Ostracoda in the Earth and Life Sciences

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Podocopid Ostracoda from freshwater caves of Australia and New Zealand

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ABSTRACT: Ostracoda were collected by cave diving in several of the principal cave regions of Australia and New Zealand. Nine samples from eight caves and a water tank in the Mt Gambier karst region of South Australia, one from Honeycomb Cave in the Mole Creek karst area of Tasmania, and one from Ruakuri Cave in the Waitomo karst area of North Island, New Zealand, have yielded twelve species of freshwater podocopid Ostracoda. Most have eyes, are brightly colored, swim actively, and have been reported from permanent and temporary surface waters elsewhere. None appear to be troglobitic or specially adapted for subterranean life, and there is no evidence for subterranean dispersal. Collections from six caves in the Nullarbor Plain of South and Western Australia did not yield any Ostracoda.

KEYWORDS: Recent Ostracoda, Australia/New Zealand, cave diving, freshwater podocopids.

1 INTRODUCTION
As part of a 2 year-long expedition investigating the composition and biogeography of aquatic cave faunas in the South Pacific, collections were made by T.M. Iliffe from several of the principal cave regions of Australia and New Zealand. Each cave is represented by a single composite sample, usually a plankton tow that may or may not include wall scrapings or bottom sediment. This limited sampling derives in part from the ecomimese nature of the expedition and in part from the necessarily cumbersome logistics of cave diving. The absence of Ostracoda in some caves and the relatively small numbers of species discovered in most caves should be regarded as a temporary finding, likely to be rectified by additional sampling.

2 PREVIOUS STUDIES
No troglobitic ostracodes are known at present from Australia or New Zealand. Indeed, the ostracodes reported here are probably the first to be noted as inhabiting caves in this region. McKenzie (1990) listed one sample from pools in a cave in the Kimberleys, Western
Australia, that did not contain Ostracoda. De Deckker (1981a) reported two species of *Gomphodella* and "other freshwater Ostracoda" as fossils in a short core from Blue Lake in the Mt Gambier region, and Horne (1985) collected three unidentified species from Blue Lake. De Deckker (1983). Table 1 listed the terrestrial ostracode *Mesocypris australiensis* at Cammoo Caves near Rockingham in Queensland but implied that it was collected in wet moss or rain forest leaf-litter. Among other Crustacea, troglobitic symbionts (Zeidler 1985) and amphipods (Stock & Little 1990) are present in the Mt Gambier caves, while a blind amphipod has been reported from a higher salinity (31.7 ppt) cave in the Nullarbor (Knott 1983). Aquatic troglobites inhabiting Tasmanian caves include amphipods (crangonyctids), isopods (pleurobranchs and janirids), and synchronids (Eberhard in press). Two troglobitic amphipods from the Waitomo caves are under study by Dr Ian Stock.

The Ostracoda of terrestrial waters of these regions are only partly catalogued. The Australian freshwater-derived fauna comprises about 130 named species of free-living Ostracoda (not counting 23 species of Entocytheridae, which are ectoparasitic on larger Crustacea). The corresponding taxonomic literature includes perhaps 75 titles (the latest checklist is by De Deckker & Jones 1978). Most of the older work was concentrated in the southeastern corner of the continent, in the relatively well watered coastal districts of New South Wales and eastern Victoria. More recently the focus has shifted to paleoecological studies of the athalassic saline lakes and springs of western Victoria, South and Western Australia (see numerous papers by K.G. McKenzie & P. De Deckker). By and large, knowledge of Queensland, the Northern Territory, and Tasmania remains on a reconnaissance level. Freshwater Ostracoda of New Zealand total roughly 35 named species and 30 references, mostly from the eastern side of South Island (see checklists by Chapman 1968; Eagar 1971), and there is little taxonomic activity at present.

3 HABITATS AND LIST OF STATIONS

The karst regions included in this report are the Mt Gambier area of South Australia, the Nullarbor Plain of South and Western Australia, the Yule Creek area of Tasmania, and the Waitomo karst of North Island in New Zealand. The Mt Gambier region (Figure 1) consists of a level karst plain composed of Oligocene limestone. During low sea stands of the Pliocene, solutional caves were formed and then modified by collapse. The numerous sinkholes of this region penetrate the water table, reaching depths of over 70 m. The fresh groundwater of the region consists of an unconfined aquifer with flow moving slowly toward the coast and emerging in several high-volume springs. The Mt Gambier sinkholes and springs provide access to often-imense, submerged chambers in total darkness, accessible only by diving (Figure 2). Members of the Cave Divers' Association of Australia have divided underwater caves into three categories of increasing diving difficulty (Lewis & Stace 1982). Category 2 includes open sinkholes with no submerged passages. Category 2 sinkholes have submerged passages leading off, while Category 3 sinkholes and caves have submerged passages and silted conditions. Limestone caves in the Nullarbor Plain contain clear, deep, brackish pools situated about 100 m below the surface of the ground. Sulphides (measured by refractometer at time of sampling) in these water table pools range from 10 to 17.5 ppt, with dissolved salts having a mineral rather than a marine origin. Much of the cave development is apparently phreatic, as is evidenced by broad underwater tunnels extending for distances of several kilometers.
All underwater caves in the Nullarbor region are rated as Category 3 dives. The stream caves of both Tasmania and North Island, New Zealand, have a vadose origin, above the water table. Many of these cave streams originate above ground from the capture of surface streams.

3.1 Caves in which Ostracoda were collected

1. The Pines (Station 87-232), 3.5 km northwest of Burrungule, South Australia (24 km inland); 5 December 1987, specimens collected with a plankton net from the water column in 3 to 24 m depths; 6 Cypretta minua, 41 Cypretta viridis. This sinkhole, rated a Category 3 dive, consists of a spacious underwater chamber offering a spectacular view of the surrounding pine forest that gives this cave its name. From a collapse mound immediately beneath the entrance pool, the cave extends down a breakdown slope to reach a flat, silty floor at 33 m depth. Although the undisturbed water in this cave is exceptionally clear, dark bottom silt that can reduce underwater visibility to zero provides a hazard to the diver. A new genus of triglaebitic crangonyctid amphipod *Unonyctus longicaudus* (Stock & Illiffe 1990) and isopods were also collected from the cave.

2. Goulden’s Hole (Station 87-233), 7 km north of Allendale East, South Australia (13 km inland); 6 December 1987, specimens collected with a plankton net from the water
column in 3 to 20 m depths; 3 Candonocypris incoua, 8 Cypretta viridis, 13 Cypridopsis sp. I, 5 Cypricopsis sp. 2. This 20 m diameter open sinkhole has steep walls dropping 10 m to water level. A ramp has been cut on one side of the sink to allow livestock to drink.
Underwater, this Category I cave belt isward, reaching a maximum depth of 24 m. Copepods, amphipods, and isopods were also collected, while smallfish and crayfish were observed.

3. Benara Sinkhole (Station 87-236), 4 km southwest of Mt Gambier, South Australia (23° km inland); 8 December 1987, specimens collected with a plankton net from the water column in 1 to 15 m depths: 10 *Cyprina minuta*, 2 *Cyprina viridis*, 1 *Gomphosella mara*. The cave is entered using iron ladders to descend a 24 m deep well shaft. At the bottom of the shaft, a short artificial tunnel intersects the 30 m diameter collapse chamber of the cave at an iron platform. 2 m above the water level. The bottom of this circular chamber is completely covered by a clear deep lake, with the exception of a central collapse cone of debris situated in the center of the lake directly beneath the natural entrance. Large calcite rafts, supported by surface tension during their crystallisation, have sunk to the bottom of the 15 m deep pool. Only dim light from the surface reaches the lake chamber. Mollusks and two epigean species, the amphipod *Uronectes longicaudus* and the syncardic *Koounga cavarum* (Zeidler 1985), were also collected from the pool.

4. Water tank near Benara Sinkhole (Station 87-237A), 4 km southwest of Mt Gambier, South Australia (23° km inland); 8 December 1987, specimens collected with a dip net; 186 *Cyprina viridis*, 70 *Heterocypris incongruens*, 22 *Surcyclopodes acaudata*. This open, 0.5 m deep, concrete water tank for livestock contains rain water as well as water pumped from the cave. Copepods were also present.

5. Piccaninmie Ponds (Station 87-237B), 2 km west of the border between Victoria and South Australia (0.5 km inland); 9 December 1987, specimens collected with a plankton net from the water column and silty bottom sediments of *The Cathedral* in 34 m depth; 27 *Candonaeefera insignis*. Situated in a national park, Piccaninmie Ponds consist of a series of deep, clear, spring-fed pools in a coastal marsh setting. The first pond is a bowl-shaped depression, 30 m in diameter and 10 m deep, while the second is a 5 m wide by 40 m long and 57 m deep channel. Abundant algal growth occurs in shallow waters. Organic debris and sandy silt are present on the floor of *The Cathedral*, a rock-filled section of the channel in partial darkness. Due to its coastal setting, the water in Piccaninmie Ponds is slightly brackish with a uniform salinity of 2 ppt measured at the time of collections. The ponds are rated as Category 2. Water temperature was uniform with depth at 18.3°C. Eels, turtles, trout, and even marine fish are present. Also collected were ocellate crangonyctid amphipods, mollusks, crabs, synarcins, copepods, and the shrimp *Paratya australiensis*.

6. Balg Arap (Station 87-239), 4 km west of Mt Sturt, South Australia (14 km inland); 10 December 1987, specimens collected with a bottle from 0-20 m depths along the shoreline; 688 *Neovetebium fenestrasut*. The open, 54 m deep, sinkhole pool is rated as a Category 2 dive. Visibility in the surface waters of this greyish-green lake is very poor. Below the thermocline at 15 m depth, water clarity improves, although temperature drops from 18.5°C to 11°C.

7. The Black Hole (Station 87-240), 15 km southwest of Mt Gambier, South Australia (15 km inland); 10 December 1987, specimens collected with a plankton net towed with a line from the upper lip of the sinkhole through 0-10 m depths; 63 *Neovetebium fenestrasut*. This 65 m long by 45 m wide sinkhole has an overhanging drop of 10 m to a ledge as water level. Under water, the top of the breakdown cone in the center of the pool is at 10 m, while a large, deep tunnel extends 70 m to the southeast, ending at 54 m depth. The water is greenish with suspended algae but becomes clear beneath the thermocline. The cave is rated as Category 2. Copepods and cladochorens were also collected in the plankton tow.

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8. Klisby's Hole (Station 87-242), 4 km northeast of Mt. Shank, South Australia (16 km inland): 13 December 1987, specimens collected with a plankton net from the water column in 3 to 33 m depths; 28 Cypretta viridis, 24 Newhamia fenestra. An iron ladder is used to negotiate the sheer, 15 m drop to water level in this 15 m diameter, open sinkhole. The site is used by the Australian Navy for equipment testing. A large steel bridge extends across the sink, while an underwater observation tower reaches to 20 m depths. The collapse mound extends against one side of the entrance sink at 10 m depth, while the cave slopes down under the opposite side to reach a maximum depth of 60 m. The water was quite clear with underwater visibility about 20 m. Water temperature was uniform with depth at 15.8°C. The cave is rated as a Category 2 dive. Troglobitic syncarids had been reported from the cave before trout had been artificially introduced. During the collecting dive, trout were observed to 33 m depth under larger rocks and overhangs. No syncarids were seen.

9. Fossil Cave (Station 87-347), 21 km northwest of Mt Gambier, South Australia (27 km inland): 13 December 1987, specimens collected with a plankton net from the water column in 0 to 6 m depths; 39 Cypretta viridis. Small pools at the southeast and northwest corners of this shallow, dirt-floored sink provides access to underwater caves. The largest chamber to the southeast reaches depths of 16 m, while the smaller one to the northwest is 8 m deep. Both contain thick black silt and breakdown. The bones of fossil kangaroos and other extinct mammals have been excavated from the underwater cave. Undisturbed water in totally dark sections of the cave had visibility of 30 m or more. Water temperatures were uniform with depth at 13.5°C. Fossil Cave is rated as Category 3. Oculate surface amphipods, syncarids, copepods, and stomatopods were also collected.

10. Honeycomb Cave (Station 87-249), 2 km southwest of Caveside, Tasmania (47 km inland): 25 December 1987, specimens collected with a plankton net from the cave stream in 0.90cm depths; 5 Candonia sp. 2. A surface stream enters this cave through the main entrance in a roadside park. The cave is developed on several levels with occasional, 1-2 m wide fissures opening to the surface. Pools in the cave are up to 2 m deep and considerable woody debris is present. The stream bottom consists of bare rock or gravel. Large syncarids, 6cm long with eyes, and copepods were also collected from the stream.

11. Rutakuri Cave (Station 88-005), 2.5 km west of Waitomo, North Island, New Zealand (35 km inland): 19 January 1988, specimens collected with a plankton net from stream gravel in 0-60cm depths; 1 Candonia sp. 2, 1 Scotia n. sp. A large stream, originating on the surface, flows through this commercially operated tourist cave. The cave contains both lower, active stream passages and upper, fossil levels. Water depths in the stream range from 30cm to over 2 m. Water temperature was 13.1°C. Cave passages are generally large, 5 m or more indiameter. Gastropods, oligochaetes, and copepods were also collected from the stream.

3.2 Caves in which ostracodes were not found

1. Ewens Ponds (Station 87-231), 7 km east of Port MacDonnell, South Australia (2 km inland): 5 December 1987, no ostracodes collected with a plankton net from the water column in 0-10 m depths.

2. Allendale Sinkhole (Station 87-234), Allendale East, South Australia (6 km inland): 6 December 1987, no ostracodes collected with a plankton net from the water column and gravel bottom in 3-24 m waterdepths.

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3. Englebrecht’s Cave (Station 87-241), Mt Gambier (28 km inland): 12 December 1987, no ostracodes collected with a plankton net from the water column in 0-10 m depths.

4. Weebubbe Cave (Station 87-244), 12 km northwest of Eucla, Western Australia (about 30 km inland): 17 December 1987, no ostracodes collected with a plankton net from the water column in 0.18 m depths; salinity and water temperature uniform with depth at 13 ppm and 18.6°C.

5. Warbla Cave (Station 87-245), 19 km northeast of Border Village, South Australia (about 30 km inland): 18 December 1987, no ostracodes collected with a plankton net from the water column in 0.5 m depths; salinity and water temperature were uniform with depth at 15 ppm and 20.3°C.

6. Winterra Cave (Station 87-246), 40 km west-northwest of Eucla, Western Australia (about 30 km inland): 19 December 1987, no ostracodes collected with a plankton net from the water column in 0.4 m depths; salinity and water temperature uniform with depth at 10 ppm and 23.3°C.

7. Cocklebiddy Cave (Station 87-247), 23 km northwest of Cocklebiddy, Western Australia (about 45 km inland): 20 December 1987, no ostracodes collected with plankton net from the water column and gravel bottom in 0.9 m depths; salinity and water temperature were uniform with depth at 2 ppm and 18.5°C.

8. Murrur El Eleyn Cave (Station 87-248), 7 km southwest of Cocklebiddy, Western Australia (about 35 km inland): 21 December 1987, no ostracodes collected with a plankton net from the water column in 0.4 m depths; salinity and water temperature were uniform with depth at 17.5 ppm and 19.4°C.

9. Kullah Khan Cave (Station 87-250), 17 km west of Mole Creek, Tasmania (45 km inland): 26 December 1987, no ostracodes collected with plankton net from water and mud bottom of pool in 0-50cm depths; water temperature, 8.1°C.

10. Croewyn Cave (Station 87-252), 22 km west of Mole Creek, Tasmania (47 km inland): 27 December 1987, no ostracodes collected with a plankton net from the water and gravel bottom of the cave stream in 0-50cm depths; water temperature, 9.4°C.

11. Gardner’s Guts Cave (Station 88-004), 3 km west of Waitomo, North Island, New Zealand (35 km inland): 17 January 1988, no ostracodes collected with plankton net from water and gravel bottom of cave stream in 0-30cm depths; water temperature, 12.8°C.

4 ECOLOGICAL AND BIOGEOGRAPHICAL OBSERVATIONS

According to the results of this reconnaissance (Table 1), the freshwater cave ostracodes of Australia and New Zealand are limited to waters that are either completely open to the surface or have their origins in surface streams. Ostracods are notably absent from both fresh and brackish pools in cave interiors. The absence of ostracodes in totally dark caves indicates that dispersal is by surface rather than subterranean routes in this region.

The low diversity and patchy distribution of ostracode species in the Mt Gambier sinkholes may result from random dispersal, the spot-sampling method, the small size and lack of connection of many pools, and perhaps from seasonality. The list of species recovered is dominated by swimmers, several of which are widely distributed in ephemeral and permanent environments and have desiccation-resistant eggs. All are of freshwater derivation, although some tolerate elevated salinities. Many are brightly pigmented and
Table 1. Ostracode species occurrences at sampling stations.

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have well developed eyes. While some are parthenogenetic populations, others include males. Most appear to be reproducing within the caves. None show morphological adaptations for crevicular or subterranean life, and while a few may tolerate dark caves (troglobitic) and even reproduce there, probably none are restricted to caves (troglobitic). The endemic, giant taxa that characterise Australian athalassic salt lakes are conspicuously absent from these cave collections. Also notably absent are the brackish water and anchialine specialists (Cyprididae, Thalasocyprididae). Apparently they have not been able to reach or to colonize Australian caves, even those near the coast and with saline water.

For freshwater species, as previously proposed by many authors, transport by birds is a likely means of dispersal to some of the open Mt Gambier sinks. Ducks and other waterfowl were observed swimming in some of the larger open sinkhole lakes. However, there is no evidence for transport of any species to these caves either from coastal-marine habitats or from athalassic salt lakes. Dispersal of breeding females or dry eggs by wind is an especially likely process. The Benara Sinkhole, containing three species of ostracodes, has only a small entrance and thus very restricted contact with the surface. Only cave swallows, among the birds, would be able to reach this cave pool. However, the two species found here, Cypretta minuta and Gemphotheca maiya, are known in certain surface habitats as well. Transport by human agency is a third possibility, because many of the Mt Gambier sinks are popular diving locations. There is no evidence that any of these forms disperse through the ground water.

One species (Candonocypris incosta, found in Goudien's Hole and Piccaninnie Ponds) was previously known in Tasmania and New Guinea but not in mainland Australia. McKenzie (1971) speculated that as temperatures and sea levels rose in the Holocene, cold-adapted species that were formerly widespread in the Australasian region may have found refuge as relics in high altitude tropical lakes such as Lake Peune. Similarly, De Deckker (1986) suggested that during the exceptionally arid period 18 000 years ago mainland species adapted to constant, freshwater habitats may have survived in mound springs, such as those around the margin of the Great Artesian Basin, and in the springs and swamps of Tasmania. In the case of C. incosta it appears that the Mt Gambier caves may have provided a third site of refuge.
The total absence of eucarids and scarcity of other aquatic animals in the athalassic saline cave pools of the Nullarbor contrasts markedly with the rich fauna in coastal brackish or marine caves elsewhere in the world. These negative findings, which cannot be explained by sampling deficiencies, are interpreted as indicating a non-marine origin of the salt water. There is no evidence for any subterranean connection between these caves and the Southern Ocean. Moreover, it would seem that a barrier of some kind prevents dispersal to or successful colonisation of these caves by the salt-adapted, freshwater-derived endemic species inhabiting the numerous athalassic salt lakes, springs, and playas of South and Western Australia.

5 SYSTEMATIC DISCUSSION

5.1 Candona sp. 1

Dimensions (mm). Female 3230 (0.69 L). Occurrence. In Honeycomb Cave, Tasmania (Station 87-249), 5 specimens (3 females, 2 juveniles).

Discussion. This species is much smaller than Candona illori McKenzie 1971, from Lake Perinde in New Guinea; it also differs by having a more elongate sixth thoracic femur, fixular claws of somewhat unequal size, and a fixular support that lacks two of the stipular ventral processes. It is smaller than C. inexpecta Chapman 1963, and differs in having slightly unequal than equal (female) or greatly unequal (male) fixular claws. It is smaller than C. arenacea Chapman 1963, and has smooth rather than hisutate setae on the maxillulae palp. It is somewhat larger than Candona tecta De Deckker 1982, and higher posterodorsally; however, the narrow inner lamella of the illustrated holotype (Figure 58) of that Tasmanian species indicates that the latter is probably juvenile, and the postabdomen has not been described.

5.2 Candona sp. 2 (Figures 4C-D, N)

Dimensions (mm). Female 3241 (0.91 L), 0.48 H. Occurrence. In Ruakuri Cave (Station 99-003), one female.

Discussion. The carapace is translucent, white in reflected light and clear light-yellow in transmitted light, with a yellow body, light yellow-brown eyes and focial shell, and no eyes. This species is of the same size as C. inexpecta but smaller than C. arenacea; both described from swamps, ponds, and creeks of New Zealand by Chapman (1963). It differs in lateral outline, being less deeply indented ventrally and not as high posterodorsally; and in anatomical details from both of these species. It is smaller and less expanded posteriorly than C. illori McKenzie 1971, from Lake Perinde, New Guinea, it also has a less elaborate, fixular support lacking the two triangular ventral processes, has fixular claws of graduated lengths, and other anatomical differences.
3.3 *Candonopsis incosta* De Decker 1981 (figures 3A-B, D-I)


Dimensions (mm). Female: 3239F: 1.37 L, 0.69 H. Male: 3239M: 1.12 L, 0.58 H. 

Occurrence. In Goulden’s Hole (Station 87-233), 3 juveniles; in Piccanannie Ponds (Station 87-237B), 27 specimens (6 males, 15 females, 3 juveniles, 3 empty carapaces). The species is recorded from Mowbray Swamp and a spring at Pullenama Swamp, both in northwestern Tasmania, and from Lake Paideau at an altitude of 3750 m in the Biarnek Range of New Guinea. Apparently it has not been reported previously in mainland Australia.

Discussion. The carapace and soft anatomy correspond in all detail to the description by De Decker (1981b). The preserved animal is milky white in both sexes.

5.4 *Cypretta minna* (King 1855) (figures 3E-F, 4I)

1855 *Cypretta minna* King, p.64. 1886 *Cyprioidopsis minna* (King); Brady, p.91. 1896 *Cyprioidopsis minna* (King); Sars, p.157. 1953 *Cypretta minna* King; Henry, p.273.

Dimensions (mm). Male: 3237M: 0.82 L, 0.58 H, 0.67 W. Female: 3028F: 0.84 L, 0.49 H.

Occurrence. In the Pines (Station 87-212), 6 specimens (1 male, 4 females, 1 juvenile); in Benara Sinkhole (Station 87-230), 10 specimens.

Discussion. In well preserved specimens the adult carapace is transparent to translucent, yellowish-white to greenish-yellow to amber. Less well conserved specimens show an irregular white motting. The carapace and the distal claws of legs are dark orange-brown, while the thin striate flap, epimeris, soft body, and the protected portions of appendages are white. External carapace sensillae are short, inconspicuous, and light golden. Juveniles have a more transparent carapace, which takes on a greenish-grey cast when empty, and write body with colourless legs. The lateral eye-cups are distinct, medium-sized, and black, with a remarkably short, thick tubular connection of the same diameter. This population lacks the variegated epidermal color patches described by Sars (1986) for *C. minna*. In comparison with *C. viridis*, *C. minna* has a more highly arched dorsal margin and more trigonal lateral outline.
5.5 Cyprina viridis (Thomson 1879) (Figures 3C, M-N, H)

1879 Cypris viridis Thomson, p.253. 1894 Cypridopsis viridis (Thomson); Sars, p.32. 1982 Cypris viridis (Thomson); De Deckker, p.258.

**Dimensions (mm).** Male 3238M, 0.72 L, 0.53 H, 0.57 W. Female 3025F, 0.86 L, 0.58 H.

**Occurrence.** At The Pits (Station 87-232), 41 specimens (8 males, 11 females, 22 juveniles); at Goulburn’s Hole (Station 87-233), 8 specimens (1 male, 5 females, 2 juveniles); at Benara Sinkhole (Station 87-236), 2 specimens (2 juveniles); at water tank near Benara Sinkhole (Station 87-237A), 186 specimens (males, females, juveniles); at Köth’s Hole (Station 87-242), 28 specimens (3 males, 5 females, 6 juveniles, rest undetermined); at Fossil Cave (Station 87-243), 30 specimens (7 males, 5 females, 18 juveniles, rest undetermined).

**Discussion.** Preserved adult specimens have bright grass-green to pastel blue-green epidermis, somewhat irregularly mottled neat without definable bands. Juveniles have more uniform, light sky-blue to blue-green epidermis. The body and chitinous parts of the adult carapace are pale yellow to yellow-orange; the lateral eye-cups are thick and black with a slightly thinner black tubular connection.

5.6 Cypridopsis sp. 1 (Figures 3G-H)

**Dimensions (mm).** Female 3233F, 0.69 L, 0.43 H.

**Occurrence.** In Goulburn’s Hole, 13 specimens (12 females, 1 juvenile).

**Discussion.** The adult epidermis has four very dark green to black ventral bands, of which the two middle bands merge in the area of the adductor muscles, and all four bands merge dorsally into a continuous colored region along the hinge. Clear spaces between these bands have colorless epidermis beneath the transparent, light yellow carapace. The ventral carapace region is clear yellow with a narrow greenish yellow margin. In shape and coloration this species resembles *C. riduos* (O.F. Müller 1776), which has been reported from New Zealand (Bradey 1906, p.693; Barclay 1968, p.74). In comparison with *C. sp. 2, C. sp. 1* has more intense and more regularly patterned color, is proportionately more inflated, and is more rounded in shape.

5.7 Cypridopsis sp. 2 (Figures 3P-Q)

**Dimensions (mm).** Femalé 3234F, 0.62 L, 0.38 H.

**Occurrence.** In Goulburn’s Hole, 5 females.

**Discussion.** Color of adult epidermis is light yellow-green with three (one anterior and two median gray-green, somewhat discontinuous vertical bands, which do not reach the ventral nor merge dorsally or medially. Compared with *C. sp. 1, C. sp. 2* is lighter and more irregularly colored, smaller, proportionately less inflated, and has more tapering anterior and posterior ends in dorsal view.
5.8 Gomphodella maia De Deckker 1981


Dimensions (mm). Female 0.46 L, 0.31 H, 0.34 W.

Occurrence. In Benara Sinkhole (Station 87-236), one female, white in color. De Deckker (1981a, 1982) reported it live from Fresh Dip Lake in South Australia, fossil in a con from Blue Lake in the Mt Gambier region, and fossil in sediment from Pulbeena Swamp, Tasmania. The species is said to live in permanent waters and to have brood care.

1.9 Heterocyclops incongruens (Ramsdorft 1808) (Figures 4G-H, L)

1808 Cyprinotus incongruens Ramsdorft, p.83. 1894 Cypris sylvestris King; Sars, p.27. 1896 Cypris sylvestris King; Sars, p.50. 1923 Cyprinotus incongruens (Ramsdorft); Henry, p.278.

1966 Heterocyclops sylvestris (King); McKenzie, p.362.

Dimensions (mm). Female 0.707E 1.35 L, 0.794 H.

Occurrence. In water tank near Benara Sinkhole (Station 87-237A), 70 specimens (females and juveniles).

Discussion. This somewhat variable, apparently pan-geographic species-complex has been reported under many names. Exact determination is handicapped by lack of males, the somewhat generalised character of published illustrations, and the absence of systematic analyses of population variability. It is globally represented in ephemeral and permanent, natural and artificial, fresh and slightly saline waters and lays desiccation-resistant eggs. This population displays the anatomical traits itemised by McKenzie (1966).

5.10 Neohnamia fenestrata King 1855 (Figures 3J-L, O)

1855 Neohnamia fenestrata King, p.67. 1979 Neohnamia fenestrata King; De Deckker, p.131.

Dimensions (mm). Male 0.302E 0.71 L, 0.52 H.

Occurrence. In Ela Elap (Station 87-239), 688 specimens (males, females, juveniles) in the Black Hole (Station 87-240), 63 specimens (males, females, juveniles); in Kilsby's Hole (Station 87-242), 24 specimens (males, females, juveniles). De Deckker (1979) stated that this species is known from swamps and farm ponds in all Australian states except Queensland. It has also been recorded from New Zealand (Brady 1906; Hornibrook 1955) and from the Bismarck Archipelago (Wävek 1901).

Discussion. Preserved animals have yellow bodies, yellow-grey to grey-black dorsal epidermis, and a carapace that is colorless to light metallic grey, depending on the angle of light. Dry carapaces have a tronzyn, iridescent sheen in reflected light, produced by trapped air pockets within the polysacids of the isle-like reticulate ornament. They can only be partially rehydrated with great difficulty. All specimens have elevated ocellar tuercles and large, hemispherical, antevortroventrally-directed, clear calcite lenses above conspicuous black eyes with separated lateral cups. None of the cave populations included any of the spinose variants discussed by De Deckker (1979).
5.11 Cypriidae: C. aculeata 

1947 Cypriopsis aculeata Costa, p.11; 1968 Cypriopsis aculeata barley, p.75. 1977 Sarsecypriopsis aculeata (Costa); McKenzie, p.49. 1986 Sarsecypriopsis aculeata (Costa); De Decker, p.81.

Dimensions (mm). Female 3235F, 0.76 L, 0.47 H.

Occurrence. In a water tank near Benara Sinkhole (Station 87-237A), 22 specimens (9 females, 13 juveniles). This cosmopolitan species was first reported from Australia by De Decker (1981b), who found it to be common in temporary pools in Western Australia, South Australia, and Victoria.

Discussion. Adult females are slightly more elongate in lateral view and distinctly thinner in dorsal view than the specimens from the lakes of Western Australia illustrated by De Decker (1981b). They are slightly longer and much larger than S. procula De Decker (1982, in Quaternary deposits of Pulpeena Swamp, Tasmania) but have similar length/width ratios. These dimensions also agree with those given by Barclay (1968) for Cypriopsis obtinata in New Zealand. These nearly "smooth" specimens have abundant, short, seminile originating at simple, round, mostly unrimmed normal pores, but no spines of the sort that have been reported in S. aculeata. The micro-ornament consists of numerous, very small, regularly spaced, circular punctae, which are much smaller, shallower, and more numerous than those illustrated for either S. aculeata or S. procula by De Decker (1981b, 1982). In lateral view, the ventral margin of the right valve is slightly indented, rather than straight as in S. aculeata, and the two valves are more nearly symmetrical. The near-marginal position of the suture in the left valve and the breadth of the inner lamellae in both valves are other characters resembling S. procula but not S. aculeata. Preserved specimens have light blue-green epidermal, darkest in the postero-medial region. The fifth limb has at least four feathered scutes (Strahlen) on the rudimentary branchial plate, rather than only two as specified by McKenzie (1977). The third masticatory process of the maxilla has one smooth and one barred claw, rather than two smooth claws. The rami of the female fifth limb has three setae of graduated lengths, with the longest about twice as long as the next longest. These details match those illustrated by Barclay (1968, fig.5) but not De Decker (1981b, fig.18). The absence of males makes it impossible to confirm the suggested assignment to Sarsecypriopsis. The tentative specific identification (following De Decker 1981b) is based on the assumption that S. aculeata is

widely distributed in Australia and variable. However, several morphological details suggest a close relationship to *S. proxi*a (soft anatomy unknown) and to the New Zealand population reported as *Cypredopsis obtinata*. Meticulous analysis of patterns of geographic and ecological variability will be necessary to resolve the many questions regarding this globally reported species.

5.12 Scotia n. sp. (Figures 4E-F, K)

*Dimensions (mm):* Female 32425: 0.63 L, 0.32 H.

*Occurrence.* In Raunka Cave (Station 88-005), one female.

**Discussion.** The carapace is thick, transparent, yellowish-white with light yellow sensilla, and the body is yellow with a reddish-brown eye. Unlike previously described species, this specimen is not very hairy; although the external carapace sensilla are numerous, they are short, very thin, and pale yellow in color. The appendage anatomy also is not hirsute, lacking the conspicuous fringes of setules that line many setae and podomeres of the tergalial species of *Scotia* and *Mesocypripis*. For this reason, it is hypothesised that this species has a fully aquatic habit.

The right valve is larger than and overlaps the left. It is much smaller than *S. insularis* Chapman 1963 (transferred to *Mesocypripis* by De Decker 1980). De Decker (1983) warned that Australian species are variable in size. In anatomical characters this species fits the revised diagnosis of Scotia by De Decker (1983). It has more elongate proportions of podomeres and setae than those illustrated for *Scotia insularis* (Chapman 1963), in past ponds of New Zealand; transferred to *Mesocypripis* by De Decker 1980), *S. pseudobronnii* n. Kempf (1971, in past ponds, circulating tufa, and floating fen vegetation of Europe); and *S. andas Chapman* (1981, in forest leaf mold and sphagnum moss of North, South and Stewart Islands, New Zealand; redescribed and reported from Queensland and New South Wales, Australia, by De Decker 1983). Other noteworthy traits include fusion of podomeres 6 and 7 of the antennule, a flexible joint between podomeres 3 and 4 of the seventh limb, and furcae that are not conspicuously asymmetrical.

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