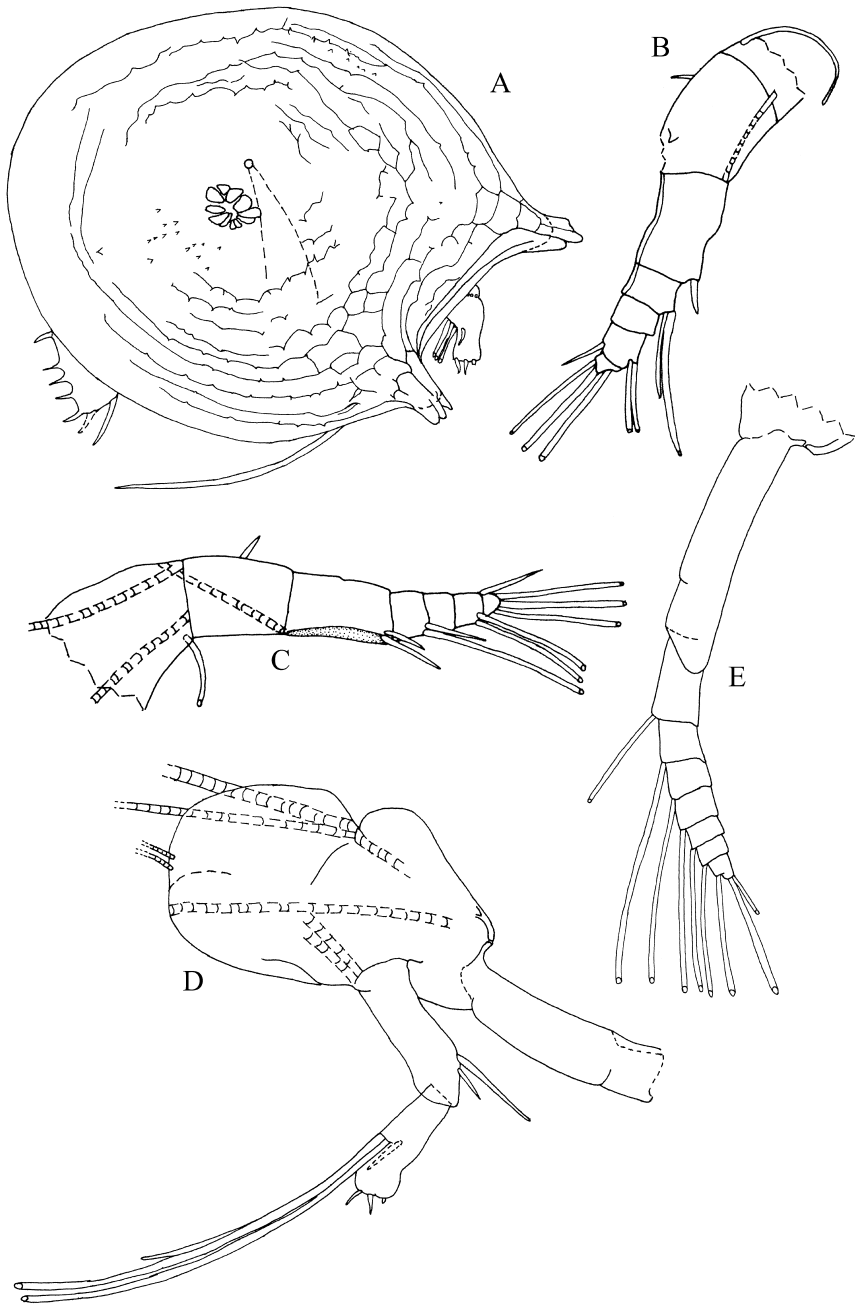
Fig. 5. *Danielopolina baltanasi* sp. n., juvenile male (Strangler Cave): A, complete specimen showing adductor muscle scars, mandible coxa (dashed) and terminal claw-like bristle projecting from ventral edge of carapace, maxilla projecting from anterior, and furca (length of carapace including anterior process 0.56 mm, without anterior process 0.51 mm); B, C, right and left 1st antennae, respectively; D, E, left and right 2nd antennae, respectively.

concentric delicate ridges mostly parallel to outer edge of valve; ridges bear fairly evenly spaced minute projections that generally continue as slender ribs connected to adjacent concentric ridges. Concentric ridges and slender cross-ribs form reticulations with 4 to 6 sides. Width of some cross-ribs same as width of concentric ridges, but most thinner, and not always easily visible. Cross-ribs often absent (possibly eroded). Delicate reticulations may break off or dissolve on preserved specimens.

Carapace size. Length of right valve with body removed and including anterior prongs 0.59 mm; length without upper anterior process 0.55 mm; height 0.39 mm. Height as percent of length with upper process excluded in length measurement 71%; with upper process included 66%.

Central adductor muscle attachments (fig. 5A). Consisting of about 7 wedge-shaped scars and 3 smaller scars arranged radially.

First antenna (fig. 5B, C). Article 1 with long backward oriented bristle. Article 2 with short dorsal bristle at midlength. Articles 3 and 4 fused; article 3 bare; article 4 with 1 or 2 short terminal ventral bristles. Article 5 with 2 terminal ventral bristles (1 long, 1 short). Article 6 bare; article 7 with short dorsal a-bristle and long ventral b- and c-bristles. Article 8 with d-, e-, and f-bristles.

Second antenna (fig. 5D, E). Protopod bare. Endopod with 3 articles; article 1 with 2 short dorsal bristles on left limb, and 1 on right limb; articles 2 and 3 fused; article 2 with 4 bristles (3 long medial near ventral edge, 1 short lateral at midwidth); article 3 short, with blunt distal end bearing 2 small terminal bristles and 1 minute terminal peg. Exopod with 9 articles; article 1 divided into long proximal and short distal parts, both bare; articles 2 to 8 with long ventral bristle with long distal marginal spines; article 9 small and with 2 terminal bristles.

Mandible (for terminology of coxa see Richter & Kornicker, 2006) (figs. 6A–D, 7A–D). Coxa: molar process (mp) with 4 tooth-like structures with spines between and around teeth; incisor process (ip) with 6 or 7 teeth; lacinia mobilis (lm) with about 5 teeth; triangular tooth present between pars molaris and lacinia mobilis. Basis: dorsal edge with hairs; medial side near distal dorsal corner with 1 or 2 bristles (indistinct) on left limb, but none observed on right limb (possibly broken off); lateral surface with 5 bristles (distal bristle spine-like on right limb); anterior margin with 1 long distal bristle; posterior margin with hairs and 2 short bristles (distal one of these with tubular tip); ventral edge of basis with 5 triangular teeth. Endopod: article 1 with anterior bristle near mid-length (not observed on left limb); article 2 with 2 anterior bristles, 1 distal posterior bristle, 2 distal medial bristles (not observed on left limb); 3rd article with many bristles broken off on both limbs during dissection; with long terminal claw-like bristle and several shorter bristles.

Maxilla (figs. 6E, F, 7A). Precoxa: dorsal edge with medial extension; endite I with 10 bristles including 2 tubular bristles. Coxa: endite II with 5 bristles
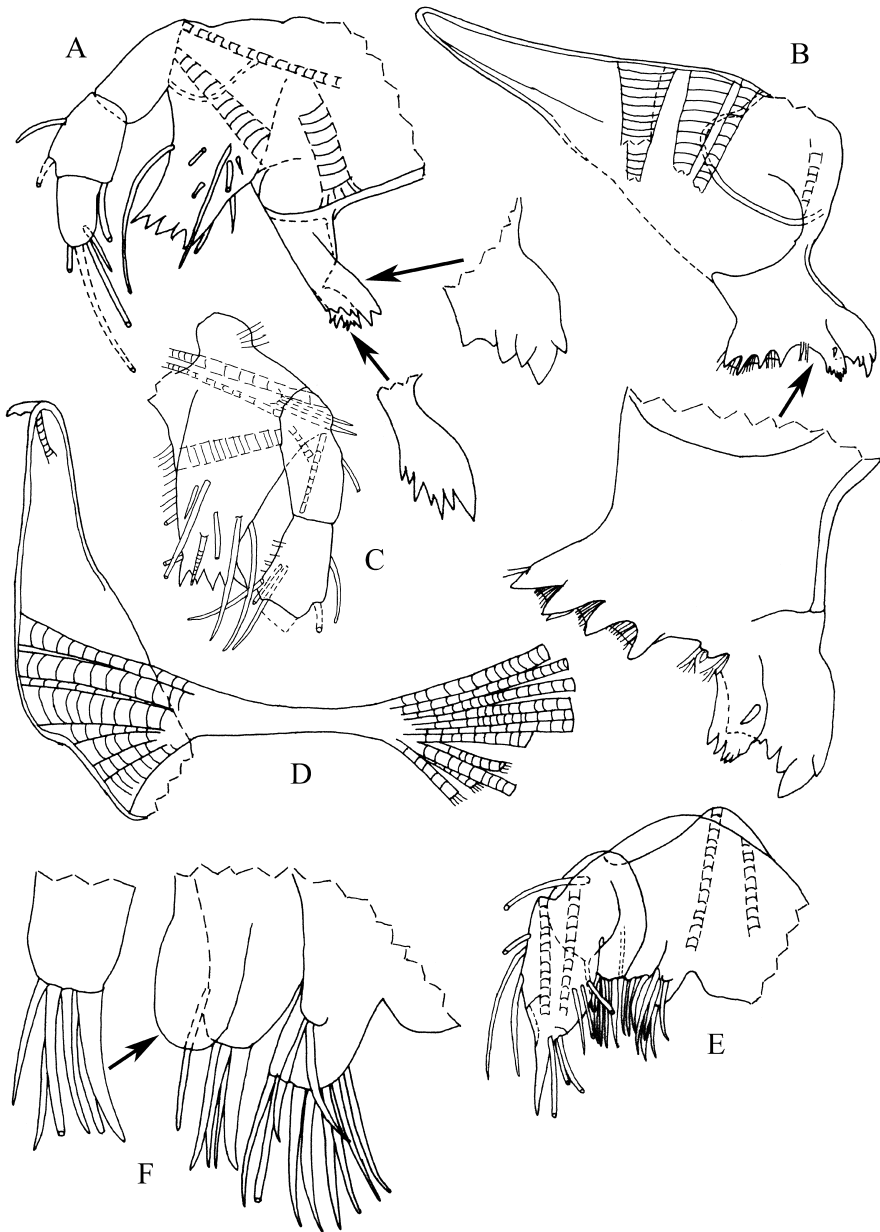
Fig. 6. *Danielopolina baltanasi* sp. n., juvenile male (Strangler Cave): A–D, mandible; A, left limb; B, C, right limb; D, coxa and central adductor muscles; E, F, left maxilla.

including 2 tubular bristles; endite III with 6 bristles including 2 tubular bristles; dorsal margin of coxa with long spinous bristle. Basis: with terminal medial exopodial bristle on ventral margin. Endopod: article 1 with 3 bristles on anterior
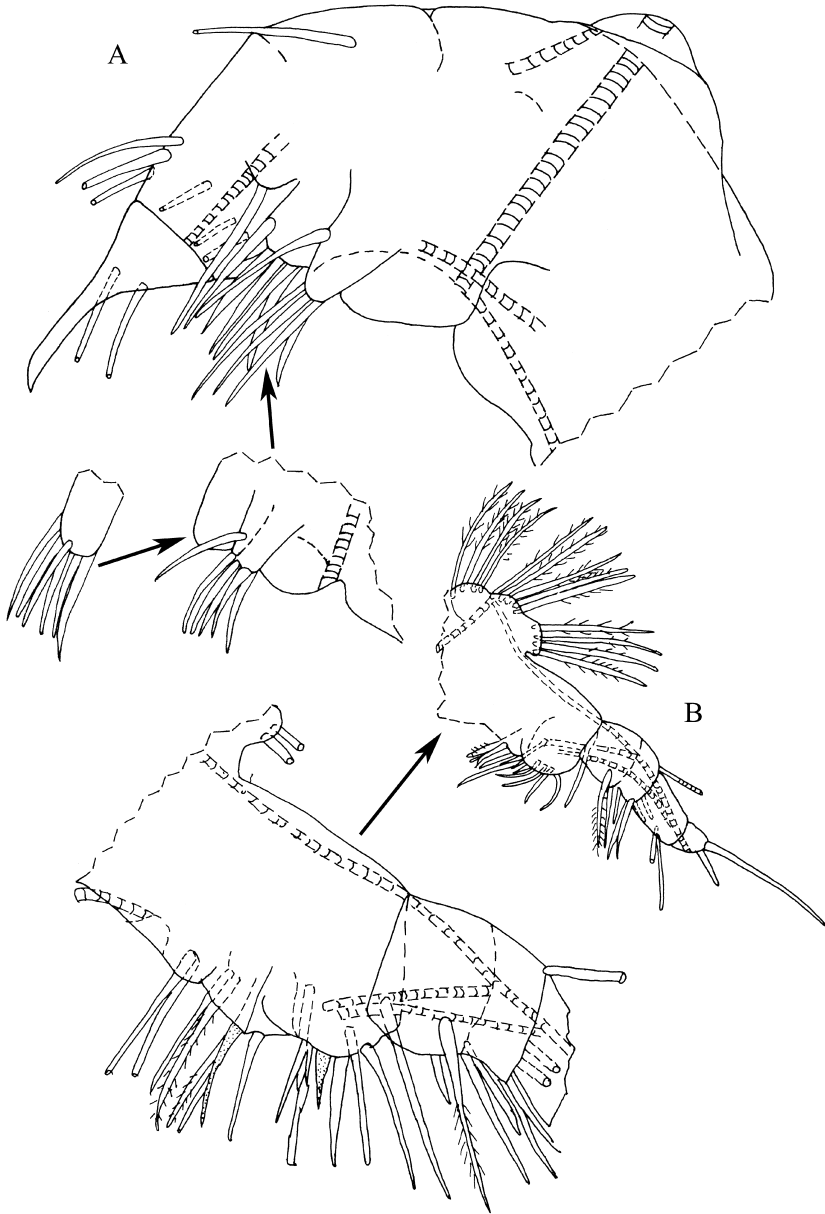
Fig. 7. *Danielopolina baltanasi* sp. n., juvenile male from Strangler Cave: A, right maxilla; B, left 5$^{\text{th}}$ limb.

margin and 2 to 4 distal lateral bristles in posterior 2/3; article 2 with terminal bare claw without rings or basal suture and 2 to 4 short bristles.

Fifth limb (fig. 7B). Epipod with long bristles forming 3 groups: proximal and distal groups with 4 bristles; middle group with 5 bristles. Precoxa with 4 or

5 bristles near ventral margin followed by endite with 4 ventral bristles. Coxal endite with 9 bristles including small triangular spine-like bristle. Basis with indentation on ventral margin and article broader in proximal part; weak medial suture separating proximal and distal halves, each half with 4 bristles on or near ventral margin. Exopod represented by long bare terminal bristle on dorsal margin of basis. Endopod with 2 articles: article 1 with 2 ventral bristles near midlength; article 2 with 2 terminal bristles (1 long, 1 short). Sixth limb extends past posterior end of 5th limb.

Sixth limb (fig. 8A). Epipod with long hirsute bristles forming 3 groups: proximal and distal groups with 5 bristles; middle group with 4 bristles. Precoxa and coxa fused, each article with endite with 2 ventral bristles. Basis separated from coxa with very weak suture and with 4 ventral bristles (2 at midlength, 2 terminal). Exopod lobe small with 2 long terminal bristles (outer bristle stouter than inner bristle). Endopod: articles 1 and 2 fused, with 2 ventral bristles at midlength; article 3 with 2 bristles (1 long terminal and 1 short ventral).

Seventh limb. Not identified with certainty. Fragments on slide containing dissected specimen could be parts of 7th limbs.

Furca (figs. 5A, 8B, C). Each lamella with 1 long articulated claw with indistinct rings, 1 shorter articulated claw on anteroventral corner (claw broken off on both lamellae, but the clean break on the lamellae where the 2nd claw had been attached may indicate that the claw had been separated from the lamella by a weak suture, but not known with certainty); ventral margin of right lamella with 4 smaller non-articulated claws, some with indistinct minute spines on each edge; ventral margin of left lamella with 3 smaller claws followed by smaller undeveloped claw. Bare, pointed unpaired process present on posterior of body following lamellae.

Bellonci Organ. Not observed.

Lips. Upper lip with anterior spines (fig. 8D). Lower lip with triangular process on each side of upper lip (fig. 8E).

Copulatory organ (fig. 8C, F). Two elongate lobes. Lobe A with small terminal process. Lobe B with terminal nodes. (Lobe B observed after specimen was dissected. It lies along dorsal edge of left 6th limb on slide.)

Posterior of body (fig. 8B). Segmented.

Food. Gut with several ovoid clumps containing dark, unrecognized particles (fig. 8G).

Juvenile ?female (Whip Cave). Carapace shape (fig. 9A–D). An elongate oval in lateral view with upper and lower anterior processes. Dorsal, ventral, and posterior margins convex; anterior margin between upper and lower processes straight. Spines at tips of upper and lower anterior processes obscured by debris.

Carapace ornamentation (fig. 9C). Tip of upper anterior processes of both left and right valves and tip of lower process of left valve with debris of slender
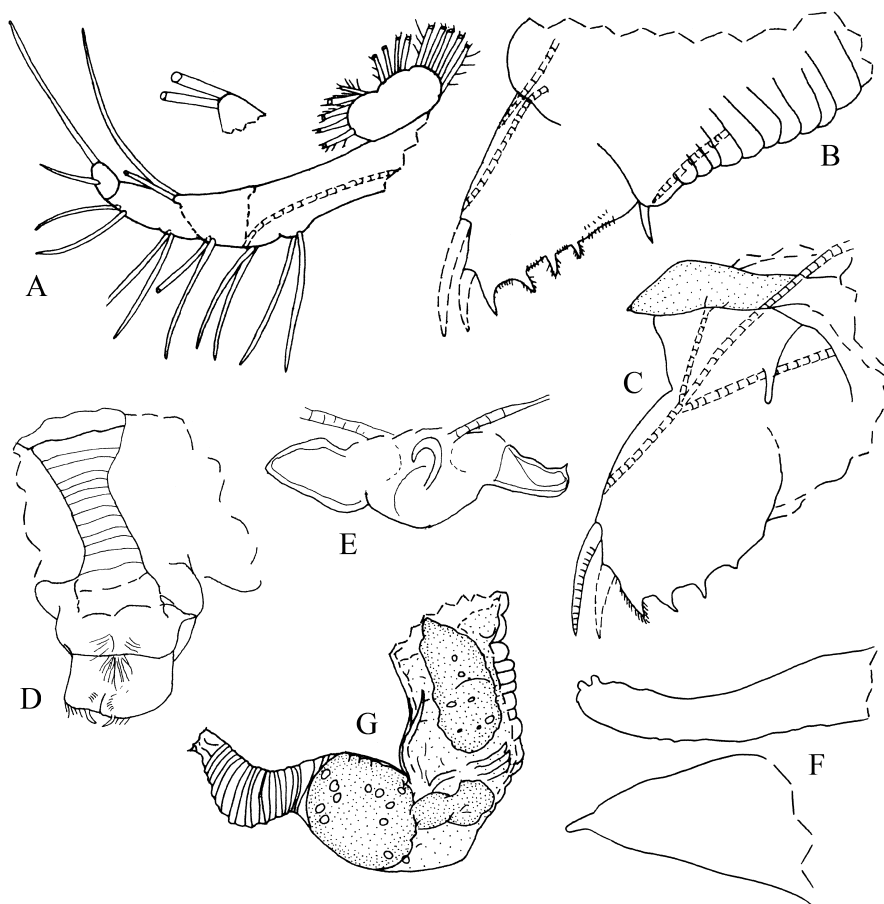
Fig. 8. *Danielopolina baltanasi* sp. n., juvenile male (Strangler Cave): A, left 6th limb; B, C, furca: B, right lamella, medial view; C, left lamella and posterior process of copulatory organ (stippled); D, upper lip and oesophagus; E, lower lip; F, anterior process and tip of posterior process of copulatory organ (see C for location of posterior process); G, oesophagus and part of gut.

spines (not shown) and without prongs. Tip of lower anterior process of right valve without prongs. Preserved valves without surface ornamentation. (Absence of terminal prongs on anterior processes interpreted to be artificial.)

Carapace size. Length including upper anterior process 0.75 mm; length without upper anterior process 0.70 mm; height 0.54 mm. Height as percent of length with upper process excluded 72%; without process included 77%.

Central adductor muscle attachments (fig. 9A, D, E). Consisting of about 12 scars (not all well defined).

First antenna (fig. 9F, G). Article 1 with long backward oriented lateral bristle. Article 2 with short dorsal bristle at midlength. Articles 3 and 4 fused and without bristles. Article 5 with 2 long terminal ventral bristles; article 6 bare; article 7 with
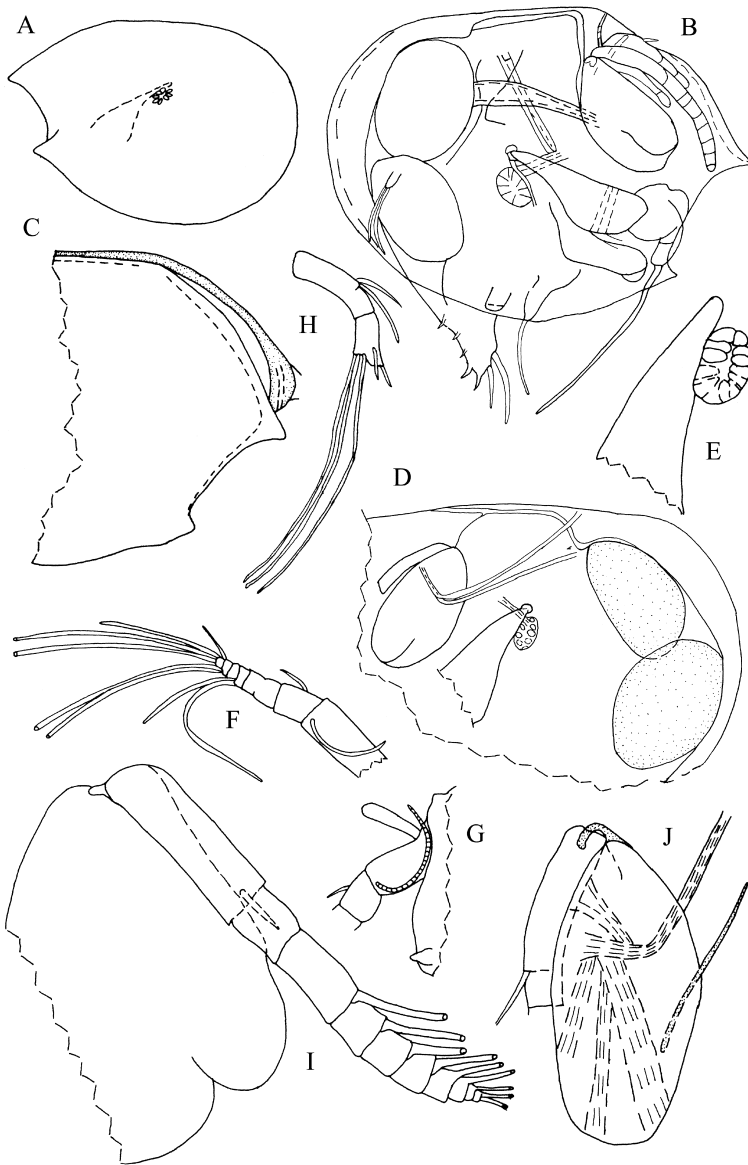
Fig. 9. *Danielopolina baltanasi* sp. n., juvenile ?female (Whip Cave): A, complete specimen showing adductor muscle scars and proximal end of coxa (dashed) of left mandible (length of carapace including anterior process 0.75 mm, without anterior process 0.70 mm); B, complete specimen showing some appendages and 2 food balls within stomach as seen through right valve; C, anterior of carapace; D, part of carapace showing adductor muscle scars, some appendages, and 2 food balls within stomach as seen through left valve; E, adductor muscle scars of left valve and proximal part of coxa of left mandible (detail from fig. 9D); F, left 1st antenna; G, anterior of body from left side showing Bellonci Organ, proximal part of left 1st antenna, and triangular process on anterior of body; H, endopod of 2nd antenna; I, J, protopod and exopod of right and left 2nd antennae, respectively (exopod twisted on right limb).

short dorsal a-bristle and long ventral b- and c-bristles; article 8 with d-, e-, and f-bristles.

Second antenna (fig. 9B, D, H–J). Protopod without bristle on posterior margin. Endopod with 3 articles; article 1 with 2 short dorsal bristles (shorter bristle indistinct); articles 2 and 3 fused; article 2 with 4 bristles (3 long ventral, and 1 short lateral closer to dorsal margin); article 3 a short process bearing 1 short terminal bristle. Exopod with 9 articles; article 1 divided by weak suture into long proximal and short distal sections (indistinct short terminal bristle may be on distal section of only left limb); articles 2 to 8 with long ventral bristle with long distal marginal spines; article 9 small and with 2 terminal bristles.

Mandible (figs. 9D, E, 10A–C). Coxa: similar to that of A-1 male. Basis: medial side near distal dorsal corner with 2 bristles on small process; lateral surface with 5 or 6 distal bristles; anterior margin with 1 long distal bristle; posterior margin with hairs and 1 short pointed bristle and distal bristle with tubular tip (later bristle missing on left limb); distal edge of basis with 5 triangular teeth. Endopod: article 1 with anterior bristle; article 2 with 2 anterior bristles, 1 distal posterior bristle, 2 distal medial bristles, and surface hairs; 3rd article with 1 long claw, 5 bristles, and anterior hairs.

Maxilla (fig. 11A, B). Precoxa: endite I with 8 bristles including 2 tubular bristles. Coxa: endite II with 5 bristles including 2 tubular bristles; endite III with 6 bristles including 2 tubular bristles; dorsal margin of coxa with long bristle. Basis: with terminal medial exopodial bristle on ventral margin. Endopod: article 1 with 5 or 6 bristles; article 2 with terminal bare claw without rings or basal suture and 3 bristles.

Fifth limb (fig. 11C–E). Epipod with long bristles forming 3 groups: proximal and middle groups with 4 bristles; distal group with 5 bristles. Precoxa with 4 or 5 bristles near ventral margin followed by endite with 4 ventral bristles. Coxa endite obscure, with about 5 bristles visible on left limb and none on right limb. Basis with indentation on ventral margin and article broader in proximal part; weak medial suture separating proximal and distal halves, each half with 4 bristles on or near ventral margin. Exopod represented by long bare terminal bristle on dorsal margin of basis. Endopod with 2 articles: article 1 with 2 ventral bristles near midlength; article 2 with 3 terminal bristles (2 long, 1 short).

Sixth limb (fig. 11C, F, G). Epipod with long hirsute bristles forming 3 groups: proximal and distal groups with 5 bristles, middle group with 4 bristles. Precoxa and coxa fused, each article with endite with a few ventral bristles. Basis separated from coxa with very weak suture and with 3 ventral bristles. Exopod lobe small with 2 long terminal bristles (outer bristle stouter than inner bristle). Endopod: articles 1 and 2 fused, with 2 ventral bristles at mid-length; article 3 with 2 bristles
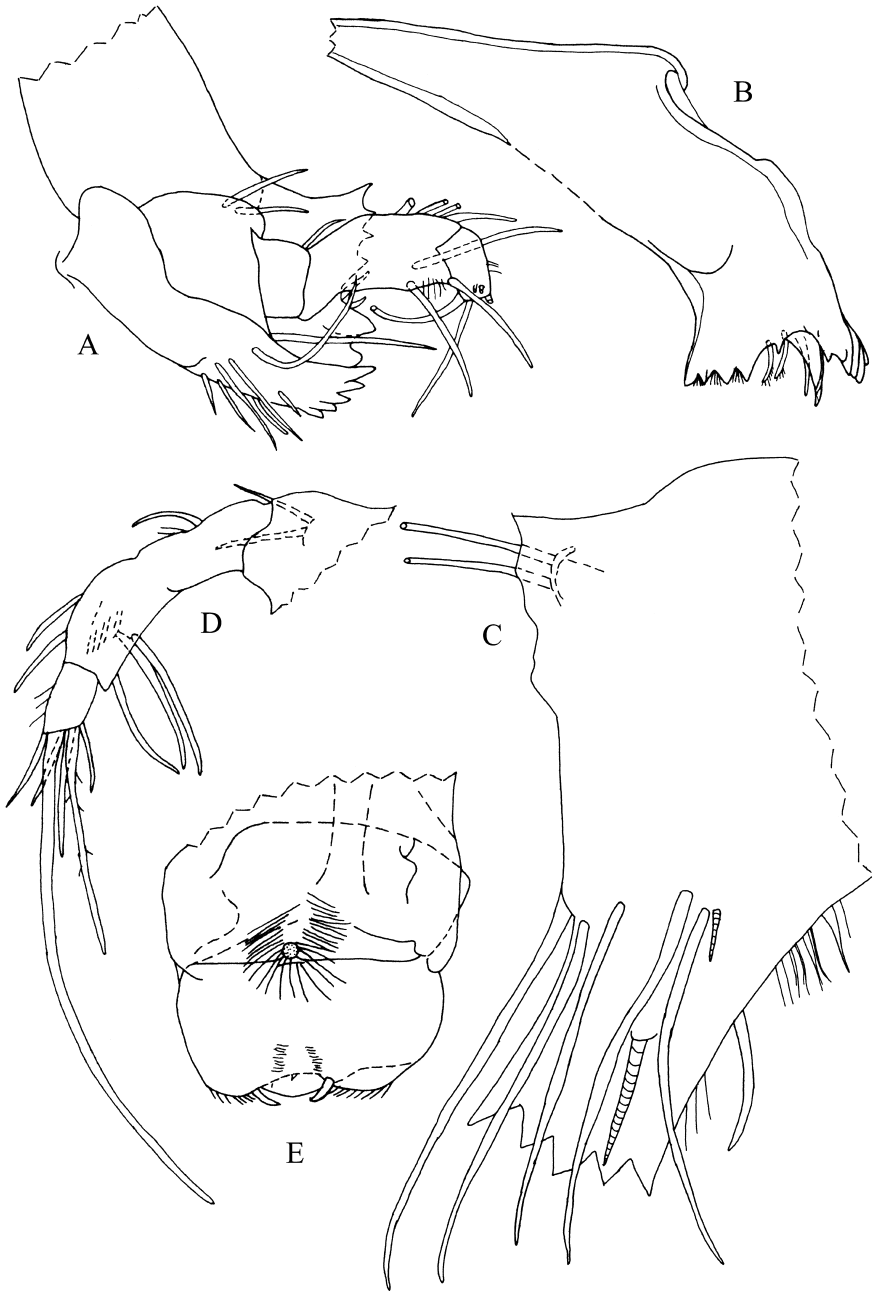
Fig. 10. *Danielopolina baltanasi* sp. n., juvenile ?female (Whip Cave): A, right mandible; B–D, left mandible: B, coxa (anterior to left); C, basis; D, endopod and anterodorsal corner of basis; E, upper lip and mouth, posterior view.
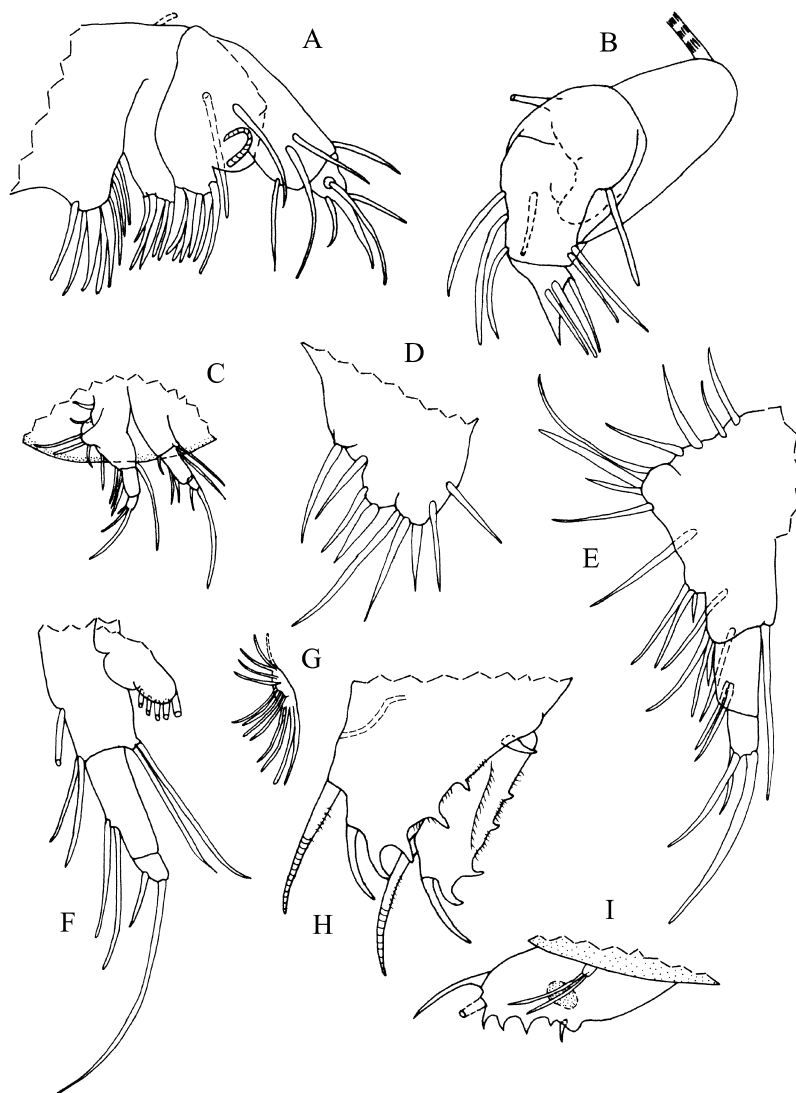
Fig. 11. *Danielopolina baltanasi* sp. n., juvenile ?female (Whip Cave): A, B, left and right maxillae, respectively; C, left 5th and 6th limbs projecting from carapace (anterior to left); D, endites of left 5th limb (anterior to left); E, right 5th limb; F, G, right 6th limb: F, complete limb; and G, epipodial appendage; H, furca; I, left lamella of furca and left 7th limb.

(1 long terminal and 1 short ventral). Sixth limb extends posteriorly past distal end of 5th limb.

Seventh limb (figs. 9B, 11I). Elongate with 2 terminal bristles.

Furca (figs. 9B; 11H, I). Each lamella with 1 long articulated anterior claw, 1 shorter articulated claw on anteroventral corner (suture appears weaker than that at base of previous claw); in addition, left lamella with 3 short nonarticulated

claws and 1 small nonarticulated undeveloped claw, and right lamella with 2 short nonarticulated claws and 2 small undeveloped claws. Unpaired process on body posterior to lamellae.

Bellonci Organ (fig. 9B, G). Elongate lobe.

Lips. Upper lip with anterior spines (fig. 10E). Lower lip not observed.

Genitalia. Not observed.

Posterior of body. Segmentation not observed.

Food. Gut with 2 large elliptical clumps containing dark unrecognized particles (fig. 9B).

Instar I (The 19th Hole). Humphreys & Danielopol (2006: 1340) and Kornicker et al. (2006: 84) identified the unique specimen from The 19th Hole as *Danielopolina* sp. (cf. *D. kornickeri*) (fig. 3). That specimen is transferred to *D. baltanasi* sp. n. herein.

COMPARISONS

Carapace. — A major difference in the carapaces of the two species, *Danielopolina kornickeri* and *D. baltanasi* sp. n., is the presence of a single terminal prong on each of the two anterior processes on the valves of *D. kornickeri* compared to three prongs in *D. baltanasi* sp. n. The prongs consist of material similar to that forming the friable surface reticulations on the valves and as a result may be missing on some preserved specimens due to solution and wear.

Appendages. — Ostracode appendages become more complex in later instars, and this must be considered when comparing specimens of *D. baltanasi* sp. n. and *D. kornickeri*. Therefore, 5 juveniles (estimated instars II-V) of *D. kornickeri* from Australia were examined. These are to be described in a later paper. The 5 juveniles of *D. kornickeri* have a posterior bristle on the protopod of the 2nd antenna that is absent on the 3 known juveniles of *D. baltanasi* sp. n. The 2nd furcal claws of known specimens (instar I unknown) of *D. kornickeri* are fused to the lamellae. The 2nd furcal claw of instar I of *D. baltanasi* sp. n. in the collection is also fused to the lamella, but the 2nd claw of the two older specimens may have a weak suture at its base; however, that could not be determined with certainty, because the claw broke off the lamella on both older instars in the collection. The ease in which the 2nd claws broke off the lamellae may support the possibility that they have a weak basal suture.

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