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## A new species of *Arenallianassa* (Decapoda: Axiidea: Callianassidae) from hydrothermal vents with notes on its ecology and a redescription of *Arenallianassa arenosa* (Poore, 1975)

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### Abstract

Schnabel, K.E., Rowden, A.A., and Poore, G.C.B. 2023. A new species of *Arenallianassa* (Decapoda: Axiidea: Callianassidae) from hydrothermal vents with notes on its ecology and a redescription of *Arenallianassa arenosa* (Poore, 1975). *Memoirs of Museum Victoria* 82: 55–69.

The hitherto monotypic genus *Arenallianassa* Poore, Dworschak, Robles, Mantelatto and Felder, 2019 is revised following the discovery of a new species, *Arenallianassa katrinae* sp. nov. from New Zealand and Tonga. The original description of the type species *Arenallianassa arenosa* (Poore, 1975) is augmented. The new species has been found in localised high abundance in the vicinity of shallow (111–181 m depth) hydrothermal vents at each end of the Kermadec–Tonga Volcanic Arc system. This brings the number of callianassoids in New Zealand to six.

### Keywords

Ghost shrimp, chemosynthetic, integrative taxonomy, Kermadec–Tonga Volcanic Arc, DNA barcoding, COI, 16S

### Introduction

Recent morphological and molecular reviews of the ghost shrimp family Callianassidae Dana, 1852 established 12 new genera, increasing the currently recognised number of genera to 27 (Poore et al., 2019; Robles et al., 2020). The monotypic genus *Arenallianassa* Poore, Dworschak, Robles, Mantelatto and Felder, 2019 was established for *Callianassa arenosa* Poore, 1975 based on its phylogenetically remote placement within the callianassid gene tree. The species was considered morphologically and genetically most closely related to *Paratrypaea* Komai and Tachikawa, 2008 and *Filhollianassa* Poore, Dworschak, Robles, Mantelatto and Felder, 2019, separated from these genera by differences in the major cheliped, uropodal endopod and telson.

Since these revisionary studies, an undescribed species belonging to *Arenallianassa* has been collected from two disjunct localities along the Kermadec–Tonga Volcanic Arc system. Interestingly, the new species was in both cases collected around shallow (~100–200 m depth) hydrothermal vents, an

environment very different from its congener, *A. arenosa*, which is abundant in the intertidal and shallow waters of eastern Australia (Poore, 1975; Butler et al. 2009).

This paper redescrines the type species *A. arenosa* and describes the new species from New Zealand. Anecdotal evidence indicates that the new species occurs in localised high abundances.

### Material and methods

**Morphological examination.** Size is expressed as carapace length (cl) or total length (tl), including rostrum, in mm. Measurements for the holotype are indicated in square brackets. Material examined is deposited in Museums Victoria, Melbourne (NMV), Northern Territory Museum and Art Gallery, Darwin (NTMAG), and the National Institute of Water and Atmospheric Research Invertebrate Collection, Wellington (NIWA).

**Molecular taxonomy.** DNA was extracted from a pleopod and using the DNeasy Blood & Tissue Kit (QIAGEN, Germantown, MD, USA) following the manufacturer's protocols. A partial

Table 1. Pairwise percentage genetic distances for aligned partial 16S rRNA gene (432 bp) between *Arenallianassa katrinae* sp. nov. (grey columns) and published GenBank sequences for a selection of Callianassidae previously presented by Porter et al. (2005) and Robles et al. (2009, 2020).

Species	Study	Accession Number	NIWA 157710	NIWA 157716	NIWA 32198	DQ079705	EU874945n	MN237673.1	EU874949.1	MN237723.1	EU882913.1	MN237847	EU882950.1	EU882947.1
<i>A. katrinae</i> sp. nov. paratype	this study	OP178649	–											
<i>A. katrinae</i> sp. nov.	this study	OP178651	0.002	–										
<i>A. katrinae</i> sp. nov.	this study	OP178650	0.015	0.017	–									
<i>A. arenosa</i> (Poore, 1975)	Porter et al. 2005	DQ079705	0.069	0.071	0.074	–								
<i>A. arenosa</i> (Poore, 1975)	Robles et al. 2009	EU874945	0.064	0.066	0.069	0.007	–							
<i>Filholianassa ceramica</i> (Fulton and Grant, 1906)	Robles et al. 2020	MN237673.1	0.076	0.078	0.081	0.073	0.069	–						
<i>Filholianassa filholi</i> (A. Milne-Edwards, 1879)	Robles et al. 2009	EU874949.1	0.069	0.071	0.074	0.066	0.062	0.048	–					
<i>Paratrypaea bouvieri</i> (Nobili, 1904)	Robles et al. 2009	MN237723.1	0.085	0.087	0.09	0.093	0.089	0.101	0.094	–				
<i>P. bouvieri</i> (Nobili, 1904)	Robles et al. 2009	EU882913.1	0.084	0.086	0.089	0.092	0.087	0.1	0.093	0.06	–			
<i>Trypaea australiensis</i> Dana, 1852	Robles et al. 2020	MN237847	0.126	0.128	0.131	0.123	0.118	0.123	0.116	0.15	0.149	–		
<i>Neotrypaea gigas</i> (Dana, 1852)	Robles et al. 2009	EU882950.1	0.153	0.155	0.158	0.15	0.146	0.15	0.143	0.178	0.176	0.15	–	
<i>Neotrypaea californiensis</i> (Dana, 1854)	Robles et al. 2009	EU882947.1	0.153	0.155	0.158	0.15	0.146	0.15	0.143	0.178	0.177	0.15	0.025	–

sequence of the mitochondrial cytochrome c oxidase I (COI) gene was amplified using the universal primer pairs LCO1490/HCO2198 (Folmer et al., 1994); a partial sequence of the mitochondrial 16S rRNA gene was amplified using primers 16S-arL/brH (Palumbi and Benzie, 1991) or 16S-SF (Tsang et al., 2014)/16S-1472 (Crandall and Fitzpatrick, 1996). The polymerase chain reaction (PCR) was conducted with MyTaq™ HS DNA Polymerase (Meridian Bioscience, www.meridianbioscience.com) with a protocol as follows: the reactions were conducted in a total volume of 25 µL and processed with an initial denaturation step (95°C, 1 min), followed by 35 cycles of denaturation (95°C, 20 s), annealing (48°C, 25 s) and extension (72°C, 20 s), with a final extension of 5 min at 72°C. PCR products were assessed by agarose gel electrophoresis, cleaned using ExoSAP-IT reagent (USB, Cleveland, Ohio, USA) and commercially sequenced (Macrogen Inc., Seoul, Korea) with the same primers used for the PCR. Sequences were checked for potential contamination using the Basic Local Alignment Search Tool through GenBank. Newly generated sequences were checked and edited and aligned with reference sequences available on GenBank using Geneious (v 2021.1.1) (<http://www.geneious.com>; Kearse et al., 2012). The default Geneious Tree Builder function parameters were applied to calculate the percentage identity and patristic distance matrix (Tamura-Nei distance mode, neighbour-joining tree build method, outgroup not specified). A bootstrap consensus tree was generated using a random seed, 1,000 replicates and a 50% support threshold. Sequences are deposited on GenBank under accession numbers OP174573–

OP174574 (COI) and OP178649–OP178651 (16S) and in BOLD under DECNZ388-22–DECNZ389-22 for COI.

### Molecular taxonomy results

Sequences were successfully generated for the 16S (452–527 bp) and COI (652–657 bp) genes and cover at least one sample for *A. katrinae* sp. nov. from the type locality in the Bay of Plenty, New Zealand (NIWA 157710, 157716) and Volcano 1, Tonga (NIWA 32198). Qi Kou (Chinese Academy of Sciences) kindly shared some sequence information for the latter specimen. Reference sequences for COI are not available on GenBank for most callianassids, but comparing sequences obtained for specimens of *A. katrinae* revealed significant intraspecific divergences (3.2%) between the southern and the northern populations, pointing to a level of genetic isolation (compare sequences deposited on GenBank and BOLD). In the absence of further material from Tonga, this so far represents cryptic diversity yet to be resolved.

Several gene sequences are available on GenBank for *A. arenosa*: Porter et al. (2005) published sequences for 16S, 18S, 28S and H3; Robles et al. (2020) included 16S, 18S, 12S and H3 in their study. One sequence for 16S (AY583895) published by Ahyong and O'Meally (2004) includes ambiguous nucleotides and significant sequence divergence from those reported in the earlier two studies. This sequence is not considered *A. arenosa* s.s. here and should be revisited.

A global 16S alignment of 432 base pairs was assembled for 12 sequences covering eight species of callianassids,

which Robles et al. (2020) showed to be closely related (Table 1, fig. 1). Two sequences for *A. katrinae* sp. nov. from the type locality are near-identical (p-distance: 0.002), while the single specimen from Tonga (NIWA 32198) resolved a p-distance of 0.015–0.017. The most similar sequences represent *A. arenosa* (p-distances: 0.064–0.074) but sequences representing species of *Filhollianassa* Poore, Dworschak, Robles, Mantelatto and Felder, 2019 and *Paratrypaea* Komai and Tachikawa, 2008 show similar divergence (p-distances: 0.069–0.090).

The multi-gene analysis presented for 123 species of Callianassoidea by Robles et al. (2020: figs 1, 3) found *Arenallianassa* as a monotypic taxon placed between two clades, one representing three species of *Paratrypaea* and the other, two species of *Filhollianassa*. With the addition of *A. katrinae*, albeit with the consideration that this analysis only covers a single gene (16S), the monotypy of *Arenallianassa* is

not maintained in a strict consensus tree (fig. 1), even if more sequences of species of (e.g.) *Paratrypaea* are added (not shown). Poore et al. (2019) highlighted the morphological affinities between these genera and proposed fixed morphological differences to support the generic delineation: *Paratrypaea* species have dense setation on the dactylus of the major cheliped and lack the prominent meral hook on the major cheliped; *Filhollianassa* species have a strongly domed anterior carapace and asymmetrical, angular uropodal endopod, the latter proposed as diagnostic difference from the ovoid shape shared by *Arenallianassa* and *Paratrypaea*. These morphological characters are upheld with the addition of *A. katrinae*. While the sequence divergence is marginally closer between the two species of *Arenallianassa*, it is clear that the systematic delineation between these closely related taxa needs further attention.

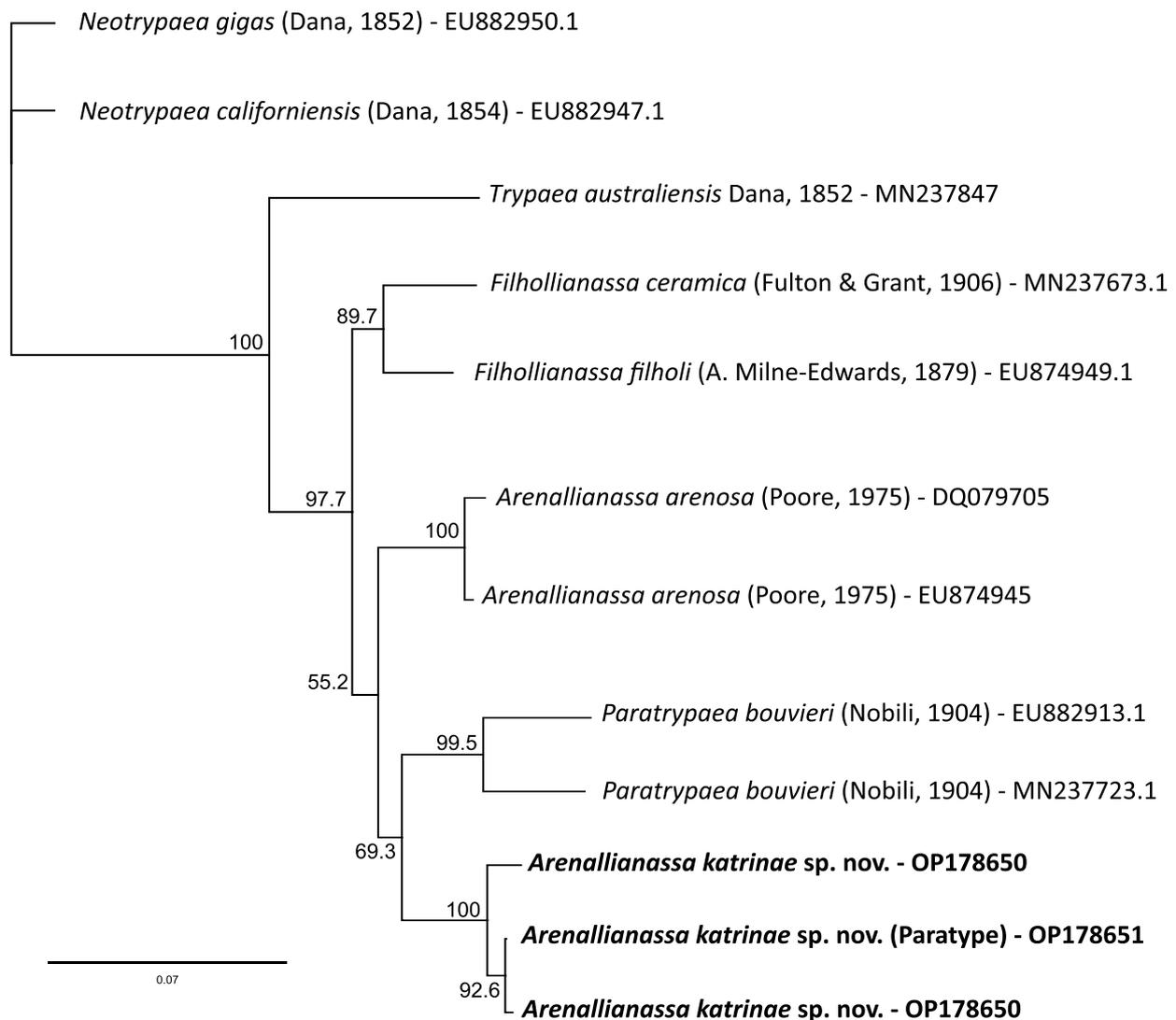


Figure 1. Neighbour-joining consensus tree inferred from the 16S rRNA gene sequences for eight species of Callianassidae. Genbank Accession numbers are appended. Consensus support (%) based on 1000 bootstrap replicates is shown for each node. Scale indicates patristic distances.

## Systematics

### Family Callianassidae Dana, 1852

#### *Arenallianassa* Poore, Dworschak, Robles, Mantelatto and Felder, 2019

*Arenallianassa* Poore et al., 2019: 91.—Robles et al., 2020: 118, 128, figs 1, 3, 6, 8.

**Diagnosis.** Rostrum obtusely triangular, flat, not reaching cornea. Pleomere 1 tergite with weak transverse ridge. Maxilliped 3 merus wider at ischium-merus suture than long. Male major cheliped merus with prominent truncate or oval hook armed with serrations along lower margin, excavate laterally at base; carpus and propodus flattened, upper and lower margins carinate, blade-like, submarginal mesial face especially of carpus deeply concave; propodus distal margin with deep notch at base of fixed finger. Pereopod 3 propodus rectangular or oval, with broadly rounded free proximal lobe. Male pleopod 2 absent. Uropodal endopod ovoid, longer than wide, anterior margin straight or slightly convex, posterodistal margin evenly convex, with few facial distal spiniform setae; exopod distal margin clearly differentiated from anterior margin, anterodistal corner right-angled. Telson lateral margins convex, subparallel or tapering distally (amended from Poore et al. 2019).

**Remarks.** The genus is diagnosed by the combination of a blade-like meral hook with serrate margins on the major cheliped of both sexes, an ovoid uropodal endopod, little longer than wide, and a telson that is about as wide as long with rounded posterolateral corners (Poore et al., 2019). With the addition of *A. katrinae* sp. nov. the diagnosis is adjusted to consider the different shapes of the pereopod 3 propodus, the distribution of spiniform setae on the uropodal endopod and the difference in the shape of the telson.

Poore's (1975) and (2004) illustrations of *A. arenosa* were basic but enabled him to distinguish the species from other Australian callianassid species. Subsequent observations presented in the supplementary description and figures below show the setae on the telson and uropod, notably the distal transverse row of short spiniform setae on the face of the uropodal endopod, a feature in one form or another shown by Poore et al. (2019) and Robles et al. (2020) to be shared with *Filhollianassa*, *Notiax* Manning and Felder, 1991, *Paratrypaea*, *Trypaea* Dana, 1852 and *Tastrypaea* Poore, Dworschak, Robles, Mantelatto and Felder, 2019.

#### *Arenallianassa arenosa* (Poore, 1975)

Figures 2, 3

*Callianassa arenosa* Poore, 1975: 197–201, figs 1, 2.—Poore and Griffin, 1979: 250, figs. 15–17.—Sakai, 1988: 57.—Sakai, 1999: 39.—Sakai, 2005: 73.

*Biffarius arenosa*.—Tudge et al., 2000: 142.

*Biffarius arenosus*.—Boon et al., 1997: 503–511 (diet).—Bird et al., 1999: 523–532 (sediment transport).—Bird and Poore, 1999: 77–87 (burrow morphology).—Davie, 2002: 457.—O'Hara, 2002: 680.—Poore, 2004: 181, fig. 49b, d, pl. 12a.—Butler et al., 2009: 43–59 (population biology).

*Trypaea arenosa*.—Sakai, 2011: 391.

*Arenallianassa arenosa*.—Poore et al., 2019: 91, 136, 142.—Robles et al., 2020: figs 1, 3, 6.

**Material illustrated.** **Australia**, Victoria, Tooradin, 38.22° S, 145.37° E, NMV J16708 (male, cl 6.9 mm). Cannons Creek, 38.25° S, 145.32° E, NMV J16670 (female, cl 7.3 mm). Sandringham, 37.5° S, 144.99° E; NMV J31887 (male, not measured). Queensland, Conway Beach, Prosperine, 20.48° S, 148.75° E; NMV J16726 (male, cl 5.1 mm). Northern Territory, Gove, 12° 12' S, 136° 43' E; NTMAG Cr009860 (female, cl 5.3 mm, with Bopyridae in branchial cavity).

**Types.** Australia, Victoria, Port Phillip Bay, 3.5 km off Seaford, 13 m, sandy sediment, 8 Sep 1971 (PPBES station 951). Holotype: NMV J271, female, tl 24 mm. Paratypes: NMV J272, male, tl 22 mm; NMV J273, 10 specimens.

**Diagnosis.** Male major cheliped merus lower margin with strong proximal truncate tooth, its apex directed distally, margins serrate, plus low denticulate convex blade beyond midpoint. Minor cheliped merus lower margin with spine at midpoint. Pereopod 3 propodus oval. Telson with convex parallel lateral margins.

**Supplementary description.** Carapace 0.24 total length; with distinct linea thalassinica, with defined dorsal oval marked posteriorly by shallow transverse cervical groove (at 0.8 cl) extending anteroventrally to each side above linea thalassinica as shallow groove; frontal margin scarcely oblique, anterolateral lobe obsolete. Rostrum convex in lateral view, broadly triangular, reaching halfway to cornea. Pleonites 1 and 2 together as long as carapace; ratio of lengths of pleonites 2–6 – 1 : 0.8 : 0.7 : 1 : 1.

Antennular peduncle 0.5 times carapace length, article 3 2.3 times as long as article 2, with ventrolateral row of long setae. Antennal peduncle almost as long as antennular peduncle; article 5 0.75 times as long as article 4; scaphocerite semicircular. Maxilliped 3 ischium 1.2 times as long as wide, dilating distally; crista dentata curved, of about 15 sharp spines, not overlapping ischium-merus suture; merus semicircular, 1.8 times as wide as long, distal margin curved beyond base of carpus; propodus 1.8 times as long as wide, flexor margin almost straight; dactylus with convex extensor margin, flexor margin with dense setal brush over distal half.

Pereopods 1 (chelipeds) unequal, dissimilar, sexually dimorphic. Male major cheliped carpus-palm (fingers of chelae not included) 1.6 times carapace length; ischium slender, lower (flexor) margin with 2 proximal denticles; merus body twice as long as wide, upper margin with 5 proximal tubercles, lower margin with strong proximal truncate tooth (meral hook), its apex directed distally, margins serrate, plus low denticulate convex blade beyond midpoint, lateral face with deep well-defined excavation at base of tooth; carpus as wide as long, upper and lower margins carinate, rolled mesially; propodus upper margin 1.3 times as long as carpus, 1.1 times as long as greatest width, lower margin of palm carinate; palm distomesial margin with denticulate tubercle at base of fixed finger, strongly excavate between tubercle and fixed finger and mesially; fixed finger 0.4 length of lower margin, almost conical; dactylus 0.75 as long as upper margin of palm, cutting edge with blunt tooth in proximal third, another near midpoint, with acute reflexed tip. Minor cheliped carpus-palm about as long as carapace; palm 0.3 times width of major; ischium narrow, unarmed, longer than merus; merus twice as long as wide, lower margin

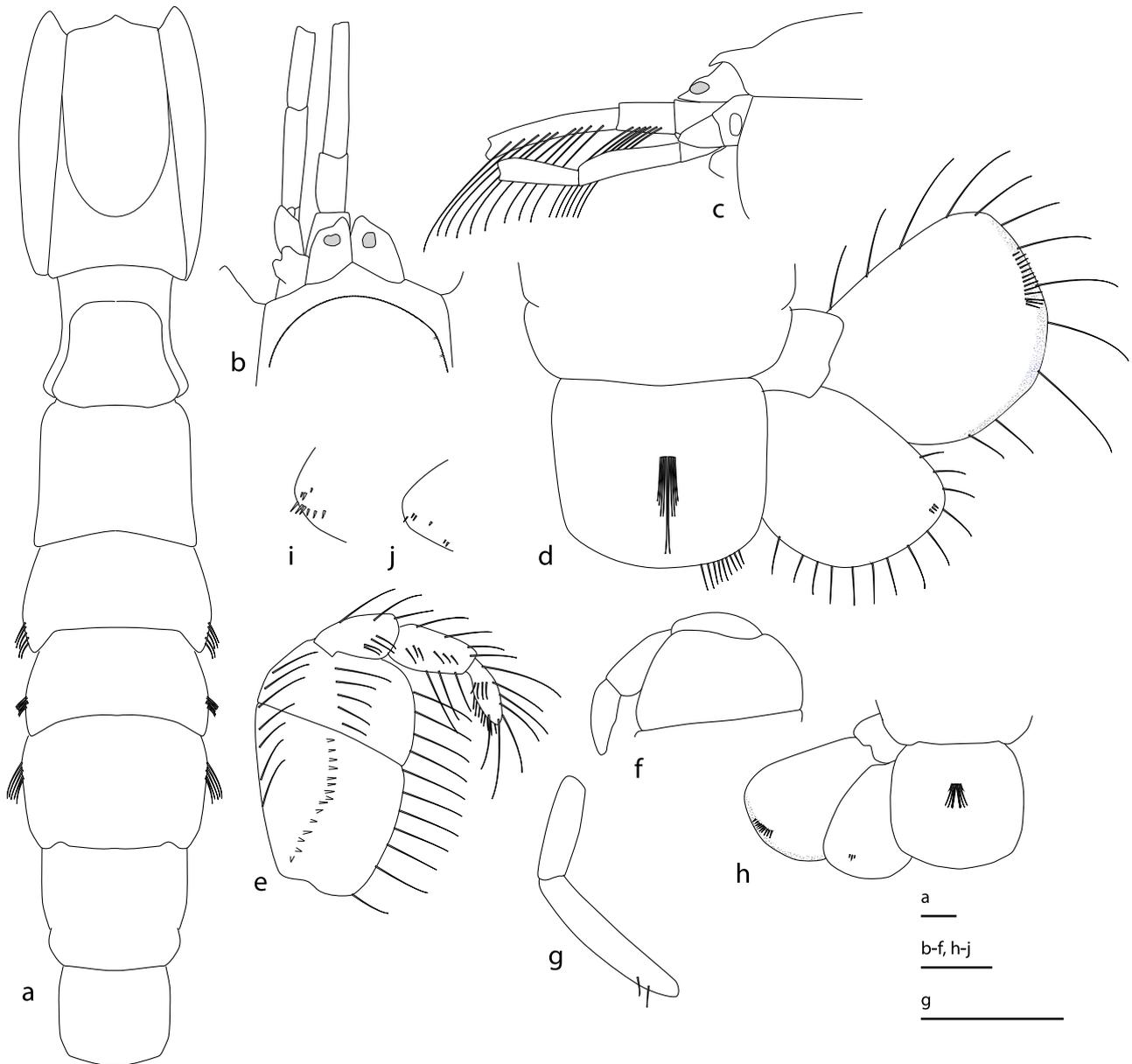


Figure 2. *Arenallianassa arenosa* (Poore, 1975). NMV J16708 (male, cl 6.9 mm): a, carapace, pleon, telson, dorsal view; b, c, anterior carapace, eyestalk, antennule, antenna, dorsal view (only left appendages shown in b); d, telson, right uropod, dorsal view; e, maxilliped 3, mesial view; f, same, distal articles, lateral view; g, pleopod 1, lateral view. NTMAG Cr009860 (female, cl 5.3 mm): h, telson, left uropod, dorsal view. NMV J31887 (male); i, left uropod, anterodistal angle of endopod. NMV J16726 (male, cl 5.1 mm); j, left uropod, anterodistal angle of endopod. Scale bars = 1 mm.

with spine at midpoint; carpus 1.5 times as long as merus, 2.3 times as long as wide, parallel-sided over distal half; palm upper margin 0.55 times as long as carpus, 1.2 times as long as wide, lower margin as long as carpus; fixed finger evenly tapering, half-length of lower margin, cutting edge smooth; dactylus curved, cutting edge unarmed.

Female major cheliped carpus-palm 1.3 times carapace length; ischium slender, lower (flexor) margin with obsolete proximal denticles; merus essentially as in male; carpus 1.3

times as long as wide, upper and lower margins carinate, rolled mesially; propodus upper margin 0.9 times as long as carpus, 1.2 times as long as greatest width, lower margin of palm carinate; palm distomesial margin with denticulate tubercle at base of fixed finger, with shallow notch between tubercle and fixed finger; fixed finger 0.4 length of lower margin, almost conical, cutting edge minutely denticulate proximally; dactylus 0.8 times as long as upper margin of palm, cutting edge convex, with acute reflexed tip.

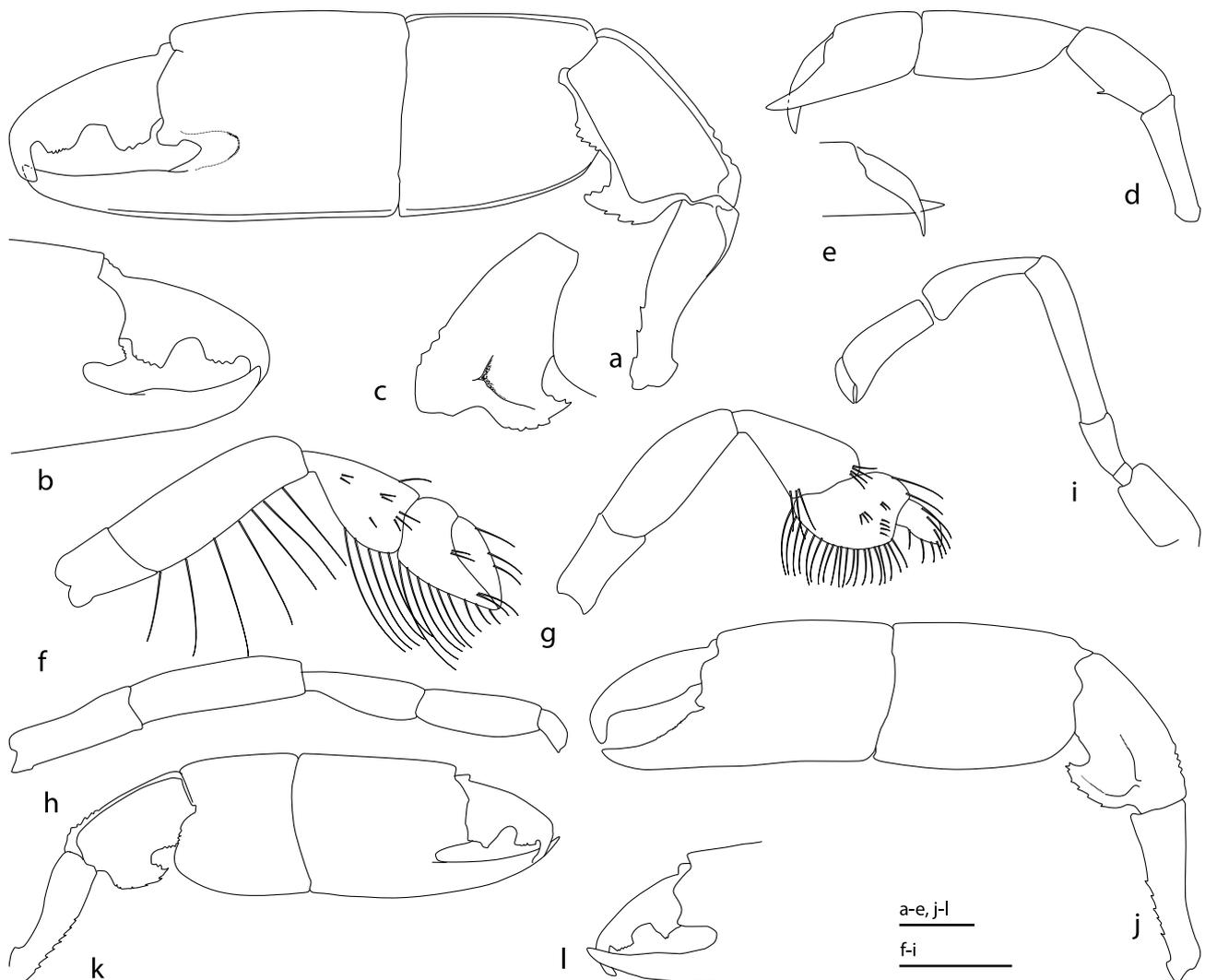


Figure 3. *Arenallianassa arenosa* (Poore, 1975). NMV J16708 (male, cl 6.9 mm): a, major (right) cheliped, mesial face; b, major cheliped fingers, lateral face; c, merus, lateral face; d, minor (left) cheliped, lateral face; e, minor cheliped fingers, mesial face; f, pereopod 2; g, pereopod 3; h, pereopod 4; i, pereopod 5. NMV J16670 (female, cl 7.3 mm): j, major (right) cheliped, lateral. NMV J16726 (male, cl 5.1 mm): k, major (left) cheliped, mesial; l, major cheliped fingers, lateral. Scale bars = 2 mm.

Pereopod 2 chelate; carpus 1.7 times as long as wide; palm twice as wide as upper margin. Pereopod 3 propodus with evenly convex lower margin, proximally reaching lower margin of carpus, almost truncate distally, 1.4 times as long as wide at midlength, with spiniform seta on flexor margin, near distal end, buried among finer setae. Pereopod 4 simple, propodus densely setose laterally. Pereopod 5 chelate, propodus and dactylus densely setose.

Male pleopod 1 of 2 simple articles; article 2 1.7 times as long as article 1. Male pleopod 2 absent.

Uropodal endopod 1.1 times as long as wide, anterior margin gently convex, ending at rounded right angle with distal margin; distal and posterior margins indistinguishable; margins setose; with dorsal cluster of spiniform setae (usually 3 close

together) near anterodistal margin; exopod as wide as anterior margin, anterior margin almost straight, posterodistal margin evenly curved, dorsal plate extending more than half width of exopod, slightly differentiated from distal margin, bearing spiniform setae overlapping setose margin.

Telson slightly wider than long, broadest proximally, tapering to rounded posterolateral corners, posterior margin convex; dorsal surface with c. 5 pairs of fine setae near midpoint.

*Distribution.* Eastern Australia (Gove, Northern Territory, to eastern Tasmania); marine and estuarine bays; intertidal to 25 m.

*Remarks.* *Arenallianassa arenosa* is possibly the most common callianassid in south-eastern Australia. Its ecology has been much studied (Poore, 1975; Coleman and Poore, 1980; Boon et

al., 1997; Bird and Poore, 1999; Bird, 2000; Stapleton et al., 2001; Butler and Bird, 2007, 2008; Butler et al., 2009), mostly incorrectly treated as a species of *Biffarius* Manning and Felder, 1991. Collections in Museums Victoria and the Australian Museum contain hundreds of specimens, mostly from intertidal or shallow beaches or mudflats close to Sydney and Melbourne, of which a few were re-examined here. The record from Gove, Northern Territory, is exceptional; otherwise, the northern-most record is from central Queensland.

The species is separated from other callianassids in Australia by the combination of the telson having convex parallel sides, the broad uropodal rami, operculiform maxilliped 3 with narrow propodus, and the shape of the major cheliped. The distal transverse row of short spiniform setae on the face of the uropodal endopod usually comprises three setae but more can be found sometimes (compare figs 2h, i, j).

Differences from *A. katrinae* sp. nov. are discussed under the species below.

#### *Arenallianassa katrinae* sp. nov.

<http://zoobank.org/urn:lsid:zoobank.org:act:A8C9C6CA-DF84-4F0F-A939-D0E95002FB53>

Figures 4–7

**Material examined.** Holotype. **New Zealand**, Bay of Plenty, Calypso Vent Field, 37.6125° S, 177.1018° E, 181 m, 27 April 2007, TV grab, RV *Sonne* stn SO192-2/4, NIWA 157709 (male, cl 17.6 mm). Paratypes. Collected with holotype, GenBank: OP178649 (16S), NIWA 157710 (female, cl 16.6 mm); NIWA 157715 (1 female, cl 19.0 mm, mouthparts figured); GenBank: OP178651 (16S), OP174574 (CO1), BOLD: DECNZ389-22 (CO1), NIWA 157716 (1 male, cl 23.3 mm).

**Additional material.** **Tongan Volcanic Arc**, Volcano 1, 21.143° S, 175.759° W, 111 m, 12 May 2007, TV grab, RV *Sonne* stn SO192-2/63, GenBank: OP178650 (16S), OP174573 (CO1), BOLD: DECNZ388-22 (CO1), NIWA 32198 (1 female, cl 7.2 mm). **New Zealand**, Bay of Plenty, Calypso Vent Field, 37.612° S, 177.1025° E, 179 m, 07 Oct 1998, TV grab, RV *Sonne* stn SO135/81, NIWA 157435 (1 female, cl 16.7 mm). Calypso Vent Field, same locality as holotype, NIWA 32141 (6 females, cl 5.8–20.8 mm; 5 males, cl 11.5–22.0 mm); NIWA 45911 (4 females, cl 7.6–20.8 mm).

**Diagnosis.** Male major cheliped merus lower margin with prominent oval tooth directed obliquely, followed by prominent denticulate blade near midpoint, squared off distally. Minor cheliped merus lower margin without spine at midpoint. Pereopod 3 propodus subrectangular, proximally distinctly expanded, with evenly concave lower margin. Telson with convex parallel lateral margins.

**Description.** Male. Carapace 0.2–0.3 [0.24] of total length; with distinct linea thalassinica, with defined dorsal oval marked posteriorly by shallow transverse cervical groove (at 0.7 cl) extending anteroventrally to each side above linea thalassinica as shallow groove; frontal margin broadly convex, anterolateral lobe obsolete. Rostrum level with anterior carapace, broadly triangular, acute in dorsal view, reaching about halfway to cornea; orbital margin concave; anterolateral lobe flat, round in dorsal and lateral views; subanterolateral margin oblique, concave; anterior margin of branchiostegite strongly produced.

Pleonites 1 and 2 together as long as carapace; ratio of lengths of pleonites 2–6: 1 : 0.7–1.0[0.8] : 0.6–[0.7] : [0.8]–0.9 : 0.9.

Eyestalks extending almost to end of antennular peduncle article 1, with distinct mesiodistal lobe; pigmented area covered by large, thinly pigmented, circular dome.

Antennular peduncle about half carapace length; article 1 about as wide as eyestalk; article 3 2.4–[2.6] times as long as article 2, unarmed, with ventrolateral row of long setae. Antennal peduncle as long as antennular peduncle; article 5 0.8–[0.9] times as long as article 4; scaphocerite semicircular in lateral view.

Mandibular molar process with serrate margin, incisor process toothed. Maxillule, maxilla, maxillipeds 1 and 2 as in fig. 6. Maxilliped 3 ischium 1.2–[1.3] as wide as long at meral suture, dilating distally; crista dentata curved, consisting of 14 or 15 small spines, not overlapping ischium–merus suture; merus semicircular, 1.6–[1.7] times as wide as long, 0.8 as long as ischium, distal margin curved beyond base of carpus; propodus [1.4]–1.5 times as long as wide, widest proximally, flexor margin almost straight; dactylus truncate, 0.6 as wide as long, 0.9 times as long as propodus, with convex extensor margin, flexor margin with dense setal brush over distal two-thirds.

Pereopods 1 (chelipeds) unequal, dissimilar, sexually dimorphic. Male major cheliped massive, heterochelous (split even right : left major chela), carpus–palm length (fingers of chelae not included) 1.3–1.4 times carapace length; ischium slender, outer margin concave, lower (flexor) margin with 5–6 proximal spines; ratio of dorsal lengths—merus: carpus: propodus—1:1.0–1.1:1.0–1.3; merus upper margin smooth, lower margin with prominent oval tooth (meral hook) directed obliquely, followed by prominent denticulate blade near midpoint, squared off distally, lateral face with deep, well-defined excavation at base of tooth; carpus slightly wider than long, upper and lower margins carinate, proximal margin convex, overreaching mero-carpal articulation, lower margin serrate in larger individuals; palm 1.0–1.1 times as long as greatest width, lower margin carinate, distolateral margin lobate with tooth at base of fixed finger, strongly excavate between tooth and fixed finger; fixed finger 0.4 length of lower margin, almost conical, cutting edge smooth; dactylus nearly as long as upper margin of palm, cutting edge with blunt tooth in proximal third, second tooth near midpoint, third subdistal. Minor cheliped carpus–palm about as long as carapace; palm 0.35 times width of that of major; ischium narrow, unarmed, subequal to or shorter than meral length; merus twice as long as wide, margins smooth; carpus [1.3]–1.5 times as long as merus, 2.8–[2.9] times as long as wide, parallel-sided over distal half; palm upper margin 0.5 times as long as carpus, [1.2]–1.3 times as long as wide; fixed finger evenly tapering, 0.8 length of lower margin of palm, cutting edge smooth, unarmed; dactylus weakly curved, cutting edge unarmed.

Pereopod 2 chelate; carpus 1.7 times as long as wide; palm twice as wide as upper margin. Pereopod 3 propodus elongate, subrectangular, proximally distinctly expanded, with evenly concave lower margin, 1.9 times as long as wide at midlength; spiniform seta on flexor margin, near distal end, buried among finer setae. Pereopod 4 simple, propodus densely setose laterally. Pereopod 5 chelate, propodus and dactylus densely setose.

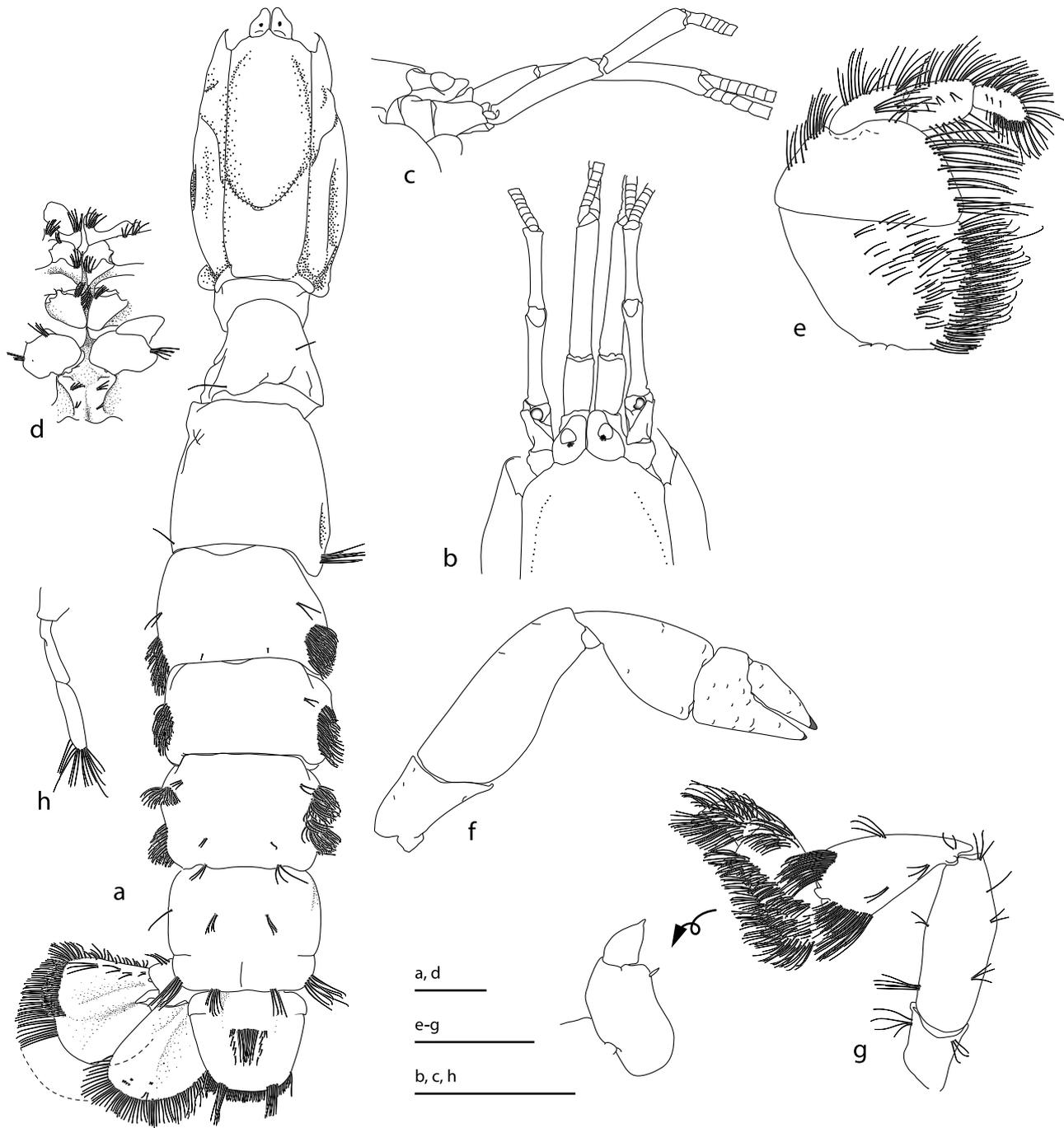


Figure 4. *Arenallianassa katrinae* sp. nov. NIWA 157709 (holotype male, cl 17.6 mm): a, eyestalks, carapace, pleon, left uropod, telson, dorsal view; b, c anterior carapace, eyestalk, antennule, antenna, dorsal view (b), lateral view (c); d, thoracic sternites 4–7, pereopodal coxae 1–4, ventral view; e, maxilliped 3, lateral face; f, pereopod 2; g, pereopod 3 (lateral view, mesial view of propodus and dactylus); h, pleopod 1, right, lateral view. Scale bars = 5 mm.

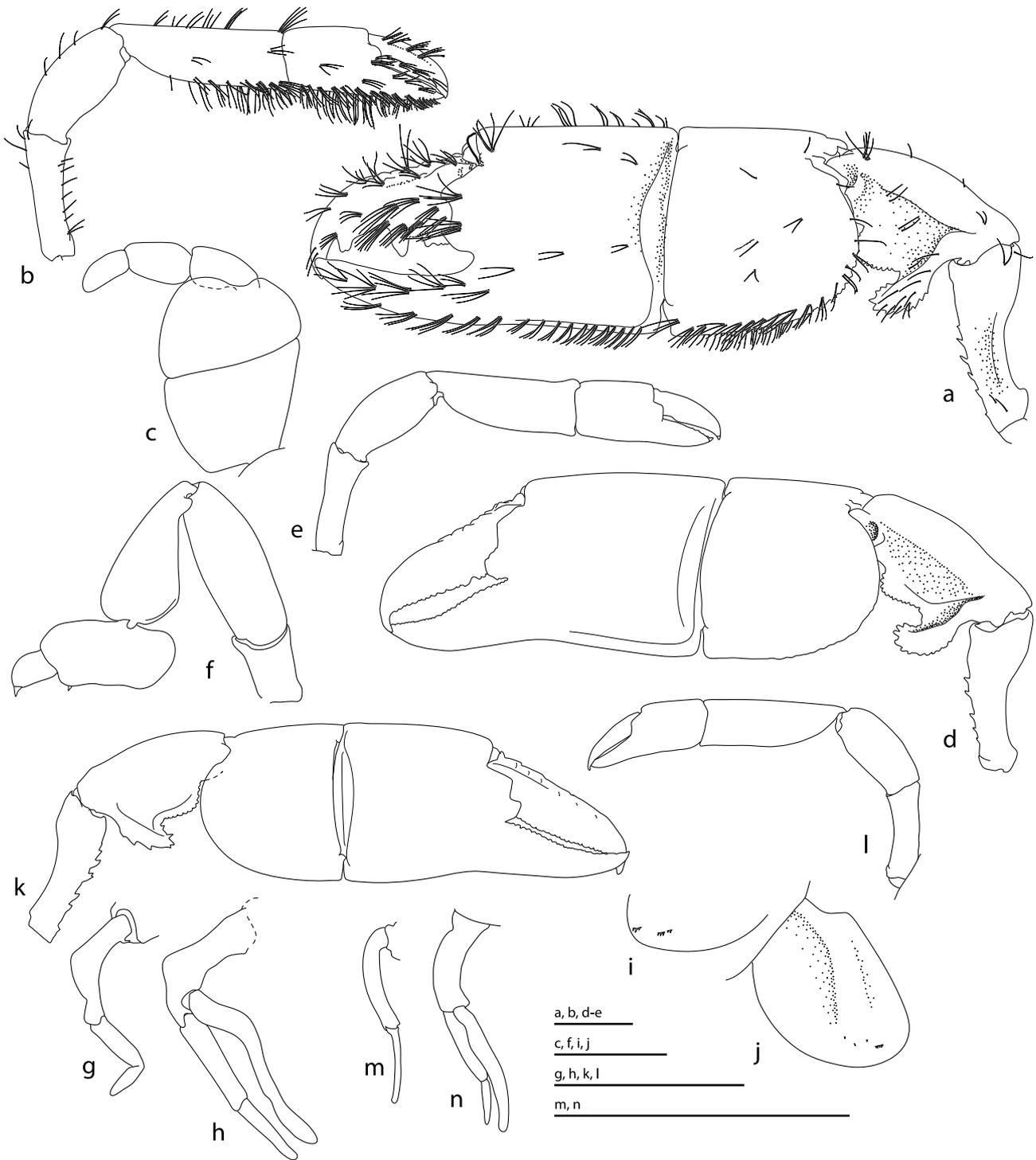


Figure 5. *Arenallianassa katrinae* sp. nov. NIWA 157709 (holotype, male, cl 17.6 mm), lateral view unless stated otherwise: a, major cheliped; b, minor cheliped, right. NIWA 157710 (paratype female, cl 16.6 mm): c, maxilliped 3, left; d, major cheliped, left; e, pereopod 3; f, pleopod 1; g, pleopod 2; h, i, left and right uropodal endopods showing distribution of robust setae. NIWA 32141 (paratype female, cl 9.5 mm); j, major cheliped; k, minor cheliped; l, pleopod 1; m, pleopod 2. Top 3 scale bars = 5 mm; bottom scale bar = 2 mm.

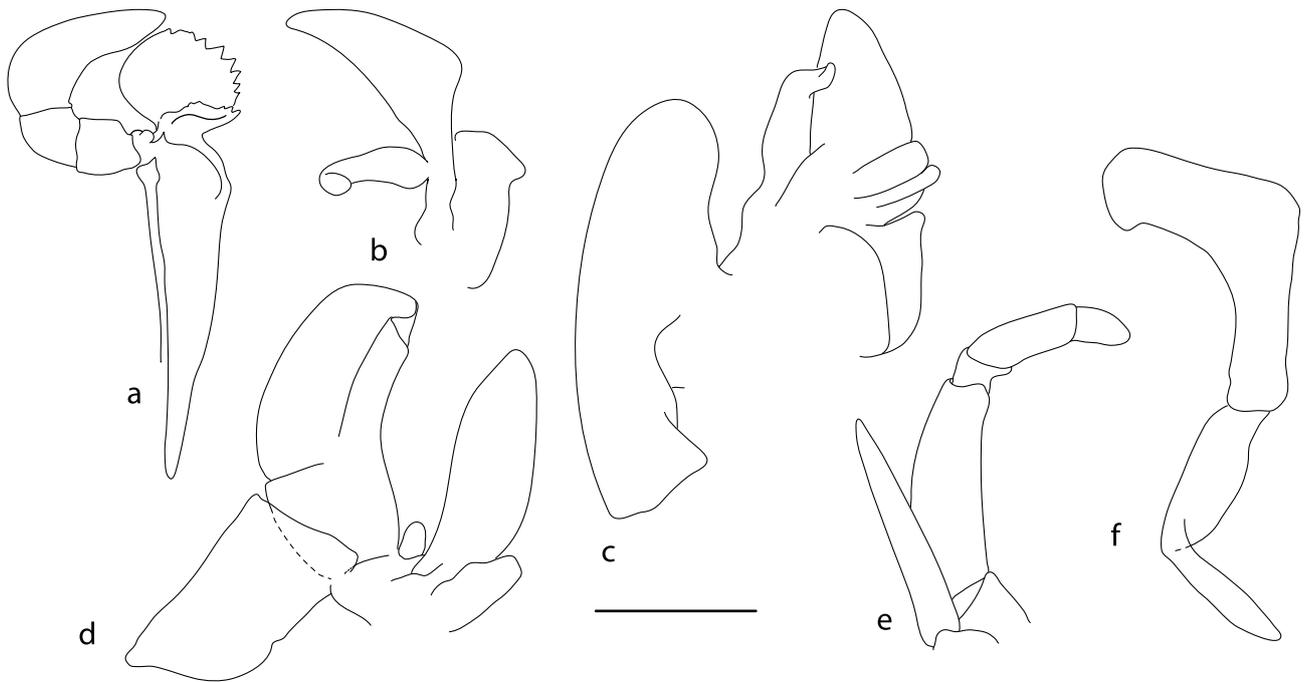


Figure 6. *Arenallianassa katrinae* sp. nov. NIWA 157715 (paratype female, cl 19.0 mm), lateral view unless stated otherwise: a, mandible, left, inside view; b, maxillule; c, maxilla; d, maxilliped 1; e, maxilliped 2; f, pleopod 1, lateral view. Scale bar = 5 mm.

Male pleopod 1 consisting of 2 simple articles, subequal in length. Male pleopod 2 absent. Pleopod 3–5 endopods with small, ovoid appendices internae, embedded at proximal third of mesial margin.

Uropodal endopod anterior margin straight, slightly longer than wide at midlength; distal margin falls away acutely, indistinguishable from posterior margin; margins setose; with variable scattered spiniform setae (usually a cluster of 3–4 distal setae with 2–3 scattered proximally) near anterodistal margin; exopod about as wide as anterior margin, anterior margin almost straight, posterodistal margin evenly curved, dorsal plate extending more than half width of exopod, slightly differentiated from distal margin, setose.

Telson trapezoid, [1.1]–1.2 times as wide as long, distinctly wider proximally, tapering to rounded posterolateral corners, posterior margin shallowly convex; dorsal surface with cluster of long, fine setae near midpoint.

**Female.** Major cheliped carpus–palm 1.4–1.7 times carapace length; ischium, merus and carpus essentially as in male; palm upper margin 1.2–1.3 as long as carpus, 1.0–1.2 times as long as greatest width, lower margin carinate, distolateral margin projected, with truncate lobe above base of fixed finger, with small notch between lobe and fixed finger; fixed finger 0.4 length of lower margin, almost conical, cutting edge denticulate; dactylus about as long as upper margin of palm, cutting edge straight, denticulate, with acute reflexed tip.

Pleopod 1 uniramous, 2-articulate, first article strongly curved in larger females, with clusters of long setae, indistinct in smaller females (cl less than ~10 mm); second article slightly

expanded medially and curved distally (slightly curved in small females, fully folded in large females). Pleopod 2 biramous, exopod narrow, curved, longer than 2-articulate endopod.

**Colour.** Dorsal oval of the carapace, chelipeds and pereopods pale, rest of carapace, pleon and tailfan darker, peach to reddish-brown (fig. 7 inset).

**Etymology.** Named for benthic ecologist Katrin Berkenbusch, in acknowledgment of her research on ghost shrimp ecology in Aotearoa/New Zealand.

**Distribution.** Kermadec and Tonga Volcanic Arc systems, from Bay of Plenty, New Zealand, to Tonga, collected around active venting (Calypso Vent Field and Volcano 1 off Tonga); 111–181 m (fig. 7).

**Remarks.** The molecular and morphological evidence shows that *A. katrinae* sp. nov. is clearly aligned with *A. arenosa* from south-eastern Australia, which occurs at a shallower depth of usually < 25 m depth and is the only other member of the genus.

Diagnostic differences between the two species are small variations in the proportions of the carapace, namely that the transverse cervical groove is at 0.7 cl in *A. katrinae* (0.8 cl in *A. arenosa*); the maxilliped 3 with the ischium wider at ischio-meral suture than long in *A. katrinae* (longer than wide in *A. arenosa*); the maxilliped 3 merus is 0.8 times as long as the ischium in *A. katrinae* (0.6 in *A. arenosa*); the major chelipeds in both males and females share the pronounced serrated meral hook but in *A. katrinae* a serrate semi-circular lobate carina is placed distally, more pronounced than apparent in *A. arenosa* and irrespective of size of the specimen; the palm of the female

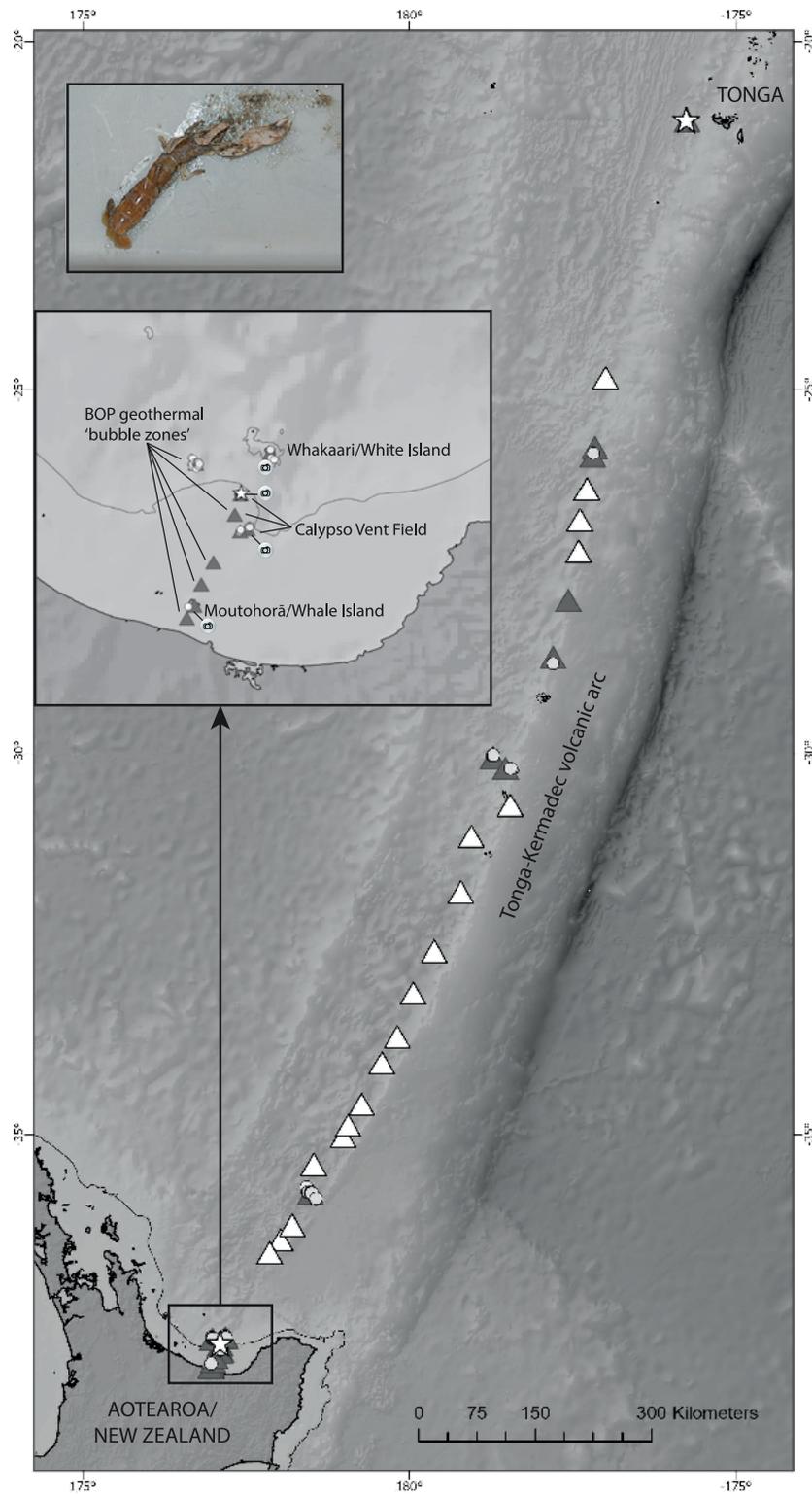


Figure 7. Sample locations of *Arenallianassa katrinae* sp. nov. (white stars). Known hydrothermal vent locations along the Kermadec-Tonga Volcanic Arc are shown in triangles with shallow ( $\leq 200$  m) vents in grey and deep ( $> 200$  m) vents in white. Locations where invertebrate specimens were collected at depths  $\leq 200$  m are indicated by white circles. The 200 m bathymetric line is shown. Lower insert shows close-up of Bay of Plenty (BOP) including locations of geothermal 'bubble zones' reported by Sarano et al. (1989). Upper insert shows colour of an undetermined specimen from type locality (RV *Sonne* stn SO192-2/4). Camera symbols indicate locations of 2010 camera tows.

major cheliped is proportionally longer in *A. katrinae* (longer than the carpus; shorter in *A. arenosa*); the minor cheliped ischium is subequal in length to the merus in *A. katrinae* (longer in *A. arenosa*) and the carpus is narrower (2.8–2.9 times as long as wide in *A. katrinae*, 2.3 times in *A. arenosa*), most notably, the lower margin of the merus is smooth in *A. katrinae* (with a spine at midlength in *A. arenosa*); pereopod 3 propodus is subquadrate and longer, 1.9 times as long as wide in *A. katrinae* with a slightly concave lower margin (1.4 times as long as wide and convex lower margin in *A. arenosa*); the telson is distinctly trapezoid in *A. katrinae* (subquadrate in *A. arenosa*).

Both species share short spiniform setae towards the distal end of the uropodal endopod upper face; *A. katrinae* usually bears a short transverse row of 3–7 setae, and usually 2–3 further single setae or pairs scattered across the posterolateral face (figs 4a, 5h, i, j).

A single female (NIWA 32198) was collected from Volcano 1 off Tonga that matches the description of the new species. However, DNA sequence information indicates some significant divergence (see remarks above) that need to be resolved, pending the collection of further material.

### Ecological remarks

At least seven species of axiideans have been recorded among chemosynthetic-based communities at hydrothermal vents and cold seeps (including mud volcanoes and pockmarks) in the NE and NW Pacific Ocean, NE Atlantic Ocean, and the Mediterranean Sea, in water depths from 12 to 1339 m (summarised by García Raso et al., 2019). These records, which occur primarily in the deep sea (> 200 m), support benthic communities largely based on chemoautotrophy. As well as chemoautotrophic organisms, heterotrophic fauna can be found at or in the vicinity of these sites, where they can benefit from enhanced food availability if they are able to tolerate the environmental conditions (Erickson et al., 2009). In the South Pacific Ocean, an undescribed species of *Vulcanocalliax* Dworschak and Cunha, 2007 and *Paraglypturus tonganus* Ahn, Kim, Ju and Min, 2017 (both Eucalliidae) have been recorded at cold seep and hydrothermal vent sites, respectively (Lörz et al., 2008; Ahn et al., 2017).

Current records for *A. katrinae* sp. nov. are restricted to sites of hydrothermal venting in relatively shallow water (111–181 m) in the Bay of Plenty and 1951 km distant on Volcano 1 on the Tongan Volcanic Arc (fig. 7). The apparently disjunct distribution of *A. katrinae* is likely to be partly explained by habitat availability. This species, like other callianassids, requires soft sandy or muddy sediment in which to burrow. Such habitat is abundant on the shelf in the Bay of Plenty but relatively rare and patchy on the intervening volcanoes of the Kermadec and Tongan Volcanic Arcs. Some of these volcanoes at water depths < 200 m (fig. 7) have been sampled but not with the TV grab used to make the collections reported here. This hydraulic grab can be guided to target soft sediment, is large, can consistently take samples to sediment depths of 50 cm and has successfully recovered ghost shrimp (Ahn et al., 2017). Small grab samplers are successful in shallow water for ghost shrimps up to about 25 mm long (e.g. Poore, 1975) but *A.*

*katrinae*, at 70 mm total length, may have eluded sampling at hydrothermal vent sites between the Bay of Plenty and Volcano 1. It is interesting to note that another ghost shrimp *P. tonganus* has been recorded from a hydrothermally active volcano (Volcano 19) about 400 km south of Volcano 1, but at a water depth of 544 m (Ahn et al., 2017).

Seabed photographs taken near the North Calypso Vent Field collection site of *A. katrinae* show numerous burrow holes and mounds (fig. 8A, B) that are similar to those made by callianassids seen elsewhere in the subtidal zone (compare with Rowden et al., 1998: plate 2). Without knowing the number of holes/mounds made by an individual shrimp, it is not possible to use these photographs or other similar photographs obtained from the sites to determine the actual density of *A. katrinae*. However, the large numbers of holes/mounds seen in the photographs suggests that the shrimp is abundant at this site. Although often less abundant than at intertidal sites, subtidal populations of callianassids are known to achieve high densities at sites favourable for their existence (e.g. 59 m<sup>-2</sup>; Rowden and Jones, 1994), particularly in organic rich sediments (~1000 m<sup>-2</sup>; Lemaître and Rodrigues, 1991). Hydrothermal sediments are generally organic-rich and, furthermore, host abundant bacterial communities that thrive in these methanic and sulphidic sediments (Teske et al., 2002). Adult callianassid diet is primarily based on deposited or redeposited organic matter (e.g. *A. arenosa*; Boon et al., 1997) but some callianassids are thought to “garden” or utilise bacteria in their burrows where conditions are suitable (Koller et al., 2006). Thus, it is possible that the apparently abundant population of *A. katrinae* at the Calypso Vent Field could be due to the existence of this type of bacteria/food-rich habitat in the region. While no physical collections of specimens have been attempted at hydrothermal vent sites shallower than the aforementioned sites, seabed photographs taken near Moutohorā/Whale Island and Whakaari/White Island at water depths of 30–244 m also show numerous burrow holes and mounds indicative of the presence of *A. katrinae* (fig. 8C, D). Should these features be confirmed in subsequent samples to have indeed been made by this shrimp, then this species will have to be considered abundant in the Bay of Plenty (e.g. occupying all of the so-called “bubble zones” of Sarano et al., 1989, see fig. 7) than indicated by the current physical records reported here, including at relatively shallow depths. Callianassids are important bioturbators of soft sediment, turning over large volumes of sediment (e.g. 96 kg [dry] m<sup>-2</sup> yr<sup>-1</sup> for an annual density range of 11–25 individuals m<sup>-2</sup>; Berkenbusch and Rowden, 1999), influencing nutrient cycling (Webb and Eyre, 2004) and biodiversity patterns (Berkenbusch et al., 2000). As such, *A. katrinae* is also likely to be an important ecosystem engineer (Berkenbusch and Rowden, 2003), particularly if it occupies large areas of the Bay of Plenty shelf.

### New Zealand Callianassoidea

Yaldwyn and Webber (2011) and Webber et al. (2010) listed four species of ghost shrimps in the family Callianassidae using three subfamilies now treated as families: (1) *Callianassa filholi* (Callianassidae), a common intertidal to

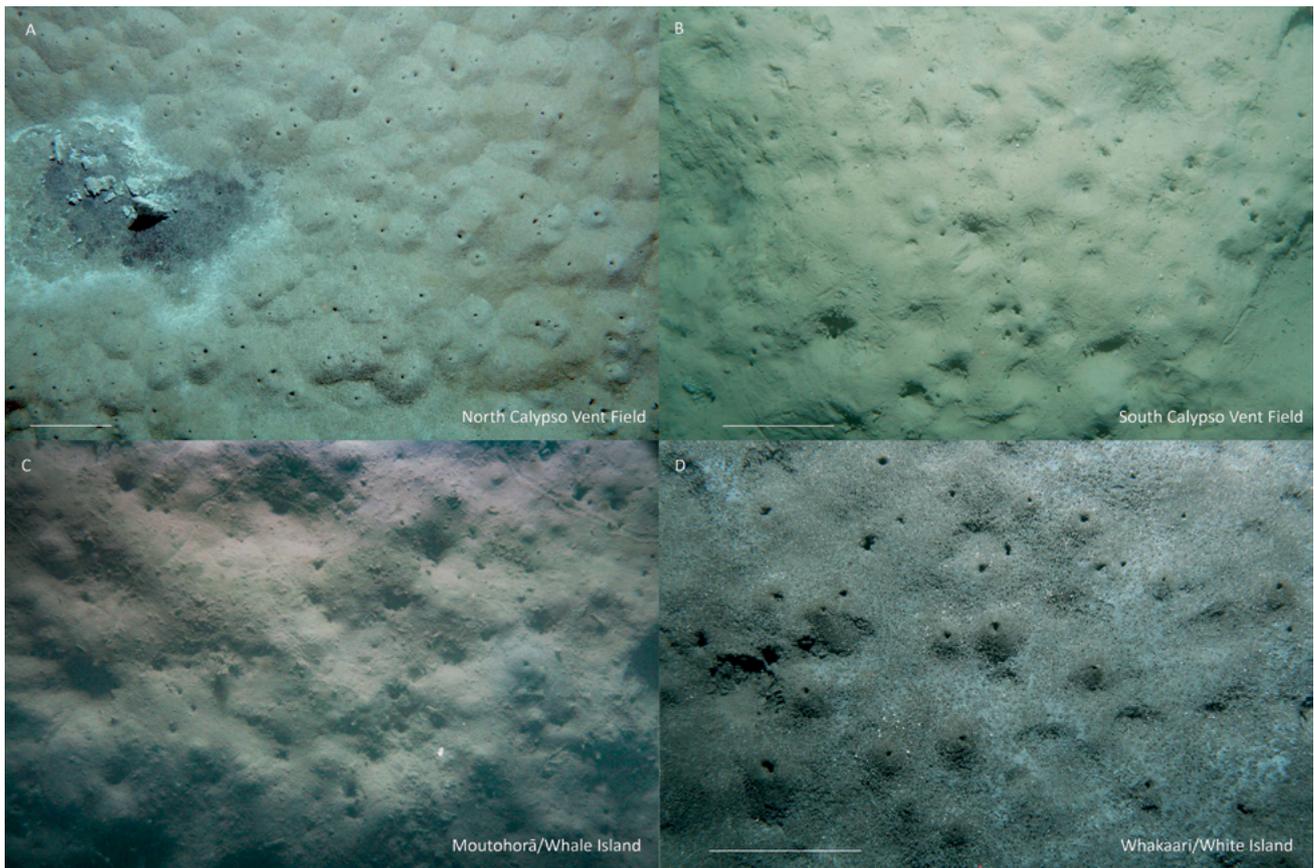


Figure 8. Seafloor images taken by NIWA's Deep-Towed Imaging System (DTIS) camera sled during 2010 RV Kaharoa voyage to the Bay of Plenty. a, North Calypso Vent, stn KAH1004/5, approx. depth 175 m; b, South Calypso Vent, stn KAH1004/8, approx. depth 195 m; c, Moutohorā/Whale Island, stn KAH1004/12, 20–30 m depth; d, Whakaari/White Island, stn KAH1004/14, approx. 225 m depth. Scale bars = 200 mm.

shallow subtidal species endemic throughout New Zealand, now accepted as *Filhollianassa filholi* (A. Milne Edwards, 1879); (2) *Corallianassa articulata* (Callichiridae), the New Zealand record now accepted as *Articullichirus chiltoni* Poore, Dworschak and Schnabel, 2022; (3) *Corallianassa* cf. *collaroy*, reported from New Zealand as *Glypturus collaroy* (Poore and Griffin, 1979) by Sakai (2005) is unlikely to be this Australian species (Poore et al. 2022); and (4) *Vulcanocalliax* sp. (Lörz et al., 2008) (now in Callianopsidae). More recently, Ah Yong (2015) added a single record of *Paratrypaea* sp. from the Kermadec Islands, and *A. katrinae* herein described (both Callianassidae) now brings the known fauna to six species.

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