

**TWO NEW SPECIES OF *ORCOVITA* (CRUSTACEA: DECAPODA:
BRACHYURA: VARUNIDAE) FROM ANCHIALINE CAVES ON
CHRISTMAS ISLAND, EASTERN INDIAN OCEAN**

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ABSTRACT. — Two new species of anchialine varunid crabs of the genus *Orcovita* Ng & Tomascik, 1994, *O. orchardorum* and *O. hicksi*, are described from Christmas Island, eastern Indian Ocean. This marks the first record of *Orcovita* from the Indian Ocean. The new species are easily distinguished from congeners by differences in the form of the carapace, chelae, ambulatory legs, and male abdomen. Two groups of *Orcovita* are recognised, and their affinities discussed. A new key is provided for the 10 known species.

KEY WORDS. — Crustacea, Brachyura, *Orcovita*, new species, Christmas Island

INTRODUCTION

Species of the varunid genus *Orcovita* Ng & Tomascik, 1994, are apparently anchialine cave specialists. Thus far, eight species have been described, all from caves in the northwestern Pacific region south to the Loyalty Islands, viz., *O. saltatrix* Ng & Tomascik, 1994 (Indonesia); *O. angulata* Ng, Guinot & Iliffe, 1996 (Philippines); *O. fictilia* Ng, Guinot & Iliffe, 1996 (Philippines); *O. gracilipes* Ng, Guinot & Iliffe, 1996 (Niue); *O. mollitia* Ng, Guinot & Iliffe, 1996 (Guam); *O. mcneiceae* N. K. Ng & Ng, 2002 (Loyalty Islands), *O. miruku* Naruse & Tamura, 2006 (Ryukyus, Japan), and *O. holthuisi* N. K. Ng & Ng, 2009 (Philippines) (Ng et al., 2008).

The present study arose out of collecting trips to explore the decapod crustacean diversity of Christmas Island in Jan.2010 (Xmas Island Expedition 2010) and Mar.2011 (Xmas Island Expedition 2011). One paper on a new arboreal crab (Ng & Davie, 2011) has already been published, and a new land crab is described in this volume (Ng & Davie, 2012). Collapsible bait traps and tubular plastic shrimp and crab traps (of a type commonly used in Taiwan), were laid in the more accessible anchialine caves, in the hope of collecting additional material of the decapod crustaceans previously reported from the island (Humphreys & Eberhard, 2001; Namiotko et al., 2004;

Bruce & Davie, 2006). Although, no anchialine crabs have been previously reported from Christmas Island, our efforts were immediately rewarded with the discovery of two new species of *Orcovita* living sympatrically in the same caves. This represents the first record of this genus from both the Indian Ocean and Australia. The new species are described herein.

Christmas Island is the tip of an isolated seamount rising 4.5 km from the ocean floor in the Wharton Basin of the Indian Plate. It is part of a chain of volcanoes that formed from the mid-Cretaceous starting about 80 Ma. It is the only one to be exposed above sea-level, and was the model for Charles Darwin's concept of oceanic islands. Grimes (2001) reviewed what is known of the geomorphology, geology and genesis of the cave systems on the island. "The basaltic core of Christmas Island is encased in a series of limestones dating from the Eocene to the Recent and eustatic changes have produced a series of marine terraces...near the coast seawater intrudes beneath the freshwater within the karstic limestone...so forming an anchialine collar around the island. The saltwater interface caves are strongly tidal" (Humphreys & Eberhard, 2001: 60).

The term 'anchialine' was first coined by Holthuis (1973: 3) to differentiate 'pools with no surface connection with the sea,

containing salt or brackish water, which fluctuates with the tides'. For a review of the diversity of anchialine cave fauna, its ecology, and its origins see Iliffe & Kornicker (2009).

The present new species were compared with material of known *Orcovita* species as listed in N. K. Ng & Ng (2002, 2009). Measurements provided (in millimetres) are of the carapace width and length, respectively. Measurements of the various leg segments follow Ng et al. (1996) and N. K. Ng & Ng (2002, 2009). The abbreviations M, P, and D refer to the merus, propodus, and dactylus of the ambulatory legs, respectively, while the number preceding it refers to the respective leg; G1 and G2 are used for the male first and second pleopods, respectively. Specimens are deposited in the Queensland Museum, Brisbane (QM); Western Australian Museum, Perth (WAM); and the Zoological Reference Collection, Raffles Museum of Biodiversity Research, National University of Singapore, Singapore (ZRC).

In a local Christmas Island newsletter, Anonymous (2011) reported that the authors, together with their team, had discovered the two new species of *Orcovita* and gave their proposed scientific names, *Orcovita hicksi* and *Orcovita orchardorum*, as well as a photograph of the latter taxon. While this publication gave Latin names and etymologies, it does not provide any diagnosis, description, or indication of how many specimens there were or their depositories. As such, both names are nomina nuda.

TAXONOMY

Family VARUNIDAE H. Milne Edwards, 1853
Subfamily VARUNINAE H. Milne Edwards, 1853

Orcovita Ng & Tomascik, 1994

Orcovita orchardorum, new species

(Figs. 1, 4, 5, 6A, 6B, 9A, 9B, 10A, 11A–D, 12)

Material examined. — Holotype: male (21.0 × 16.7 mm) (QM-W29114), station CI-14, Whip Cave, Waterfall Road, 10°25.377'S, 105°42.081'E, coll. Xmas Island Expedition 2010, 27 Jan.2010. Paratypes: 1 male (15.5 × 12.5 mm), 1 female (18.9 × 15.2 mm) (QM-W29115), same data as holotype — 3 males (23.2 × 18.7 mm, 20.4 × 16.7 mm, 14.2 × 11.9 mm), 3 females (largest 19.9 × 16.3 mm, 19.9 × 16.1 mm, 16.7 × 13.5 mm) (ZRC 2012.0062), station CI-14, Whip Cave, Waterfall Road, 10°25.377'S, 105°42.081'E, coll. Xmas Island Expedition 2010, 27 Jan.2010 — 2 males, 1 female (ZRC 2012.0063), station CI-17, Runaway Cave, Waterfall Road, 10°25.386'S, 105°42.063'E, coll. Xmas Island Expedition 2010, 28 Jan.2010 — 1 male (16.0 × 13.4 mm), 1 ovigerous female (17.3 × 14.3 mm) (ZRC 2012.0064), station CI-18, Whip Cave, Waterfall Road, 10°25.377'S, 105°42.081'E, coll. Xmas Island Expedition 2010, 28 Jan.2010 — 1 male (15.4 × 12.9 mm) (ZRC 2011.0065), station CI-26, Whip Cave, Waterfall Road, 10°25.377'S, 105°42.081'E, coll. Xmas Island Expedition 2011, 25 Mar.2011 — 1 male (17.3 × 14.4 mm) (QM-W29116), station CI-29, Whip Cave, Waterfall Road, 10°25.377'S, 105°42.081'E, coll. Xmas Island Expedition 2011, 26 Mar.2011 — 1 male (QM-W29214), station CI-30, Freshwater Cave, near The Blowholes, 10.51325°S, 105.62421°E, coll. Xmas Island Expedition 2010, 02 Feb.2010 — 1 male (17.6 × 14.4 mm) (QM-W29215), station CI-31, Whip

Cave, Waterfall Road, 10°25.377'S, 105°42.081'E, coll. Xmas Island Expedition 2011, 27 Mar.2011. All localities in Christmas Island.

Description. — Carapace subrectangular (Figs. 1, 4, 5A), distinctly broader than long (width to length ratio ca. 1.25), dorsal surface mostly smooth, glabrous, finely punctate, but becoming finely granular anteriorly and anterolaterally, especially in females; regions poorly defined except for deep H-shaped gastro-cardiac groove and pair of strong medial postfrontal lobes; cervical grooves indistinct, shallow, broad; epigastric cristae low, indistinct; low ridge present adjacent to junction between posterolateral margin and posterior carapace margin. Anterolateral margin edged with low, indistinct, rounded granules; not clearly demarcated from posterolateral margin; exorbital angle very broad; with 2 epibranchial teeth, first tooth prominent, rounded, separated from exorbital angle by V-shaped cleft, second tooth smaller and lower; posterolateral margins straight or weakly concave, clearly converging posteriorly; posterior carapace margin straight; supraorbital margin granulate, medially moderately convex, inner margins convergent towards frontal margin; frontal margin (Fig. 5A) sinuous, with broad shallow medial

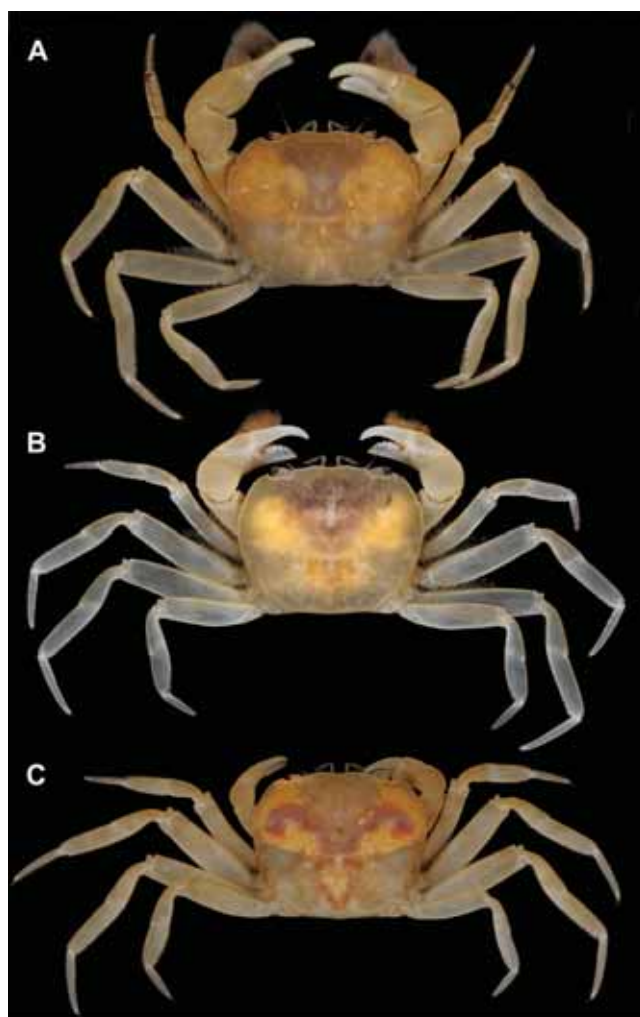


Fig. 1. *Orcovita orchardorum*, new species. Colours in life, overall dorsal views. A, paratype male (23.2 × 18.7 mm) (ZRC 2012.0062), station CI-14, 2010; B, paratype male (15.4 × 12.9 mm) (ZRC 2011.0065), station CI-26, 2011; C, paratype female (19.9 × 16.3 mm) (ZRC 2012.0062), station CI-14, 2010.

sinus, low transverse ridge of granules just behind true frontal margin defining a deflexed narrow anterior median strip (Fig. 5B); infraorbital margins incomplete, median lobe low, convex, coarsely granulate, separated from exorbital tooth by deep sinus; distinct row of rounded granules below infraorbital margin on suborbital region, extending to subbranchial region (Fig. 5B). Antennal segments entering orbital hiatus. Antennules broad; interantennular septum broad. Eyes well-developed, cornea pigmented. Epistome (Fig. 5B) relatively narrow, posterior margin with 2 lateral clefts, median part broadly triangular, margin coarsely granulate. Third maxilliped (Fig. 5B) with broad, stout exopod, exopod 0.9 times as narrow as ischium, flagellum well developed; ischium stout (length to width ratio ca. 2.0, measured along outer edge), smooth, outer margin minutely granulate; merus broad (length to width ratio ca. 1.4), antero-external margin minutely granular, markedly auriculiform.

Chelipeds relatively long, surface of segments smooth. Male chelae swollen, subequal; fingers as long as palm; base of fingers and adjacent areas with long, dense setae (Fig. 6A, B), longer on smaller adult males, without distinct pulvinus. Merus trihedral, external and posterior margins with low granules, inner anterior margin armed with row of 8–10 large rounded granules. Carpus rounded, smooth, inner distal angle with low, obtuse tooth. Female chelae similar to those of male but smaller, non-setose.

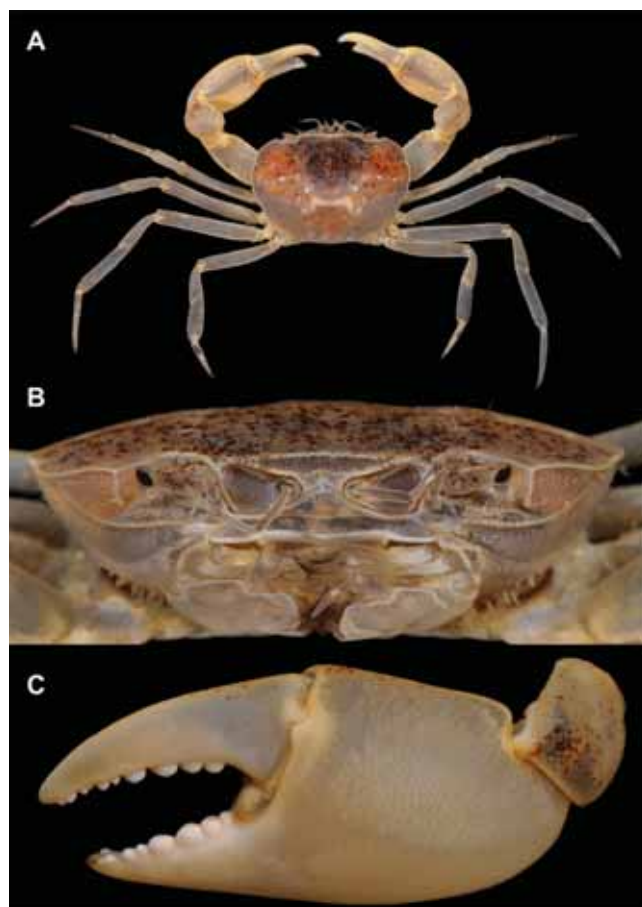


Fig. 2. *Orcovita hicksi*, new species. Colours in life, paratype male (23.5 × 17.3 mm) (ZRC 2012.0076), station CI-14, 2011. A, overall dorsal view; B, frontal view of carapace; C, outer view of left chela.

Ambulatory legs somewhat dorsoventrally flattened, all segments long, slender; second ambulatory leg slightly longer than third; surface smooth. Meri each with long patch of fine setae over upper third adjacent to carapace, relatively sparse on last leg; anterior margin of merus with blunt subdistal lobe. Outer surface of carpus smooth, lacking setae; anterior and posterior margins of propodus with small clumps of long and short setae, respectively; dactylus tapering to slender, acute tip. Dactyli rectangular in cross section, upper and lower margins fringed with dense short setae; 3M long, slender (length to width ratio 4.0), 3P long, slender (length to width ratio 3.8), 3D very long, slender (length to width ratio 7.5); 4M long, slender (length to width ratio 3.7), 4P long (length to width ratio 2.6), 4D long, slender (length to width ratio 5.5).

Male abdomen narrowly triangular (Fig. 9A); lateral margins edged with very short, dense setae interspersed with several long, stiff setae; first abdominal somite widest, slightly wider than third, weakly arched, with transverse ridge; second abdominal somite reduced to short strip, slightly narrower

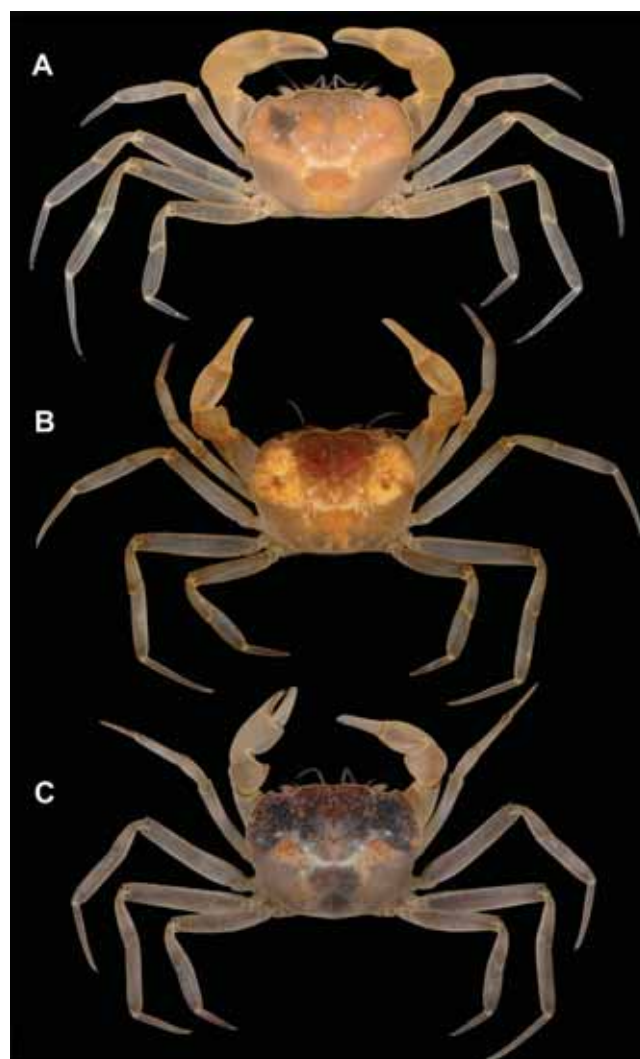


Fig. 3. *Orcovita hicksi*, new species. Colours in life, overall dorsal views. A, paratype male (15.9 × 12.2 mm) (ZRC 2012.0080), station CI-12, 2011; B, paratype male (14.4 × 11.3 mm) (ZRC 2012.0073), station CI-14, 2010; C, paratype female (20.8 × 15.9 mm) (ZRC 2012.0073), station CI-14, 2010.

than third; third abdominal somite broad, weakly convex laterally; fourth abdominal somite broader but shorter than fifth abdominal somite; fifth abdominal somite with proximal and distal margins moderately sinuous, lateral margins convergent; sixth abdominal somite rectangular 1.9 times wider than long, lateral margins weakly convex distally, proximal margin straight; telson slightly longer than wide (ca. 1.1 times), lateral margins subparallel, broadly rounded distally. Female abdomen very broad, covering most of thoracic sternum (Fig. 9B).

Male thoracic sternum (Fig. 9A) generally smooth, punctate; lateral margins of first 2 thoracic sternites armed with large smooth granules; triangular part of sternites 1 and 2 with patch of long dark setae inside medial excavation; suture between sternites 2 and 3 slightly convex antero-medially; lateral margins of sternites 3 and 4 sinuous, with deep, broad notch and granulate lobe, indicating edge of fused suture; deep narrow median longitudinal groove between sternites 7 and 8. Female thoracic sternum similar in form but relatively

broader. G1 (Fig. 11A–C) slender, weakly curving outwards, reaching to or slightly beyond anterior margin of sternite 5; terminal lobe elongate; genital opening lateral to base of apical corneous section; subterminal lobe pectinated, elongate, densely setose. G2 short, small (Fig. 11D). Vulva raised, convex, oval.

Colour. — In life, the colour was an orangish-yellow to pale yellowish-white, with branchial regions paler; setae on the chela were dark brown (Fig. 1).

Etymology. — Named for Max and Beverley Orchard. As Head Ranger on Christmas Island for 18 years, and continuing on as Project Officer, Max, with the wonderful support of his wife Bev, have worked tirelessly for the conservation of the biota of Christmas Island. In particular Max, has spearheaded the control of the Yellow Crazy Ant (*Anoplolepis gracilipes*), which has had a devastating effect on the crab populations of the island. Without people who care, like Max and Bev, the world would be a much poorer place!

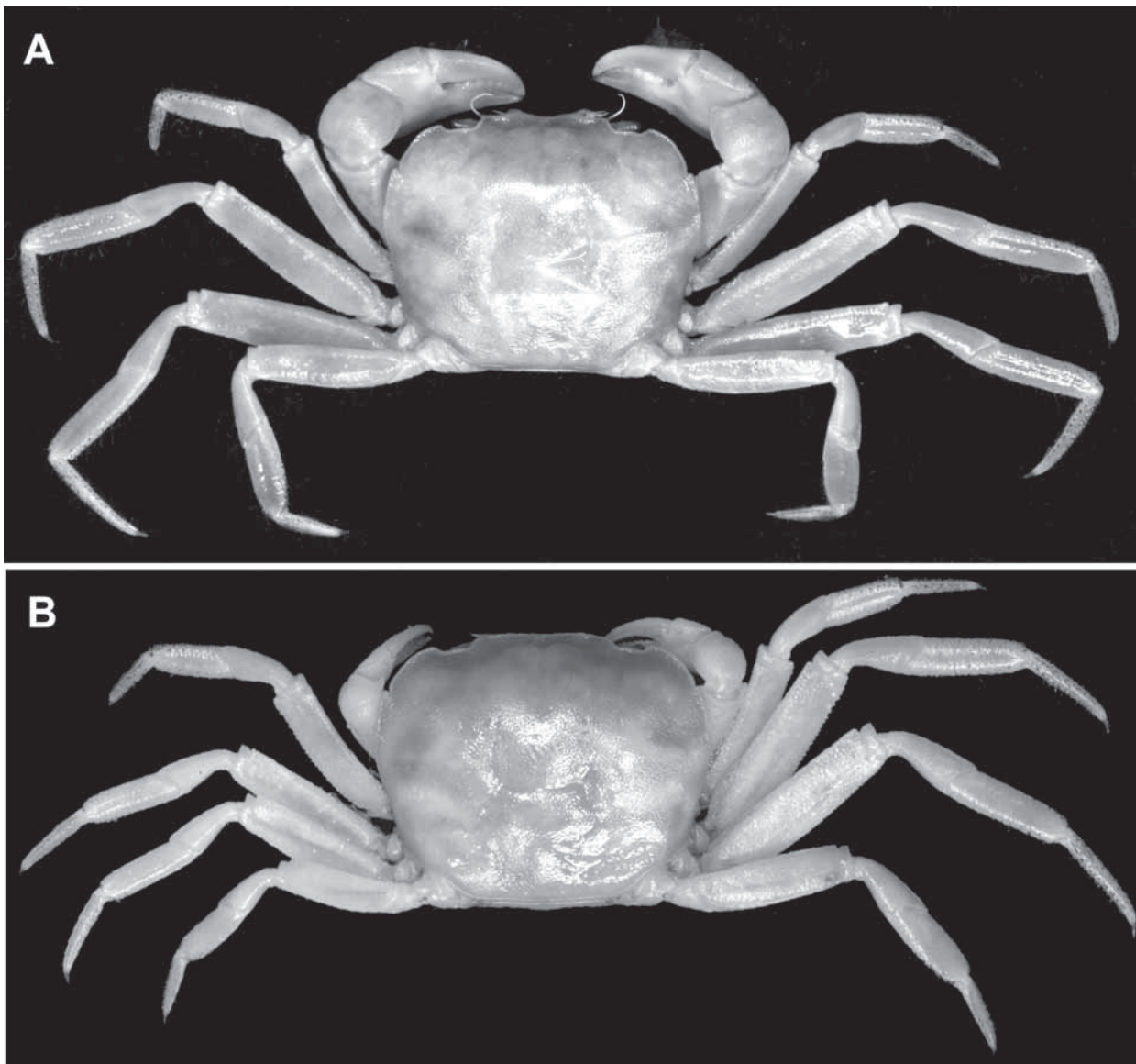


Fig. 4. *Orcovita orchardorum*, new species, dorsal view. A, holotype male (21.0 × 16.7 mm) (QM-W29114); B, paratype female (18.9 × 15.2 mm) (QM-W29115).

Remarks. — *Orcovita orchardorum*, new species, most resembles *O. holthuisi* from Coron Island, the Philippines, and *O. miruku* from the Ryukyus, Japan.

In *O. holthuisi*, the anterolateral teeth are both acute (cf. N. K. Ng & Ng, 2009: Figs. 1, 3A), whereas in *O. orchardorum*, new species, the second tooth is more in the form of a broad lobe without a deep notch (Figs. 1, 4, 5A); the sixth male abdominal somite about 2.3 times wider than long (cf. N. K. Ng & Ng, 2009: Fig. 3K) versus 1.9 times in *O. orchardorum*, new species (Fig. 9A); and the male telson 1.5 times the length of the sixth abdominal somite (cf. N. K. Ng & Ng, 2009: Fig. 3K) versus ca. 1.1 times in *O. orchardorum*, new species (Figs. 9A). Their leg proportions (P4 & P5) also differ, as summarised in Table 2.

In *O. miruku*, the anterolateral teeth are similarly broadly rounded but both are clearly defined and similar in prominence (cf. Naruse & Tamura, 2006: Figs. 1, 2a), whereas in *O. orchardorum*, new species, the first anterolateral tooth is deeply notched and prominently projecting, while the second is smaller and less strongly defined by a deep notch (Figs. 1, 4, 5A). Also in *O. miruku*, the male telson is slightly longer, 1.2 times length of sixth abdominal somite (cf. Naruse & Tamura, 2006: Fig. 2g) versus 1.1 times in *O. orchardorum*, new species (Fig. 9A).

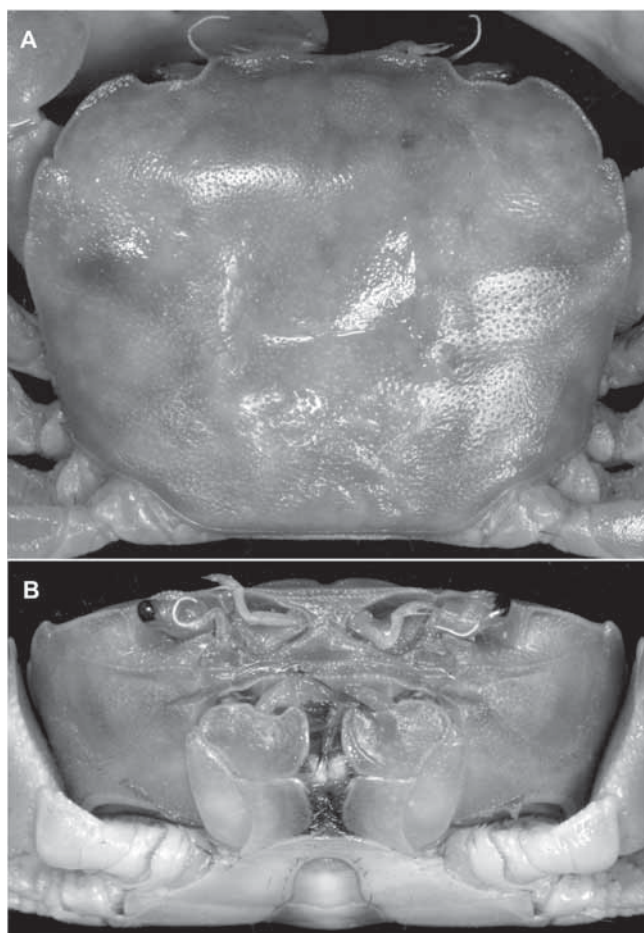


Fig. 5. *Orcovita orchardorum*, new species, holotype male (21.0 × 16.7 mm) (QM-W29114). A, carapace; B, frontal view.

Orcovita orchardorum, new species, can also be easily separated from its fellow islander, *O. hicksi*, new species, by having two epibranchial teeth instead of only one (Figs. 1, 4, 5A versus Figs. 2A, 3, 7, 8A); relatively prominent post-frontal lobes compared with post-frontal lobes obsolete (Figs. 1, 4, 5A versus Figs. 2A, 3, 7, 8A); relatively shorter, stockier legs versus longer more slender legs (Figs. 1, 4 versus Figs. 2A, 3, 7); and a distinct thick patch of long setae at the base of the gape of the male chela that extends onto the fingers, a feature that is lacking in *O. hicksi*, new species (Fig. 6A, 6B versus Figs. 2C, 6C, 6D). In addition, the deflexed portion of the front above the interantennular septum is a narrow strip in *O. orchardorum*, new species, but is relatively wider in *O. hicksi*, new species (Fig. 5B versus Figs. 2B, 8B). Finally, the sixth abdominal somite is proportionately narrower in *O. orchardorum*, new species (1.9 times wider than long versus 2.2 times) (Fig. 9A versus Fig. 9C).

Habitat. — *Orcovita orchardorum*, new species, and *O. hicksi*, new species, are relatively abundant in Whip and Runaway Caves that are about 50 m apart from each other above ground and almost certainly have a subterranean connection. Both caves are tidally and freshwater influenced brackish anchialine habitats. *Orcovita hicksi*, new species, has also been collected 19th Hole Cave, which is only a few kilometres away. Both species were found from Freshwater Cave, near The Blowholes a site much further south. As these animals clearly have a marine dispersal phase, this is not surprising. We only managed to collect one ovigerous female (17.3 × 14.3 mm, ZRC) from Whip Cave but we could not get the eggs to hatch. The eggs are small and numerous, and typical of varunids.

Both new species of *Orcovita* were collected with other decapods including the alpheid shrimp *Metabetaeus minutus* (Whitelegge, 1897) (see Anker, 2010), a possible new species of hippolytid shrimp, *Parahippolyte* sp., a new species of *Macrobrachium* (Palaemonidae), and an atyid shrimp *Antecaridina* (?) *lauensis* (Edmondson, 1935).

Besides these, numerous other aquatic species have already been previously reported within the same wider cave systems including: an unidentified Scyllidae sp. (Polychaeta); *Nerilla* sp. (Archiannelida: Nerillidae); *Microceratina martensi* (Ostracoda: Cytheruridae); *Danielopolina baltanasi* (Thaumatoctyprididae: Halocyprida) (Humphreys & Danielopol, 2006; Humphreys et al., 2009); *Nitocrella/Nitokra* complex (Harpacticoida: Ameiridae); *Bryocyclops muscicola* (Menzel)(Cyclopoida: Cyclopinidae); a new copepod genus (Calanoida: Arietellidae); *Leucothoe* sp. (Amphipoda: Leucothoidae); *Macrobrachium lar* (Fabricius)(Decapoda: Palaemonidae); Gobioidea indet. (Pisces: Perciformes); unidentified Eleotridae (Pisces: Perciformes) (see Humphreys & Eberhard, 2001; Namiotko et al., 2004); *Eleotris* (?) *fusca* (Eleotridae) (Humphreys & Eberhard, 2001; Namiotko et al., 2004). Three species of eels (*Anguilla bicolor*, Anguillidae), *Echidna* sp. (Muraenidae), and an unidentified muraenesocid were also present in Whip and Runaway Caves (H. H. Tan, pers. comm.).

Table 1. Physical and chemical parameters of groundwaters from Runaway Cave and from an adjacent cave in the same anchialine system where the new *Orcovita* species were found. Measurements were taken on 5–6 Apr.1998. Data reproduced from Namiotko et al. (2004).

Cave		Dissolved oxygen		Conductivity (mS cm ⁻¹)	Temperature (°C)	pH
		(mg dm ⁻³)	%			
Runaway Cave (CI-2)	surface	7.06	97.7	5.5	26.9	7.99
	2 m depth	6.67	96.6	8.1	26.5	7.50
The 19 th Hole (CI-19)	surface	6.60	94.0	31.2	27.0	7.60
	2 m depth	5.05	73.0	34.4	27.4	7.35

In general, according to Humphreys & Eberhard (2001), the cave waters are all well oxygenated (dissolved oxygen >73% saturated) and the pH (7.65±0.41, N =13), with the marine caves having salinities ranging from 0.39–16.5 g L⁻¹ TDS (sea water c. 36 g L⁻¹ TDS). Specific physico-chemical measurements for Runaway Cave, and the nearby 19th Hole Cave, are presented in Table 1. Runaway Cave is brackish with salinities ranging from about 9–18 ppt. No measurements deeper than 2 m were taken so it is not known if deeper waters become suboxic as reported for many other anchialine systems (see Sket, 1996; Humphreys, 1999; Iliffe, 2000).

***Orcovita hicksi*, new species**

(Figs. 2, 3, 6C, 6D, 7, 8, 9C–E, 10B, 11E–I, 12)

Material examined. — Holotype: male (17.4 × 13.2 mm) (WAM-C49450), field no. BES14437, Whip Cave, Waterfall Road, Christmas Island, 10°25'22.0"S, 105°42'04.4"E, coll. R Anderson, 8 May 2006 — Paratypes: 1 female (14.2 × 10.8 mm) (WAM-C49451), same data as holotype — 1 immature female (15.2 × 11.9 mm) (QM-W29117), station CI-14, Whip Cave, Waterfall Road, 10°25.377'S,

105°42.081'E, Xmas Island Expedition 2010 — 1 male (14.4 × 11.3 mm), 2 females (larger 20.8 × 15.9 mm) (ZRC 2012.0073), station CI-14, Whip Cave, Waterfall Road, 10°25.377'S, 105°42.081'E, coll. Xmas Island Expedition 2010, 27 Jan.2010 — 1 male, 1 female (QM-W29118), station CI-15, Runaway Cave, Waterfall Road, 10°25.386'S, 105°42.063'E, coll. Xmas Island Expedition 2010, 27 Jan.2011 — 2 females (QM-W29119), station CI-17, Runaway Cave, Waterfall Road, 10°25.386'S, 105°42.063'E, coll. Xmas Island Expedition 2010, 28 Jan.2010 — 1 male (ZRC 2012.0074), station CI-18, Whip Cave, Waterfall Road, 10°25.377'S, 105°42.081'E, coll. Xmas Island Expedition 2010, 28 Jan.2010 — 1 male (16.4 × 13.8 mm) (ZRC 2012.0075), station CI-30, Whip Cave, Waterfall Road, 10°25.377'S, 105°42.081'E, coll. Xmas Island Expedition 2010, 02 Feb.2010 — 1 male (23.5 × 17.3 mm) (ZRC 2012.0076), station CI-10, Freshwater Cave, near The Blowholes, 10.51325°S, 105.62421°E, coll. Xmas Island Expedition 2011, 22 Mar.2011 — 3 females (ZRC 2011.0077), station CI-10, Freshwater Cave, near The Blowholes, 10.51325°S, 105.62421°E, coll. Xmas Island Expedition 2011, 22 Mar.2011 — 2 females (ZRC 2011.0079), station CI-12, 19th Hole Cave, next to Christmas Island Golf Course, 10.42488°S, 105.70123°E, 19th Hole, near Golf Course, coll. Xmas Island Expedition 2011, 22 Mar.2011 — 1 male (15.9 × 12.2 mm) (ZRC 2012.0080), station CI-12, 19th Hole Cave, next to Christmas Island Golf Course, 10.42488°S, 105.70123°E, coll. Xmas Island

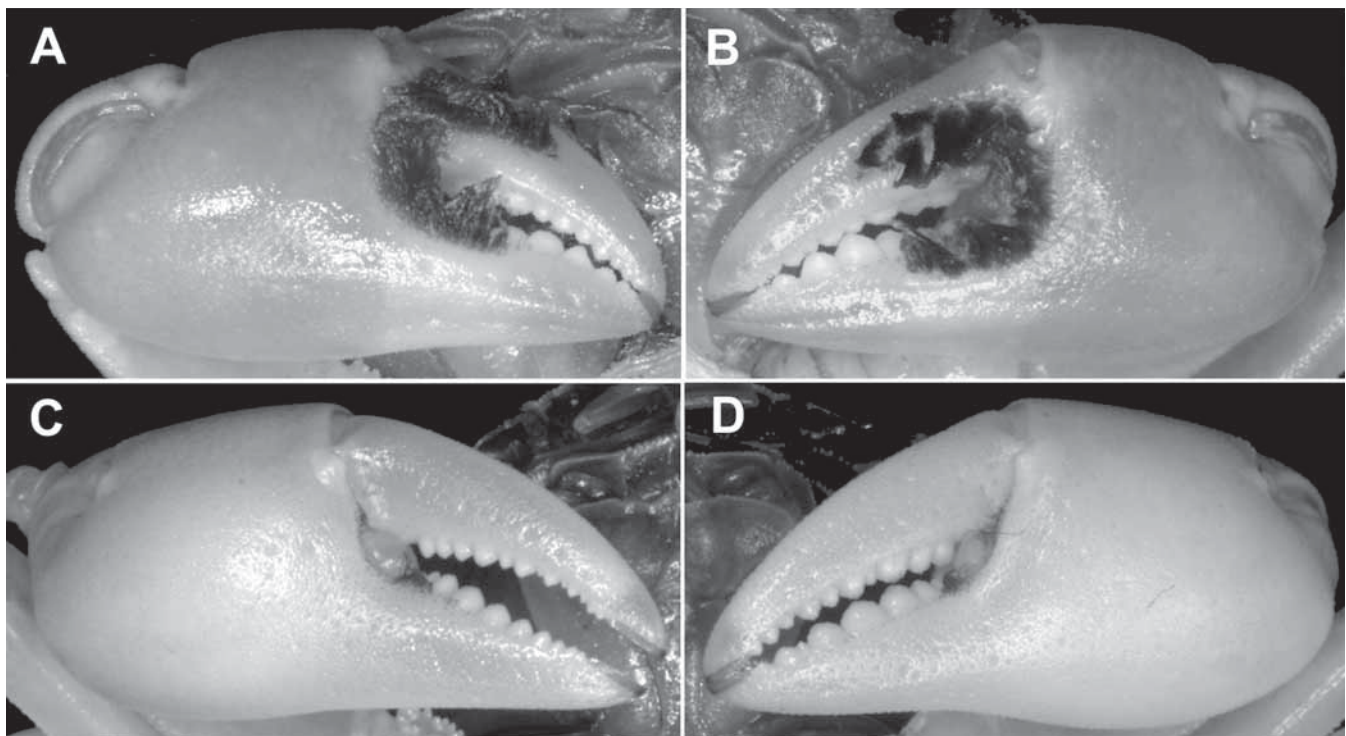


Fig. 6. Male left and right chelae. A, B, *Orcovita orchardorum*, new species, holotype male (21.0 × 16.7 mm) (QM-W29114). C, D, *Orcovita hicksi*, new species, holotype male (17.4 × 13.2 mm) (WAM-C49450).

Expedition 2011, 22 Mar.2011 — 5 males (largest 21.2 × 15.9 mm) (ZRC 2012.0066), station CI-14, Freshwater Cave, near The Blowholes, 10.51325°S, 105.62421°E, coll. Xmas Island Expedition 2011, 23 Mar.2011 — 4 males (largest 19.7 × 15.3 mm), 1 female (18.3 × 14.3 mm) (QM-W29218), station CI-19, Runaway Cave, Waterfall Road, 10°25.386'S, 105°42.063'E, coll. Xmas Island Expedition 2011, 24 Mar.2011 — 1 male, 1 female (QM-W29225), station CI-35, Freshwater Cave, near The Blowholes, 10.51325°S, 105.62421°E, coll. Xmas Island Expedition 2011, 28 Mar.2011 — 1 male (16.3 × 12.5 mm), 1 female (19.9 × 14.8 mm) (WAM-C49452), field no. BES11648, Whip Cave, 10°25.377'S, 105°42.081'E, coll. R. D. Brooks, 19 Jun.2004 — 1 male (15.0 × 11.4 mm) (WAM-C49453), field no. BES14439, 19th Hole Cave, next to Christmas Is. Golf Course, 10°25'30.0"S, 105°42'04.2"E, coll. R Anderson, 19 May 2006. All localities in Christmas Island.

Description. — Carapace subrectangular to subovate (Figs. 2A, 3, 7, 8A), distinctly broader than long (width to length ratio ca. 1.25), dorsal surface mostly smooth, glabrous, finely punctate, but becoming finely granular anteriorly and anterolaterally, especially in females; regions mostly poorly defined, gastro-cardiac groove deeply grooved laterally; postfrontal lobes obsolete; cervical grooves indistinct, shallow, broad; epigastric cristae low, indistinct; short, low ridge present adjacent to junction between posterolateral margin and posterior carapace margin. Anterolateral margin lined with distinct, rounded granules; not clearly demarcated from posterolateral margin; exorbital angle very broad, separated from single epibranchial tooth by rounded sulcus; posterolateral margins straight or weakly concave, clearly converging posteriorly; posterior carapace margin straight;

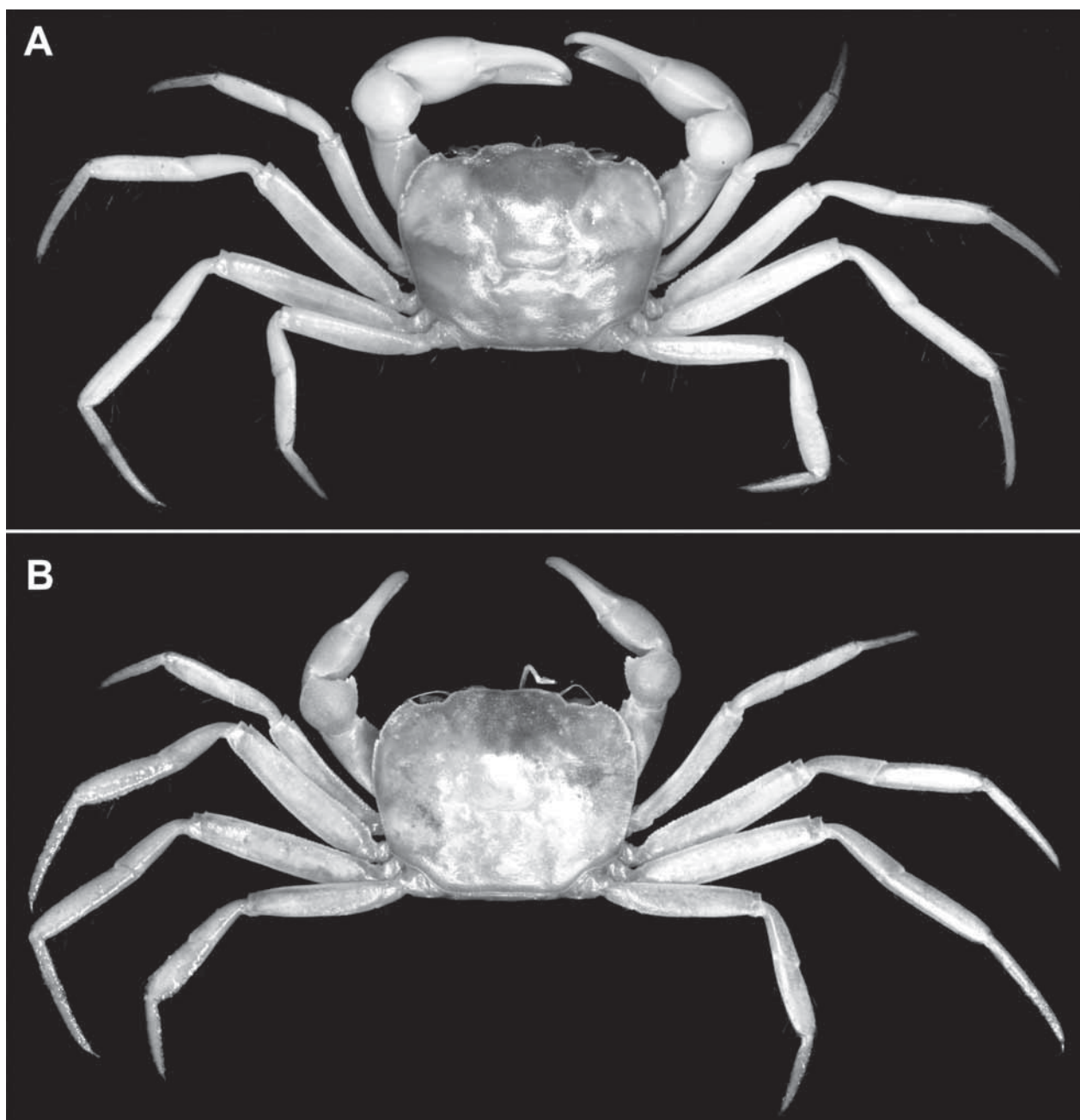


Fig. 7. *Orcovita hicksi*, new species, dorsal view. A, holotype male (17.4 × 13.2 mm) (WAM-C49450); B, paratype female (15.2 × 11.9 mm) (QM-W29117).

supraorbital margin granulate, medially moderately convex, inner margins obliquely convergent towards frontal margin; frontal margin dorsally (Fig. 8A, B) appearing broadly concave, defined by transverse ridge of granules; true frontal margin almost vertically deflexed, sinuous, concave medially, separated from dorsal granular ridge by relatively wide strip tapering laterally; infraorbital margins incomplete, median lobe low, convex, coarsely granulate, separated from exorbital tooth by deep sinus; strong row of rounded granules below infraorbital margin on suborbital region, extending to sub-branchial region (Fig. 8B). Antennal segments entering orbital hiatus. Antennules broad; interantennular septum broad. Eyes well-developed, cornea pigmented. Epistome (Figs. 8B, 10B) relatively narrow, posterior margin with 2 lateral clefts, median part broadly triangular, margin finely granular. Third maxilliped (Figs. 8B, 10B) with broad, stout exopod, exopod 0.9 times width of ischium, flagellum well developed; ischium stout (length to width ratio ca. 1.9, measured along outer edge), surface smooth, bearing scattered very short setae, outer margin minutely granulate; merus broad (length to width ratio ca. 1.4), antero-external margin minutely granular, markedly auriculiform.

Chelipeds relatively long, surface of segments smooth. Male chelae swollen, subequal; surface very finely granular; fingers as long as palm; with a small but distinct pulvinus at base of fingers, some very short setae around pulvinus but otherwise naked (Fig. 6C, D). Merus sharply trihedral, upper inner margin finely granulate, ventral margins more coarsely granular. Carpus rounded, smooth, inner distal angle finely dentate. Female chelae similar to those of male but smaller.

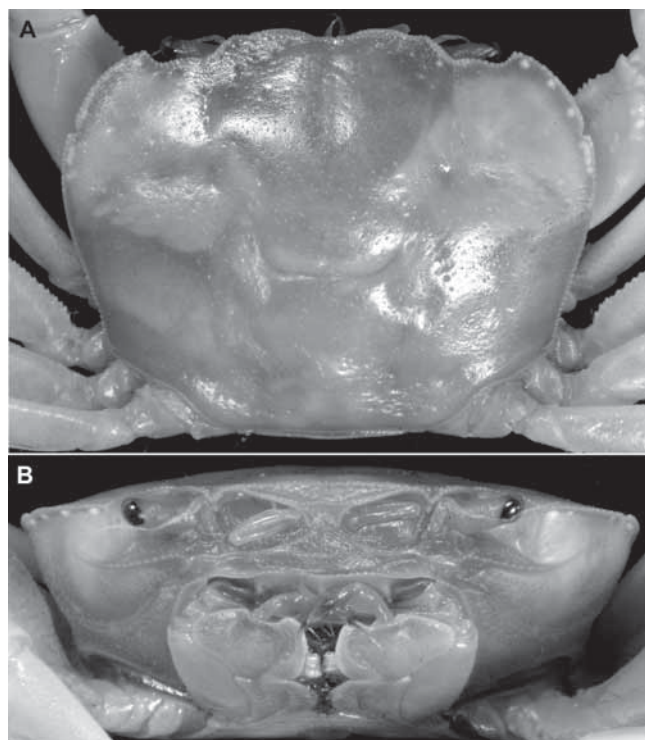


Fig. 8. *Orcovita hicksi*, new species, holotype male (17.4 × 13.2 mm) (WAM-C49450). A, carapace; B, frontal view.

Ambulatory legs somewhat dorsoventrally flattened, all segments long, slender; second and third ambulatory legs equal longest; upper and lower surfaces mostly smooth. Meri with upper and lower borders finely serrated; proximal upper surface granular; anterior margin of merus with blunt subdistal lobe. Outer surface of carpus smooth, lacking setae; anterior and posterior margins of propodus with small clumps of long and short setae, respectively; dactylus tapering to slender, acute tip. Dactyli rectangular in cross section, upper and lower margins fringed with dense short setae; 3M long, slender (length to width ratio 5.6), 3P long, slender (length to width ratio 4.8), 3D very long, slender (length to width ratio 11.0); 4M long, slender (length to width ratio 4.5), 4P long (length to width ratio 2.4), 4D long, slender (length to width ratio 6.4).

Male abdomen narrowly triangular (Fig. 9C); lateral margins edged with very short, dense setae interspersed with several long, stiff setae; first abdominal somite widest, slightly wider than third, weakly arched, with transverse ridge; second abdominal somite reduced to short strip, slightly narrower than third; third abdominal somite broad, weakly convex laterally; fourth abdominal somite broader but shorter than fifth abdominal somite; fifth abdominal somite with proximal and distal margins straight, lateral margins convergent; sixth abdominal somite rectangular 2.2 times wider than long, lateral margins weakly convex distally, proximal margin straight; telson about as long as wide, lateral margins subparallel, broadly rounded distally. Female abdomen very broad, covering most of thoracic sternum (Fig. 9D).

Male thoracic sternum (Fig. 9C) generally smooth, punctate; lateral margins of first 2 thoracic sternites armed with large smooth granules; triangular part of sternites 1 and 2 with patch of long dark setae inside medial excavation; suture between sternites 2 and 3 relatively straight; lateral margins of sternites 3 and 4 sinuous, with deep, broad notch and granulate lobe, indicating edge of fused suture; deep narrow median longitudinal groove between sternites 7 and 8. Female thoracic sternum similar in form but relatively broader. G1 (Fig. 11E–H) slender, weakly curving outwards, reaching to anterior margin of sternite 5; terminal lobe elongate; genital opening lateral to base of terminal lobe; subterminal lobe pectinated, elongate, densely setose. G2 short, small (Fig. 11I). Vulva raised, convex, oval (Fig. 9E).

Colour. — Smaller specimens (up to ca. 16 mm in carapace width) tend to be yellowish-white to orange (Fig. 3A, B). When they exceed this size, both males and females become more whitish, and the anterior half of the carapace is covered with scattered brown spots and blotches (Figs. 2A, 2B, 3C). The chela also becomes almost white (Fig. 2C).

Etymology. — Named for John Hicks who was the Australian Government Conservator on Christmas Island from 1979 to 1983. His book “Christmas Crabs”, written with the late Holger Rumpff and Hugh Yorkston, did much to publicise this unique crab fauna to the eyes of the world, and could only have been written by one who was as thoroughly entranced by the Christmas Crabs, as we are ourselves.

Remarks. — *Orcovita hicksi*, new species, can easily be separated from *O. orchardorum*, new species, and its close allies *O. miruku* and *O. holthuisi*, by its single epibranchial tooth (vs. two epibranchial teeth present in the latter species) and the absence of a tuft of setae at the base of cheliped fingers in males (vs. present in the latter three species) (see Remarks

for *O. orchardorum*, new species). It can be separated from its closest long-legged relatives (see discussion of Groups I and II later) by the new key presented here.

Habitat. — See comments for *Orcovita orchardorum*, new species.

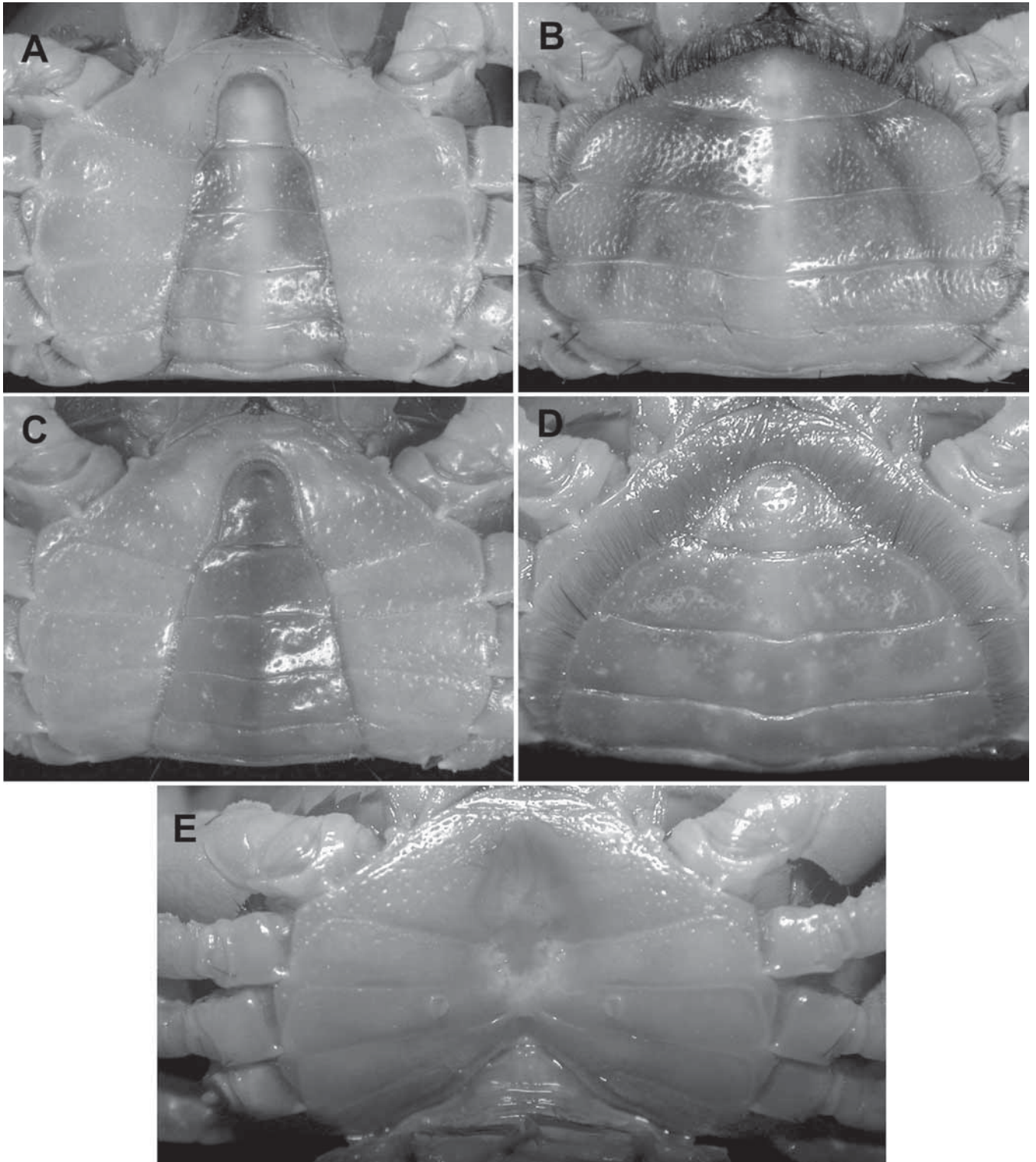


Fig. 9. Sternal view showing male and female abdomens. *Orcovita orchardorum*, new species: A, holotype male (21.0 × 16.7 mm) (QM-W29114); B, paratype female (18.9 × 15.2 mm) (QM-W29115). *Orcovita hicksi*, new species: C, holotype male (17.4 × 13.2 mm) (WAM-C49450); D, E, paratype female (20.8 × 15.9 mm) (ZRC 2012.0073), station CI-14, 2010.

GENERAL DISCUSSION

Orcovita Ng & Tomascik, 1994, has been described and discussed in detail by Ng & Tomascik (1994), Ng et al. (1996), N. K. Ng & Ng (2002, 2009), and Naruse & Tamura (2006). As previously discussed, the genus currently has 10 species.

The two new species described here are likely to be indigenous to Christmas Island, as this narrow range endemism seems to be the pattern for each of the other *Orcovita* species. All species can be separated from each other using the new key provided.

KEY TO THE GENUS ORCOVITA

- 1. Carapace appearing distinctly rectangular; posterolateral margins almost straight, subparallel, not distinctly convergent towards posterior carapace margin 2
- Carapace appearing more hexagonal; posterolateral margins concave, distinctly convergent towards posterior carapace margin 3

- 2. Junction between antero- and posterolateral margins rounded; posterolateral margin smooth; lengths of 3P and 4P propodus 4.3 and 3.1 times width, respectively, lengths of 3D and 4D 7.8 and 5.5 times width, respectively (Kakaban: Indonesia) .. *O. saltatrix*
- Junction between antero- and posterolateral margins angular; posterolateral margin granulated; lengths of 3P and 4P 5.4 and 3.7 times width, respectively, lengths of 3D and 4D 16.1 and 6.6 times width, respectively (Coron: Philippines) *O. angulata*
- 3. Male chela with thick patch of setae at base of gape; exorbital tooth always clearly separated from rest of anterolateral margin by deep, distinct cleft, margin never entire 4
- Male chela without an obvious thick patch of setae at base of gape (at most some sparse short setae along edge; exorbital tooth separated from rest of anterolateral margin by small cleft, sometimes absent, with margin appearing almost entire 8
- 4. Anterolateral margins with 2 teeth behind exorbital angle (second may be reduced to only a broad lobe) 5
- Anterolateral margins with only a single distinct tooth behind exorbital angle (Loyalty Islands) *O. mcneiceae*
- 5. Carapace relatively broad (ca. 1.4 times wider than long); ambulatory legs relatively longer, more slender (4M ca. 5.7 times longer than wide) (Niue) *O. gracilipes*
- Carapace narrower (ca. 1.2 times wider than long); ambulatory legs relatively shorter (4M \leq 4.3 times longer than wide) 6
- 6. Anterolateral teeth both acute; ambulatory legs relatively short, stout (4M 3.9 times longer than wide); sixth male abdominal somite about 2.3 times wider than long; male telson 1.5 times length of sixth abdominal somite *O. holthuisi*
- Anterolateral teeth broadly rounded; ambulatory leg proportions not as above; sixth male abdominal somite about twice as wide as long; male telson 1.1-1.2 times length of sixth abdominal somite 7
- 7. Anterolateral teeth both clearly defined, similar in prominence (Ryukyus: Japan) *O. miruku*
- First anterolateral teeth deeply notched, prominently projecting, second tooth in form of broad lobe, not defined by distinct notch (Christmas Is.) *O. orchardorum*, new species
- 8. Ambulatory legs relatively long, slender, length of 3P about 5 times width or more 9
- Ambulatory legs relatively shorter, length of 3P 4.2 times width, lengths of 3D and 4D 9.1 and 6.2-6.9 times width, respectively (Panglao: Philippines) *O. fictilia*
- 9. Supraorbital margin relatively straight, without distinct lateral concavity such that exorbital tooth low, not appearing markedly produced; anterolateral tooth of carapace marked by only indistinct notch, or obsolete; length of 3P 5.2 times width, lengths of 3D and 4D 12.9 and 7.6 times width, respectively; small species (< 15 mm c.b.) (Guam) *O. mollitia*
- Supraorbital margin sinuous, markedly concave laterally such that exorbital tooth appears more prominently produced; single anterolateral tooth of carapace marked by strong V-shaped notch; length of 3P 4.8 times width, lengths of 3D and 4D 11.0 and 6.4 times width, respectively; larger species (>15 mm c.b.) (Christmas Is.) *O. hicksi*, new species

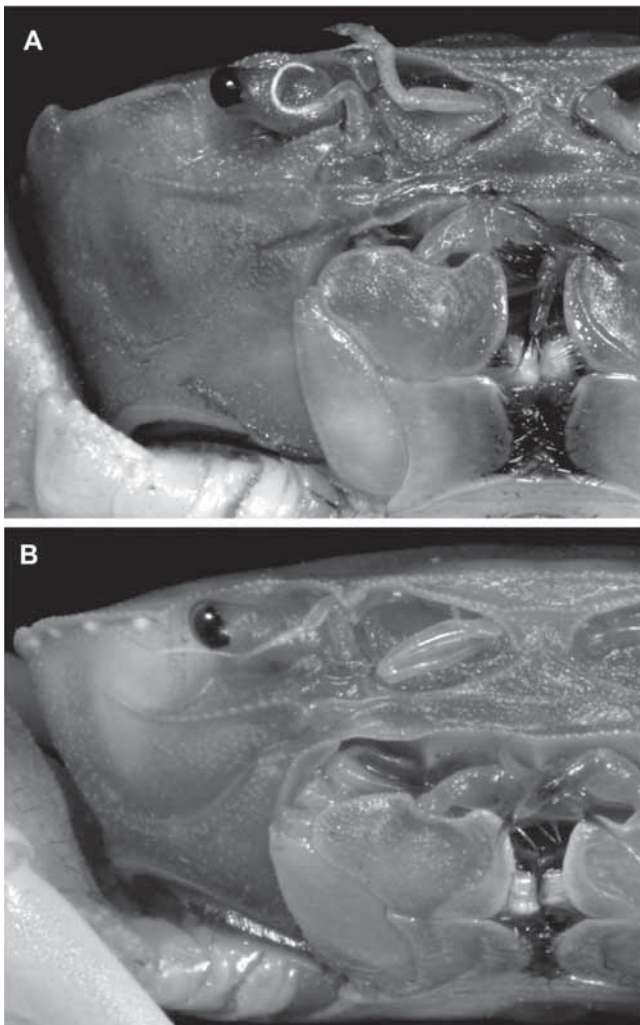


Fig. 10. Frontal view showing epistome, frontal and anterolateral margins and orbital and suborbital margins. A, *Orcovita orchardorum*, new species, holotype male (21.0 × 16.7 mm) (QM-W29114). B, *Orcovita hicksi*, new species, holotype male (17.4 × 13.2 mm) (WAM-C49450).

The present collection is remarkable in recording two species living sympatrically in the same caves. The only similar but not identical situation is with *O. holthuisi* and *O. angulata* both reported from Coron Island in the Philippines, although at different sites. In that instance it is not known if the separate caves in which those species each live have any subterranean connection, and/or if the species occur together in the same location. The presence of more than one

stygobitic species of the same genus in the same cave is not unprecedented in other groups. In brachyurans, two species of freshwater potamids (*Cerberusa*) have been found in the Mulu Caves in Sarawak, Borneo (Holthuis, 1979) while two species of sesarmids (*Karstarma*) occur in the same cave in Bali, Indonesia (Ng, 2002; Davie & Ng, 2007). Three new species of the remipede, *Speleonectes* have been described from one underwater room in a cave in the Bahamas (see Koenemann et al., 2003). Likewise, two stygobitic species of the halocyprid ostracode, *Danielopolina*, have been described from an anchialine lava tube cave in the Canary Islands (see Danielopol et al., 2000).

We have re-examined the morphology of all 10 species of *Orcovita*, and it is now apparent that on the basis of the morphology, there are two separate species-groups that may represent distinct lineages. Species in Group I typically have two epibranchial teeth; relatively prominent post-frontal lobes; shorter, stockier legs (for proportions of last two pereiopods, see Table 2); and a distinct thick patch of long setae at the base of the gape of the male chela that

extends onto the fingers. It includes three species: *O. miruku* Naruse & Tamura, 2006, *O. holthuisi* Ng & Ng, 2009, and *O. orchardorum*, new species.

Species in Group II have a single epibranchial tooth; lack obviously raised post-frontal lobes; have relatively longer and more slender legs, and mostly lack a prominent patch of setae on the chelae (with the exception of *O. gracilipes* and *O. mcneiceae*). It includes seven species: *O. saltatrix* Ng & Tomascik, 1994, *O. angulata* Ng, Guinot & Iliffe, 1996; *O. gracilipes* Ng, Guinot & Iliffe, 1996; *O. fictilia* Ng, Guinot & Iliffe, 1996, *O. mollitia* Ng, Guinot & Iliffe, 1996; *O. mcneiceae* Ng & Ng, 2002, and *O. hicksi*, new species.

Interestingly, in both cases where two separate species occur (or are believed to occur) sympatrically (*O. holthuisi* and *O. angulata* from Coron Island, the Phillipines; *O. orchardorum*, new species, and *O. hicksi*, new species, from Christmas Island), there is, in each case, a representative of each of the two lineages. This is further good evidence that there is likely to be a deep-rooted ecological/phylogenetic split

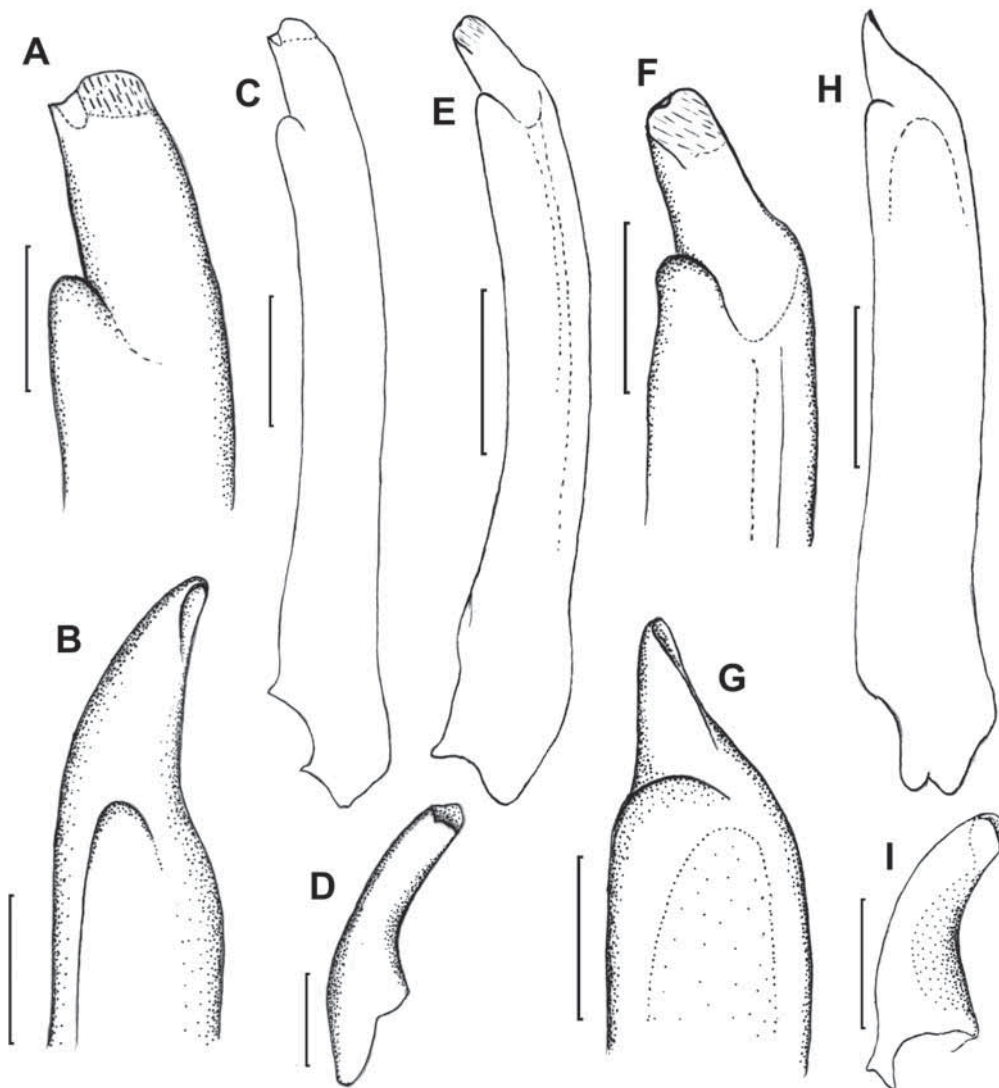


Fig. 11. Male gonopods (denuded). *Orcovita orchardorum*, new species, holotype male (21.0 × 16.7 mm), (QM-W29114): A–C, abdominal and sternal views of G1, D, G2; *Orcovita hicksi*, new species, holotype male (17.4 × 13.2 mm) (WAM-C49450): E–H, abdominal and sternal views of G1, I, G2.

Table 2. Length to width ratios of various ambulatory leg segments of *Orcovita* species (adapted from Ng & Ng, 2002, 2009; Naruse & Tamura, 2006). 3M, 3P, 3D = third ambulatory leg merus, propodus and dactylus, respectively; and similarly for the fourth leg.

		3M	3P	3D	4M	4P	4D
Group I	<i>O. miruku</i>	4.1	3.7	9.3	3.7*	2.6	6.3
	<i>O. holthuisi</i>	4.3	3.9	8.1	3.9	2.7	2.2
	<i>O. orchardorum</i>	4.0	3.8	7.5	3.7	2.6	5.5
Group II	<i>O. angulata</i>	5.4	5.4	16.1	4.6	3.7	6.6
	<i>O. fictilia</i>	5.3	4.2	9.1	4.2–4.4	2.6–3.0	6.2–6.9
	<i>O. gracilipes</i>	5.7	5.1	10.8	4.7	3.2	5.9
	<i>O. mcneiceae</i>	5.2	5.4	9.8	5.2	3.2	4.9
	<i>O. mollitia</i>	5.7	5.2	12.9	4.2–4.7	2.8–3.2	7.6
	<i>O. saltatrix</i>	5.8	4.3	7.8	4.4	3.1	5.5
	<i>O. hicksi</i>	5.6	4.8	11	4.5	2.4	6.4

*This ratio has been previously given as 6.1 for *O. miruku* but was a mistake in the original manuscript – Tohru Naruse (pers. comm.) has checked the holotype and the correct ratio is 3.7.

that has allowed species from both lineages to co-occur. A DNA study would be ideal to investigate the veracity of this hypothesis, to possibly get an indication of the age of the genus, and perhaps some correlation with the historical biogeography of the region.

Biogeography. — The distribution of all 10 species of *Orcovita* currently known is presented in Fig. 10. It is difficult to understand the biogeography of specialised anchialine genera. Typically isolation appears to have led to speciation, but this also implies that there must have been some connectivity of such limestone cave systems in the past. A similar pattern appears for the family Procarididae, an aberrant group of shrimps restricted to anchialine caves in both the Atlantic and Indo-Pacific Oceans. Like *Orcovita*, the first record of this family for the Indian Ocean, *Procaris noelensis*, was only made recently from the same limestone caves on Christmas Island (Bruce & Davie, 2006). Hart et al. (1985) and Maciolek (1983) have speculated that the distribution of *Procaris* could be much more extensive than currently known, with gene flow over great distances occurring via semi-continuous populations distributed among shallow submerged ‘crevicular’ habitats. Boxshall

(1989) proposed that the mid-oceanic ridge islands may form a continuous route of dispersal around the globe, but as Humphreys & Eberhard (2001) have pointed out, there is no simple connection between the crevicular system of mid-oceanic ridges and hot spot islands such as Christmas Island. Thus the restriction of *Procaris* and *Orcovita* species to anchialine systems is a strong indication that they are relictual (sensu Humphreys, 2000; Humphreys et al., 2009), and that the species on Christmas Island have survived by using the karst system as a refugium. Kensley & Williams (1986) have already suggested this concept to explain the occurrence of decapod procaridids in other anchialine systems. The various biogeographic models that have been proposed have been reviewed by Iliffe & Kornicker (2009), but it seems that there is no simple unified explanation at this time. Our knowledge of subterranean or submarine karst systems remains sparse; with many such systems still poorly surveyed or even unstudied. The discovery of two new species of *Orcovita* in Christmas Island in this study is a case in point.

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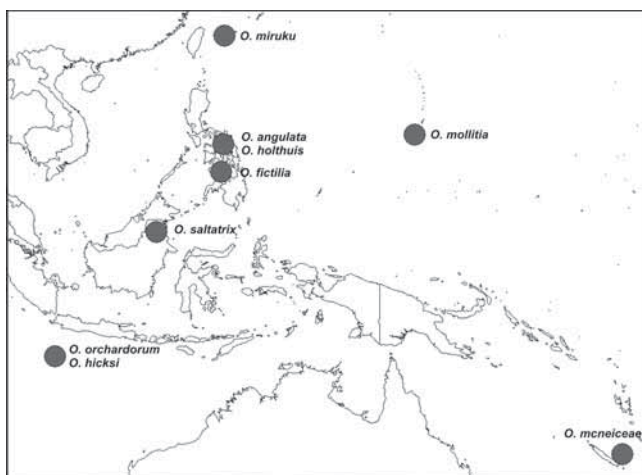


Fig. 12. Map showing the distributions of the 10 known *Orcovita* species.

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