European Journal of Taxonomy 453: 1–16
https://doi.org/10.5852/ejt.2018.453

ISSN 2118-9773
www.europeanjournaloftaxonomy.eu
2018 · Mazancourt V. de *et al.*

Research article

urn:lsid:zoobank.org:pub:445C8252-5FA2-49AA-AB89-E1C2DDEBEE7F

Caridina variabilirostris (Crustacea: Decapoda: Atyidae), a new species of freshwater shrimp from Pohnpei (Micronesia)

Valentin de MAZANCOURT[1,*], Gerard MARQUET[2] & Philippe KEITH[3]

[1,2,3] Muséum national d'Histoire naturelle, Département Adaptations du Vivant, UMR 7208, CP026, 57, rue Cuvier, 75231 Paris, Cedex 05, France.

*Corresponding author: valentin.demazancourt@laposte.net
[2]Email: gmarquet@neuf.fr
[3]Email: keith@mnhn.fr

[1]urn:lsid:zoobank.org:author:1DC1FC86-2988-4EDF-8FC1-053CCD6C06FF
[2]urn:lsid:zoobank.org:author:BB110358-4FA2-4F5B-BF3A-B51F69D81AA9
[3]urn:lsid:zoobank.org:author:FDDE84AB-E459-401C-A9BF-3F16CEEBFD7C

Abstract. Recently, the status of a new species of atyid shrimp from Pohnpei (Micronesia) was discussed in relation to *C. brachydactyla* De Man, 1908 and *C. mertoni* J. Roux, 1911. By combining morphological data with a phylogenetic analysis with closely related species, this species is here described as *Caridina variabilirostris* sp. nov. Notes on its ecological distribution are also provided. The new species is characterized by a highly variable rostrum and is present in rivers all over Pohnpei Island. The status of this new species is clarified and it is shown that neither *C. brachydactyla* De Man 1908 nor *C. mertoni* J. Roux, 1911 occur on Pohnpei Island.

Keywords. 16S, molecular, integrative taxonomy, island, morphology.

Mazancourt V. de, Marquet G. & Keith P. 2018. *Caridina variabilirostris* (Crustacea: Decapoda: Atyidae), a new species of freshwater shrimp from Pohnpei (Micronesia). *European Journal of Taxonomy* 453: 1–16. https://doi.org/10.5852/ejt.2018.453

Introduction

Micronesia is a vast expanse of more than 2000 Pacific islands and atolls stretching from the Caroline and Mariana Islands in the West, to the Marshall, Nauru and Kiribati Islands in the East. The Caroline Islands consist of a chain of seamounts, atolls and high islands extended southeastward to the Marshall Islands. The high island of Pohnpei (formely known as Ponape) is situated at 6°54′ N latitude and 158°14′ E longitude (Fig.1). It belongs to Pohnpei State, one of the four states in the Federated State of Micronesia. The island of Pohnpei covers 345 km^2. The highest elevation point is 791 m. Aged of 8.7 Ma, this volcanic island was not only the remnant of a hotspot trace, but was also produced in a fracture-induced subduction-related tectonic environment (Rehman *et al.* 2013).

The freshwater shrimp genus *Caridina* Milne Edwards, 1837, comprising 298 species (WoRMS database, as of May 2018) and mostly present in the Indo-Pacific region, is the most diversified genus of the Atyidae (De Grave *et al.* 2015) and an important ecological component in the tropical streams (Covich *et al.* 1999; Pringle *et al.* 1993). Its high diversity combined with the lack of informative morphological characters has led to a confused taxonomy (Richard & Clark 2009). Indeed, until recently, the taxonomy of the genus was mainly based on morphological characters. Some of those have been proven highly variable within a species (e.g., rostrum shape and indentation or coloration) and so taxonomically non-informative, making it difficult to establish boundaries between species (Rintelen & Cai 2009; Mazancourt *et al.* 2017). Thus, there is a need for an integrative and standardized approach to improve the group's systematics, focusing on informative morphological features and using molecular characters (Page *et al.* 2005; Page & Hughes 2011).

Maciolek & Ford (1987) recorded *Caridina brachydactyla* De Man, 1908 among seven species of Atyidae in rivers on Pohnpei. Later, this species was not collected either by Nelson *et al.* (1996) or by Buden *et al.* (2001). Keith *et al.* (2012), reviewing the decapods of Ponhpei, conducted a freshwater survey from 7 to 17 March 2012, identified the material of *Caridina* belonging to the complex of *C. nilotica* as *C. brachydactyla* or *C. mertoni* Roux, 1911 (following the previous identifications made from Guam, another Micronesian island, by Leberer & Cai 2003).

One of the aims of the Muséum national d'Histoire naturelle (MNHN) in Paris is to carry out faunistic inventories of rivers in tropical islands in order to establish a better protection of these fragile ecosystems and, in this context, to clarify taxonomy of poorly known organisms. As we examined more and more specimens from Pohnpei, we gradually started to question the validity of some species from this island. Consequently, we here re-examined our specimens collected in 2012 in combining morphological data with a 16S mtDNA analysis and found that neither *C. brachydactyla* nor *C. mertoni* occur in Pohnpei, but have been confused until now with one undescribed species. Recently, Mazancourt *et al.* (2017) highlighted the "Pinocchio-shrimp effect", in this species, which has a variable length of the rostrum depending on the altitude.

Detailed description of this new species is given as well as its ecological distribution. The position of this species is clarified by comparing it with *C. brachydactyla* and *C. mertoni.*

Material and methods

Abbreviations for collections

MNHN = Muséum national d'Histoire naturelle, Paris
NHM = Natural History Museum, London
NMB = Naturhistorisches Museum Basel, Basel
RMNH = Rijksmuseum van Natuurlijke Historie (now the Naturalis Biodiversity Center, Leiden)
WK = Werner Klotz's collection
ZRC = Zoological Reference Collection, National University of Singapore, Singapore

Abbreviations for morphological analyses

cl = carapace length (mm): measured from post-orbital margin to posterior margin of the carapace
P1 = first pereopod
P2 = second pereopod
P3 = third pereopod
P5 = fifth pereopod
Pl1 = first pleopod
Pl2 = second pleopod

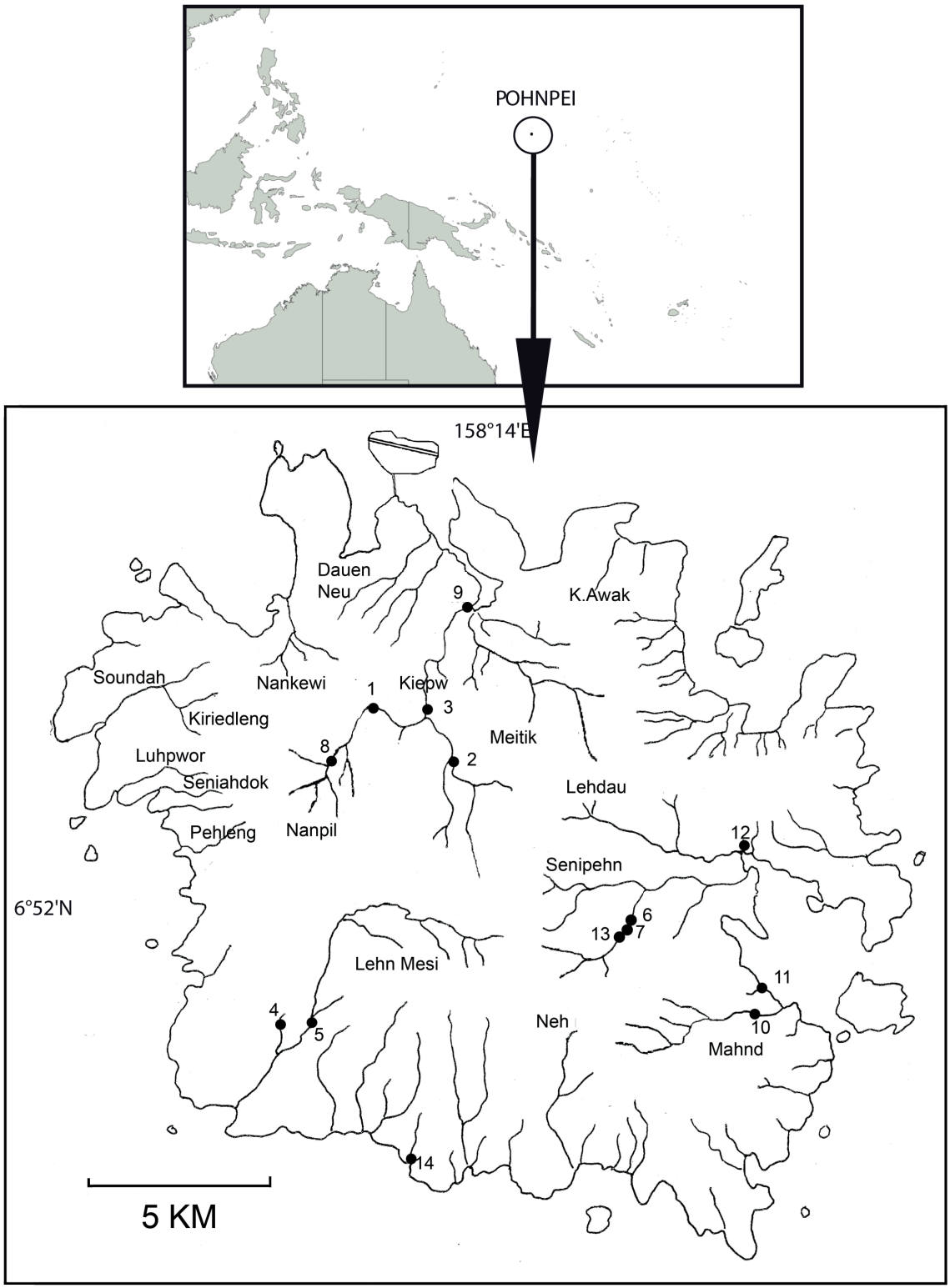

Fig. 1. Map of Pohnpei Island showing sampling stations (black dots) with their number (refers to Table 1).

Table 1. Sampling localities data.

	Dates	Coordinates	Rivers	Altitude (m)
Station 1	9 Mar. 2012	06°55.242′ N, 158°12.265′ E	Nanpil	127
Station 2	9 Mar. 2012	06°54.498′ N, 158°13.270′ E	Nanpil	93
Station 3	9 Mar. 2012	06°55.111′ N, 158°12.878′ E	Nanpil	52
Station 4	10 Mar. 2012	06°51.055′ N, 158°10.890′ E	Lehn Mesi	197
Station 5	10 Mar. 2012	06°51.107′ N, 158°11.896′ E	Lehn Mesi	139
Station 6	12 Mar. 2012	06°51.895′ N, 158°15.810′ E	Senipehn	–
Station 7	12 Mar. 2012	06°51.906′ N, 158°16.010′ E	Senipehn	95
Station 8	13 Mar. 2012	06°54.252′ N, 158°11.491′ E	Nanpil	180
Station 9	13 Mar. 2012	06°56.609′ N, 158°13.550′ E	Nanpil estuary	5
Station 10	14 Mar. 2012	06°50.221′ N, 158°17.212′ E	Mahnd	107
Station 11	14 Mar. 2012	06°51.120′ N, 158°17.854′ E	"River 1" estuary	5
Station 12	14 Mar. 2012	06°53.221′ N, 158°17.44′ E	"Petroglyphe River"	5
Station 13	15 Mar. 2012	06°51.795′ N, 158°15.622′ E	Senipehn	119
Station 14	10 Mar. 2012	06°48.579′ N, 158°12.639′ E	"River 2" estuary	5

Collection of specimens

Rivers and sites surveyed in March 2012 are indicated in Figure 1 and Table 1. Specimens from Pohnpei were collected by electrofishing (portable Dekka 3000 electric device, Germany). All material preserved in 75%–95% alcohol has been deposited in the collections of the Muséum national d'Histoire naturelle in Paris (MNHN, specimens n° MNHN-IU-2018-231 to MNHN-IU-2018-256).

DNA extraction, amplification and sequencing

For recent specimens, DNA was extracted from abdominal tissues using the semi-automatic Eppendorf ep-Motion 5075 robot. Fragments of the mitochondrial 16S rRNA (~ 520 bp) were amplified using the primers 16Sa-L (CGCCTGTTTATCAAAAACAT) and 16Sb-H2 (CTCCGGTTTGAACTCAGATCA) (Palumbi 1996). DNA amplification was performed in 25 µl PCR reactions, containing approximately 3 ng of template DNA, 2.5 mM $MgCl_2$, 0.26 mM of each nucleotide, 0.3 µM of each primer, 5% DMSO, 1 ng of BSA and 1.5 units of QBIOTAQ polymerase (MPBiomedicals). Amplification products were generated by an initial denaturation step of 4 min at 94°C followed by 35 cycles of denaturation at 94°C for 30 s, annealing at 52°C for 40 s, extension at 72°C for 60 s and a final extension step at 72°C for 7 min.

For old collection specimens (syntypes of *C. mertoni*), a CTAB protocol was used to extract DNA from pleopods. A shorter fragment of the 16S rRNA (332 bp) was amplified using two newly designed primers: 16S-Car-81F (AGGTAGCATAATAAATAGTC) and 16S-Car-413R (CTGTTATCCCTAAAGTAAC).

DNA amplification was performed in 25µl PCR reactions, containing 2.5 mM $MgCl_2$, 0.26 mM of each nucleotide, 0.3 µM of each primer, 1 ng of BSA and 1.5 units of QBIOTAQ polymerase (MPBiomedicals). Amplification products were generated by an initial denaturation step of 4 min at 94°C followed by 45 cycles of denaturation at 94°C for 30 s, annealing at 55°C for 30 s, extension at 72°C for 40 s and a final extension step at 72°C for 7 min.

PCR products were sequenced using the same primers and in both directions to insure the accuracy of base calls. Chromatograms were edited using Geneious v. 8 software (Kearse *et al.* 2012). All sequences were deposited in GenBank (Numbers MH476222 to MH476227). A sequence retrieved from GenBank for *Paratya australiensis* published by Page *et al.* (2007) was included in our analysis, used as outgroup.

A total of 17 recent specimens were sequenced (Table 2): six of the new species, of which two firstly identified as *C. brachydactyla* with a long rostrum and four as *C. mertoni* with a short rostrum; five of *C. mertoni* from Kolombangara Island; three type specimens of *C. variabilis* Mazancourt, Rogers & Keith, 2018 and three of *C. brachydactyla* from the type locality, Sulawesi. In addition, three old collection specimens, syntypes of *C. mertoni* from Kai Island were included (Mazancourt *et al.* 2018).

Molecular analyses

DNA sequences were aligned using MEGA7 software (Kumar *et al.* 2016) with Muscle algorithm (Edgar 2004). Using Bayesian information criterion in PartitionFinder (Lanfear *et al.* 2012), we retained the HKY + G + I model. Best-scoring Maximum Likelihood (ML) trees were estimated using RAxML HPC2 v. 8.2.10 (Stamatakis 2014) implemented in the Cyber Infrastructure for Phylogenetic Research (CIPRES) portal v. 3.1. (Miller *et al.* 2010). One hundred independent searches, each starting from

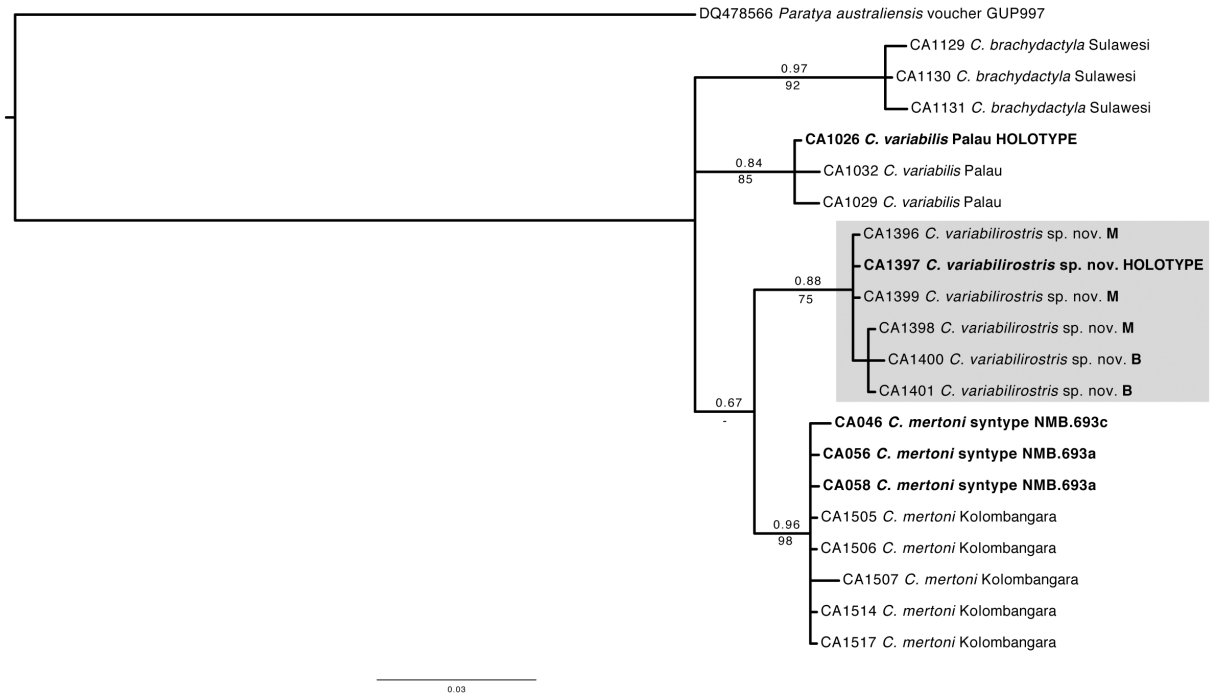

Fig. 2. Neighbour-Joining tree of the 16S sequences of the specimens. Numbers on branches indicate bootstrap values. Letters 'M' indicate specimens firstly identified as *Caridina mertoni* and letters 'B' indicate specimens firstly identified as *Caridina brachydactyla*.

Table 2. Specimens used in the genetic analysis.

Specimen n°	Species	Locality	Firstly ident. as	GenBank n°	Reference
CA1396	*C. variabilirostris*	Pohnpei (St. 1)	*C. mertoni*	MH476222	this study
CA1397	*C. variabilirostris*	Pohnpei (St. 8)	*C. mertoni*	MH476223	this study
CA1398	*C. variabilirostris*	Pohnpei (St. 8)	*C. mertoni*	MH476224	this study
CA1399	*C. variabilirostris*	Pohnpei (St. 8)	*C. mertoni*	MH476225	this study
CA1400	*C. variabilirostris*	Pohnpei (St. 9)	*C. brachydactyla*	MH476226	this study
CA1401	*C. variabilirostris*	Pohnpei (St. 9)	*C. brachydactyla*	MH476227	this study
CA1026	*C. variabilis*	Palau		MG707146	Mazancourt *et al*. 2018
CA1029	*C. variabilis*	Palau		MG707148	Mazancourt *et al*. 2018
CA1032	*C. variabilis*	Palau		MG707147	Mazancourt *et al*. 2018
CA1129	*C. brachydactyla*	Indonesia		MG707169	Mazancourt *et al*. 2018
CA1130	*C. brachydactyla*	Indonesia		MG707170	Mazancourt *et al*. 2018
CA1131	*C. brachydactyla*	Indonesia		MG707171	Mazancourt *et al*. 2018
CA046	*C. mertoni*	Indonesia		MG707138	Mazancourt *et al*. 2018
CA056	*C. mertoni*	Indonesia		MG707139	Mazancourt *et al*. 2018
CA058	*C. mertoni*	Indonesia		MG707140	Mazancourt *et al*. 2018
CA1505	*C. mertoni*	Solomon Islands		MG707141	Mazancourt *et al*. 2018
CA1506	*C. mertoni*	Solomon Islands		MG707142	Mazancourt *et al*. 2018
CA1507	*C. mertoni*	Solomon Islands		MG707143	Mazancourt *et al*. 2018
CA1514	*C. mertoni*	Solomon Islands		MG707144	Mazancourt *et al*. 2018
CA1517	*C. mertoni*	Solomon Islands		MG707145	Mazancourt *et al*. 2018
GUP997	*Paratya australiensis*	Australia		DQ478566	Page *et al*. 2007

distinct random trees, were conducted. Robustness of the nodes was assessed using non-parametric bootstrapping (Felsenstein 1985) with 1000 bootstrap replicates. Best-scoring Bayesian Inference trees were estimated using MrBayes v. 3.2.6 (Ronquist & Huelsenbeck 2003) also implemented in CIPRES with the previously determined model, running for 10 000 000 generations, a sampling frequency of 2000 and a burn in of 25%. Support for nodes was determined using posterior probabilities calculated by MrBayes.

Morphological comparison

The rostrum, general cephalon, pereopods 1, 2, 3 and 5 and abdomen were observed using a stereoscopic microscope. The proportions of the various joints of the appendages were measured using microphotographs and AnalySIS Works software (Olympus). Drawings were made using the "Digital Inking" method (Coleman 2003, 2006) by tracing vectorial paths on stacks of high-resolution photographs using Adobe Illustrator (CS6) and a WACOM MPTZ-1230 graphic tablet.

Results

Collection of specimens

About 50 specimens were collected by electro-fishing in the different rivers prospected in Pohnpei. Of these, 26 were sequenced, 18 with a short rostrum and eight with a long one. A representative sample of six specimens is shown here in the genetic study.

Phylogenetic analyses

After checking that consensus trees obtained from the two different methods were congruent, we decided to show the Bayesian consensus tree with both the ML bootstrap values and Bayesian posterior probabilities on branches. The specimens are grouped in four distinct and moderately supported clades. The most basal comprises the specimens of *C. brachydactyla* from Sulawesi (type locality), then, the type specimens of *C. variabilis* and, finally, two sister clades, one comprising recent and old specimens of *C. mertoni* and the other the specimens from Pohnpei. Due to the low support values, we cannot discuss the affinities of the different species, but we can confidently assert that the terminal clades are distinct species and consider the last one to be a new species that we describe below.

Taxonomy

Class Malacostraca Latreille, 1802
Order Decapoda Latreille, 1802
Family Atyidae De Haan, 1849
Genus *Caridina* H. Milne Edwards, 1837

Caridina variabilirostris sp. nov.
urn:lsid:zoobank.org:act:63F36D6C-9049-4D5E-902E-D38A3BCA3B0A
Figs 3–4

Etymology

The new species is named *variabilirostris* for its variable rostrum length.

Material examined

Holotype

POHNPEI (Station 8): ♂, cl 3.5 mm, Nanpil river, 06°54.252′ N, 158°11.491′ E, 180 m a.s.l., 13 Mar. 2012 (MNHN-IU-2018-231, DNA: CA1397).

Paratypes

POHNPEI – **Nanpil river (Station 1)**: 1 ♂, cl 3.2 mm, 06°55.242′ N, 158°12.265′ E, 127 m a.s.l., 9 Mar. 2012, (MNHN-IU-2018-232); 1 ♀, cl 4.6 mm, same data as for preceding (MNHN-IU-2018-233); 1 ♀ ovig., cl 4.1 mm, same data as for preceding (MNHN-IU-2018-234, DNA: CA1396). – **Nanpil river (Station 3)**: 1 ♂, cl 3.4 mm 06°55.111′ N, 158°12.878′ E, 52 m a.s.l., 9 Mar. 2012 (MNHN-IU-2018-235); 1 ♀ ovig., cl 4.5 mm, same data as for preceding (MNHN-IU-2018-236). – **Lehn Mesi river (Station 5)**: 2 ♀♀, cl 4.7 mm (MNHN-IU-2018-237) and 4.8 mm (MNHN-IU-2018-238); 1 ♀ ovig., cl 4.7 mm (MNHN-IU-2018-239), 06°51.107′ N, 158°11.896′ E, 139 m a.s.l., 10 Mar. 2012. – **Senipehn river (Station 7)**: 1 ♀, 06°51.906′ N, 158°16.010′ E, 95 m a.s.l., 12 Mar. 2012, cl 4.4 mm (MNHN-IU-2018-240); 2 ♀♀, ovig., cl. 4.1 mm (MNHN-IU-2018-241) and 4.5 mm (MNHN-IU-2018-242), same data as for preceding. – **Nanpil river (Station 8)**: 3 ♂♂, cl 3.4 mm (MNHN-IU-2018-243, DNA: CA1399), 3.5 mm (MNHN-IU-2018-244) and 3.6 mm (MNHN-IU-2018-245, DNA: CA1398), 06°54.252′ N, 158°11.491′ E, 180 m a.s.l., 13 Mar. 2012; 1 ♀, cl 4.4 mm (MNHN-IU-2018-246), same data as for preceding; 1 ♀ ovig., cl 5.1 mm (MNHN-IU-2018-247), same data as for preceding. – **Nanpil estuary (Station 9)**: 2 ♂♂, cl 2.2 mm (MNHN-IU-2018-248, DNA: CA1401) and 2.7 mm (MNHN-IU-2018-249), 06°56.609′ N, 158°13.550′ E, 5 m a.s.l., 13 Mar. 2012; 2 ♀♀, 3.5 mm (MNHN-IU-2018-250, DNA: CA1400) and 3.7 mm (MNHN-IU-2018-251), same data as for preceding; 2 ♀♀ ovig., cl 4.0 mm (MNHN-IU-2018-252) and 4.4 mm (MNHN-IU-2018-253), same data as for preceding. – **Mahnd river (Station 10)**: 2 ♂♂, cl 2.9 mm (MNHN-IU-2018-254) and 3.3 mm (MNHN-IU-2018-255), 06°50.221′ N, 158°17.212′ E, 107 m a.s.l., 14 Mar. 2012; 1 ♀ ovig., cl. 4.3 mm (MNHN-IU-2018-256), same data as for preceding.

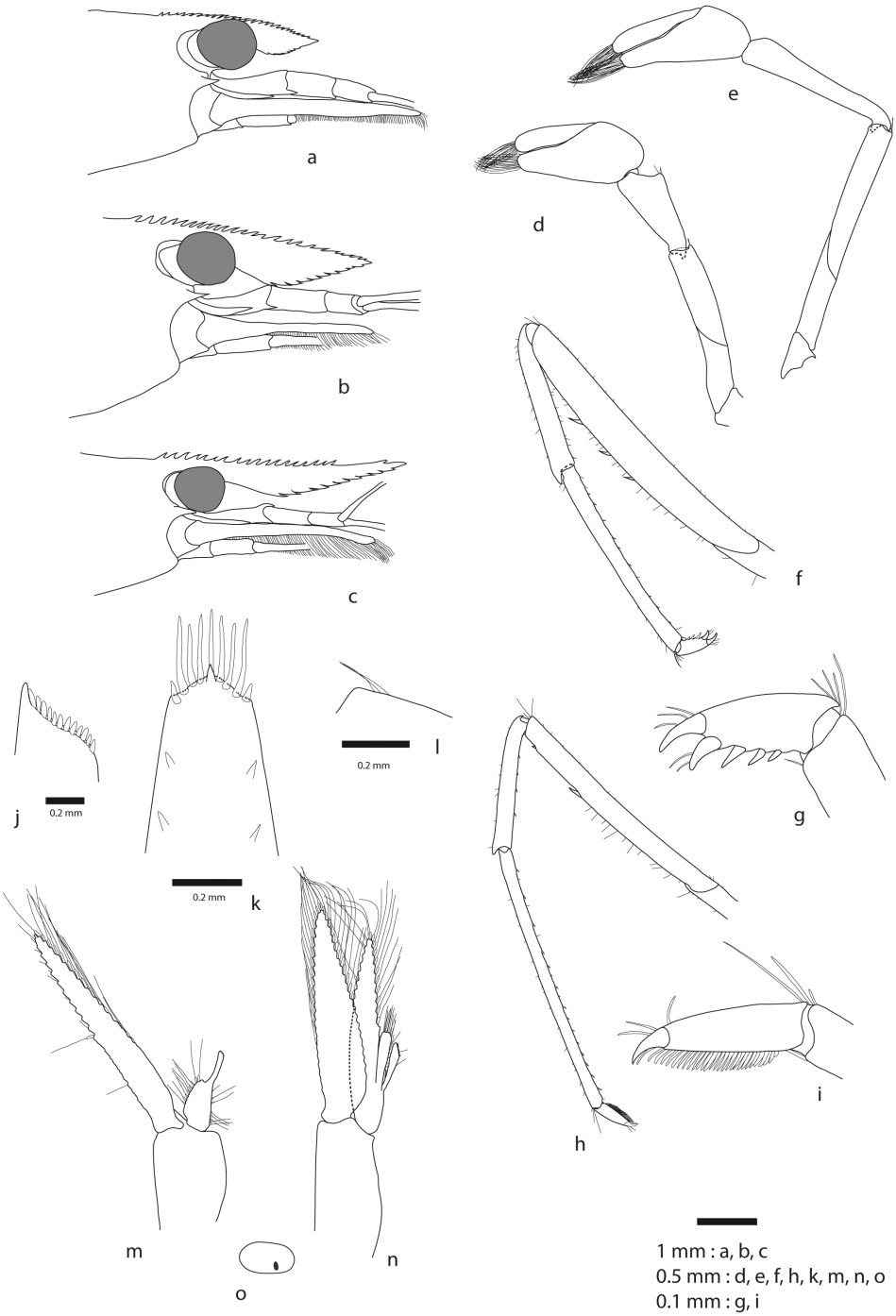

Fig. 3. *Caridina variabilirostris* sp. nov., showing the variation in rostrum length related to the altitude (a–c), drawings made from different specimens. **a, m–n.** ♂, cl 3.5 mm (MNHN-IU-2018-244). **a.** Rostrum. **m.** First pleiopod. **n.** Second pleiopod. **b.** ♀, cl 5.6 mm, rostrum (MNHN-IU-2018-252). **c, j, o.** ♀, cl 4.0 mm (MNHN-IU-2018-253) **c.** Rostrum. **j.** Uropodial diaeresis. **o.** Eggs. **d–i, k.** ♀, cl 3.5 mm (MNHN-IU-2018-250). **d.** First pereopod. **e.** Second pereopod. **f.** Third pereopod. **g.** Dactylus of third pereopod. **h.** Fifth pereopod. **i.** Dactylus of fifth pereopod. **k.** Telson. l. ♀, cl 4.3 mm, pre-anal carina (MNHN-IU-2018-256). of third pereopod. **h.** Fifth pereopod. **i.** Dactylus of fifth pereopod. **k.** Telson. **l.** ♀, cl 4.3 mm, pre-anal carina (MNHN-IU-2018-256).

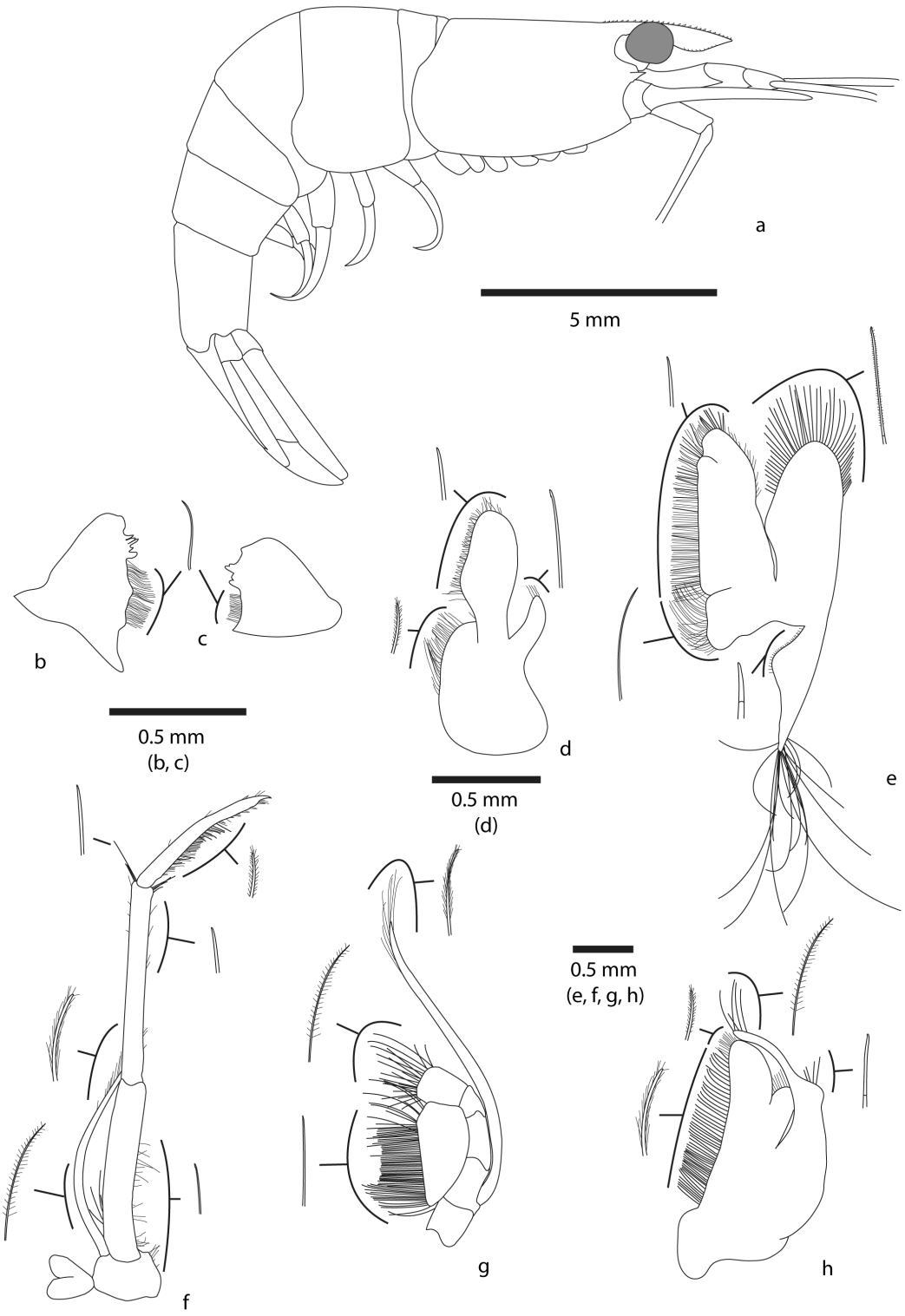

Fig. 4. *Caridina variabilirostris* sp. nov., showing drawings made from different specimens: **a.** ♂, cl 3.5 mm, general appearance (MNHN-IU-2018-244). **c–d.** ♀, cl 3.5 mm (MNHN-IU-2018-250). **c.** Right mandible. **d.** First maxilla. **b, e–h.** ♀, cl 4.8 mm, (MNHN-IU-2018-238). **b.** Left mandible. **e.** Second maxilla. **f.** Third maxilliped. **g.** Second maxilliped. **h.** First maxilliped.

Comparative material

Caridina brachydactyla De Man, 1908

Lectotype

INDONESIA: 1 ♀ ovig., cl 4.8 mm, Flores, Reo (RMNH Crus.D.977).

Paralectotypes

INDONESIA: 2 ♀♀ ovig., cl 5.3–5.4 mm, Flores, near Mbawa (RMNH Crus.D.255).

Non types

INDONESIA: 1 ♀, cl 5.8 mm, Bali (NMB 1054a); 2 ♂♂, cl 2.7 mm and 3.7 mm (DNA: CA1130), Sulawesi, Palopo, Macaui (WK 63.10); 2 ♀♀ ovig., cl 4.3 mm (DNA: CA1129) and 4.0 mm (DNA: CA1131), and 1 ♀, cl 4.8 mm, Palopo, Tojo (WK 64.10).

Caridina mertoni Roux, 1911

Syntypes

INDONESIA: 2 ♂♂, cl 2.7 mm and 3.8 mm (DNA: CA056) and 1 ♀, cl 4.1 mm (DNA: CA058), Grand Kai, Elat (NMB 693a); 1 ♂, cl 3.1 mm and 1 ♀ ovig., cl 4.8 mm, Grand Kai, Warka (NMB 693b); 1 ♀, cl 4.3 mm (DNA: CA046), Grand Kai, Enralang, (NMB 693c); 1 ♂, cl 3.8 mm, Grand Kai, Elat (MNHN-IU-2015-1819); 1 ♂, cl 3.4 mm, Grand Kai, Elat (MNHN-IU-2015-1820).

Non types

KOLOMBANGARA (SOLOMON ISLANDS) – **Manolu river**: 1 ♂, cl 3.9 mm, 08°05.312′ S, 157°00.813′ E, 10 Nov. 2015 (MNHN-IU-2017-2107, DNA: CA1506); 1 ♂, cl 3.0 mm, same data as for preceding (MNHN-IU-2017-2108, DNA: CA1507); 1 ♂, cl 3.7 mm, same data as for preceding (MNHN-IU-2017-2109, DNA: CA1505); 1 ♀ ovig., cl 3.9 mm, same data as for preceding (MNHN-IU-2017-2110). – **Sulumuni river**: 1 ♀, cl 6.2 mm, 08°02.253′ S, 157°09.257′ E, 12 Nov. 2015 (MNHN-IU-2017-2111, DNA: CA1514); 1 ♀ ovig., cl 4.1 mm, same data as for preceding (MNHN-IU-2017-2112, DNA: CA1517).

Caridina elongapoda Liang & Yan, 1977

Non types

HONG-KONG: 2 ♂♂, cl 2.8–3.5 mm, Pak Tam Chung, W. Klotz leg. (WK 22 09); 1 ♀, cl 4.2 mm and 1 ♂, cl 3.5 mm, Kai Sai Chau, W. Klotz leg. (WK 14 11).

MALAYSIA: 1 ♂, cl 4.2 mm, Pulau Tioman, Sungai Asah, 24 Jun. 1997, Ng *et al.* leg. (ZRC 1998.0865); 1 ♀, cl 4.3 mm, same data as for preceding (ZRC 1998.0865); 1 ♀ ovig., cl 4.3 mm, same data as for preceding (ZRC 1998.0865).

Caridina peninsularis Kemp, 1918

Lectotype

MALAYSIA: 1 ♂, cl 3.2 mm, Penang Island, Botanical garden, Feb. 1916, N. Anandale leg. (MNHN-IU-2015-1749).

Paralectotypes

MALAYSIA: 1 ♀ ovig., cl 5.4 mm, same data as lectotype (MNHN-IU-2015-1750); 1 ♀, cl 3.4 mm, same data as for preceding (NHM 1919.11.1.12-21 (1761124)); 1 ♀ ovig., cl 5.2 mm, same data as for preceding (NHM 1919.11.1.12-21 (1761124)); 1 ♂, cl 3.9 mm, same data as for preceding (NHM 1919.11.1.12-21 (1761124)).

Non types

SINGAPORE: 1 ♀ ovig., cl 5.1 mm, Tanglin (incorrectly spelt "Tangtum" in NHM register and on label, see Richard & Clark 2014), 1958 Bedford and Lanchester leg., D.S. Johnson det. (NHM 1958.8.7.14–17 (1749569)); 1 ♂, cl 4.2 mm, same data as for preceding (NHM 1958.8.7.14–17 (1749569)).

Description

Cephalothorax. Rostrum (Fig. 3a–c): very variable in length, 0.6–1.3 of cl, reaching to scaphocerite apex, armed dorsally with 18–26 teeth, distal unarmed portion 0.0–0.4 times that of armed portion, with one or two subapical teeth, 1–4 teeth on carapace posterior to orbital margin, ventral margin with 4–12 teeth. Number of dorsal teeth behind most proximal ventral tooth 12–18. Rostrum formula (1–4) 18-26+1-2/4-12. Antennular tooth acute, placed slightly below orbital angle. Pterygostomian margin rectangularly rounded.

Head. Eyes well developed, anterior end reaching to 0.7 length of antennular peduncle basal antennomere. Antennular peduncle 0.7 times as long as carapace. Anterolateral angle reaching 0.25 length of second antennomere; second antennomere distinctly longer than third. Stylocerite reaching to 0.7 length of antennular peduncle basal antennomere.

Mouthparts. Mandibles dimorphic; left mandible (Fig. 4b) more developed, corpus large, robust with five strong sharp teeth separated by ridged gap; incisor and molar processes separated by patch of long simple setae. Right mandible (Fig. 4c) with five sharp incisor teeth, medially with group of long setae; molar process narrow, elongate, ridged. First maxilla (Fig. 4d) having a lower lacinia with margin broadly rounded, bearing several rows of plumose setae. Upper lacinia elongate, with medial margin bearing a number of distinct teeth and simple setae, palp bearing long simple setae. Second maxilla (Fig. 4e) upper and middle endite with marginal and submarginal simple or slightly plumose setae. Lower endite with simple setae; palp narrow, shorter than upper endite cleft with few setae. Scaphognathite fringed with long simple setae, tapering posteriorly with some long, curved simple setae at posterior end. First maxilliped (Fig. 4h) endopodite ultimate segment medial margin with long plumose setae. Palp elongate, setose. Exopod flagellum long and narrow distally with marginal plumose setae. Caridean lobe large, with marginal setae. Second maxilliped (Fig. 4g) endopodite ultimate and penultimate antennomeres fused, reflected against basal antennomeres. Ultimate, penultimate and basal antennomeres medial margins with long setae of various types; flagellum very long, slender with marginal plumose setae distally. Third maxilliped (Fig. 4f) with terminal article reaching third antennular peduncle antennomere apex; distal antennomere about 10 times as long as wide, slightly shorter than penultimate, ending in large hamulate apical spine surrounded by simple setae. Penultimate antennomere about eight times as long as wide, with group of transverse rows of simple setae. Exopod flagellum well developed, about a third the length of endopodite second article, distal margin with long plumose setae.

Pereopods. Pereopods I–IV with epipods pereopod. P1 (Fig. 3d): chela about 1.9–2.2 times as long as wide, movable finger 3.6–4.4 times as long as wide, 1.2–1.7 times length of palm; carpus 2.0–2.7 times as long as wide. P2 (Fig. 3e) more slender and longer than first pereopod with chela 2.1–2.6 times as long as wide: movable finger 3.9–5.8 times as long as wide, 1.3–2.0 times length of palm; carpus slender 4.4–6.5 times as long as wide. P3 (Fig. 3f): slender, dactylus (Fig. 3g) 2.4–3.3 times as long as wide, including terminal spine), flexor margin with 4–6 spines parallel to terminal one; propodus 13.8–20.5 times as long as wide, 4.8–8.4 times as long as dactylus. P5 (Fig. 3h): dactylus (Fig. 3i) 2.1–4.2 as long as wide with 18–29 spinules on flexor margin; propodus 15.8–28.4 times as long as wide, 5.3–8.6 times as long as dactylus.

Abdomen. Third abdominal (Fig. 4a) somite with moderately convex dorsal profile. Sixth abdominal somite about 0.68 of carapace, 1.76 times as long as fifth somite, slightly shorter than telson. Telson

(Fig. 3k) with four pairs of dorsal spines and one pair of dorsolateral spines; posterior margin, with or without median process, exhibits variations, triangular or rounded with four to five intermediate simple setae longer or equal than lateral ones.

Pl1 (Fig. 3m). Endopod foliform with a developed appendix interna in males. Pl2 (Fig. 3n): appendix masculina on second pleopod reaching 0.52 times length of endopod; appendix interna reaching about 0.85 times appendix masculina length.

Preanal carina (Fig. 3l). Unarmed.

Uropodal diaeresis (Fig. 3j). With 10–15 spinules.

Ovigerous female egg size (Fig. 3o). 0.39–0.49x0.24–0. 29 mm.

Habitat

This species is found among macrophytes in flowing fresh water of the rivers of Pohnpei all along the course, showing good adaptability to different temperatures and hydrological conditions. It is more abundant in higher elevations due to reduced predator pressure.

Colour pattern (Fig. 5)

The colour of the body is hyaline with many reds dots. An oblique red band on the cephalothorax is very characteristic.

Fig. 5. *Caridina variabilirostris* sp. nov., live coloration (Photos: P. Keith)

Distribution

This new species is currently known from Pohnpei Island only.

Remarks

Caridina variabilirostris sp. nov. is most similar to *C. mertoni*, *C. brachydactyla*, *C. elongapoda* Liang & Yan, 1977 and *C. peninsularis* Kemp, 1918. The new species displays a variable rostrum length among specimens. When the rostrum is short the general appearance is like *C. mertoni*, whereas when the rostrum is long, the general appearance is of *C. brachydactyla*. In *C. variabilirostris* spec. nov. the antennal spine is placed below the orbital angle, the P5 dactylus with 18–29 spinules whereas in *C. mertoni*, the antennal spine is somewhat fused with the orbital angle and P5 dactylus with 24–43 spinules. *C. variabilirostris* spec. nov. differs from *C. brachydactyla* by the absence of spine on the preanal carina, a shorter distal unarmed portion of the rostrum 0.0–0.4 (vs 0.4–1.6) times that of armed portion, by a longer P5 propodus, which is 5.3–8.6 time as long as the dactylus (vs 3.9–5.7) and a lower number of spinules on the P5 dactylus (32–42 in *C. brachydactyla*).

This new species resembles *C. elongapoda* in its preanal carina lacking a spine, but it has larger eggs 0.39–0.49 × 0.24–0. 29 mm (vs 0.39–0.40 × 0.22–0.23), and the P5 dactylus is shorter 2.1–4.2 (vs 4.3–5.6) and with fewer spinules 18–29 (vs 33–44). It also differs from *C. peninsularis* by a lower number of dorsal rostrum teeth (18–26 vs 20–35), a lower P3 propodus-dactylus ratio (4.8–8.4 vs 4.4–5.8) and a P5 dactylus with 18–29 spinules vs 25–38.

The new species looks very much like *C. variabilis* from Guam and Palau with the preanal always non-armed, the number of teeth and their placement on the rostrum, the proportions between the joints of pereiopods, and the egg size (Mazancourt *et al.* 2018). But the P5 dactylus has a single terminal spine and a short distal propodus seta (vs two strong distal spines and a very long distal propodus seta), and the posterior margin of the telson with intermediate setae longer or equal than lateral ones (vs shorter or equal than lateral ones).

Discussion

Recently Mazancourt *et al.* (2017) highligted the "Pinocchio shrimp effect" on this new species. Indeed some specimens with a long rostrum were attributed morphologically to *C. brachydactyla* whereas others, with a short rostrum, were identified as *C. mertoni*. In fact all specimens belong to this new species. Indeed the rostrum length widely used in the taxonomy of *Caridina* might not be as reliable as it was thought. It is highly plastic and varies with environmental parameters.

Despite an increasing use of integrative taxonomy for the systematics of *Caridina* (and shrimps in general), some authors keep describing new species based not only on morphology alone, but even on a single character. For example, different species described by Richard & Clark (2009, 2014) based on rostrum morphology proved to be synonyms, and the differences observed were after all recognized as intra-specific variation (see Wood *et al.* 2018; Mazancourt *et al.* unpublished).

We thus advocate to always perform some molecular work prior to studying a new species in order to unveil this kind of variation within a species, focus on the morphology and expose the variation when describing it. Alternatively, if retrieving molecular data is not possible, using a combination of reliable characters seems more sound than a single one. This would allow to provide characters to identify confidently the species when encountered in the field. It is likely that different species described in this genus will prove to be the same one, exhibiting the same kind of polymorphism as we showed here.

Acknowledgements

We would like to thank The Conservation Society of Pohnpei and particularly Eugene Joseph (Director), Francesca Sohl Obispo, Relio Lengsi and Iakop loanis, and the Office of fisheries and aquaculture for their help with processing the research permits. Brian Lynch was an incredible source of knowledge on the biodiversity of Pohnpei. He also facilitated the organisation of various meetings with a number of local stakeholders, including assistance with some aspects of the logistics in the field. Finally, a special thought to P. Gerbeaux, M. Castelin and L. Taillebois.

The work was supported by the National Museum of Natural History of Paris, the AIMARA Association and the French Ichthyological Society.

References

Buden D.W., Lynch D.B., Short J.W. & Leberer T. 2001. Decapod crustaceans of the headwater streams of Pohnpei, eastern Caroline Islands, Federated States of Micronesia. *Pacific Science* 55 (3): 257–265. https://doi.org/10.1353/psc.2001.0019

Coleman C.O. 2003. "Digital inking": How to make perfect line drawings on computers. *Organisms Diversity and Evolution* 3 (4): 303–304. https://doi.org/10.1078/1439-6092-00081

Coleman C.O. 2006. Substituting time-consuming pencil drawings in arthropod taxonomy using stacks of digital photographs. *Zootaxa* 1360: 61–68.

Covich A.P., Palmer M.A. & Crowl T.A. 1999. The role of benthic invertebrate species in freshwater ecosystems. *BioScience* 49 (2): 119–128. https://doi.org/10.2307/1313537

De Grave S., Smith K.G., Adeler N.A., Allen D.J., Alvarez F., Anker A., Cai Y., Carrizo S.F., Klotz W., Mantelatto F.L., Page T.J., Shy J.Y., Villalobos J.L. & Wowor D. 2015. Dead shrimp blues: a global assessment of extinction risk in freshwater shrimps (Crustacea: Decapoda: Caridea). *PLoS ONE* 10 (3): e0120198. https://doi.org/10.1371/journal.pone.0120198

Edgar R.C. 2004. MUSCLE: multiple sequence alignment with high accuracy and high throughput. *Nucleic Acids Research* 32 (5): 1792–1797. https://doi.org/10.1093/nar/gkh340

Felsenstein J. 1985. Confidence limits on phylogenies: an approach using the bootstrap. *Evolution* 39: 783–791. https://doi.org/10.1111/j.1558-5646.1985.tb00420.x

Kearse M., Moi R., Wilson A., Stones-Havas S., Cheung M., Sturrock S., Buxton S., Cooper A., Markowitz S., Duran C., Thiere T., Ashton B., Meintjes P. & Drummond A. 2012. Geneious Basic: an integrated and extendable desktop software platform for the organization and analysis of sequence data. *Bioinformatics* 28 (12): 1647–1649. https://doi.org/10.1093/bioinformatics/bts199

Keith P., Gerbeaux P., Marquet G., Taillebois L. & Castelin, M. 2012. *Freshwater Survey of Pohnpei*. Muséum national d'Histoire naturelle, Paris.

Kumar S., Stetcher G. & Tamura K. 2016. MEGA7: Molecular Evolutionary Genetics Analysis Version 7.0 for Bigger Datasets. *Molecular Biology and Evolution* 33 (7): 1870–1874. https://doi.org/10.1093/molbev/msw054

Leberer T. & Cai Y. 2003. Shrimps of the family Atyidae from Guam, Mariana Islands. *Micronesica*, 35–36: 353–358.

Maciolek J.A. & Ford J.L. 1987. Macrofauna and Environment of the Nanpil-Kiepw River, Ponape, Eastern Caroline Islands. *Bulletin of Marine Science* 41 (2): 623–632.

Mazancourt V. de, Marquet G. & Keith P. 2017. The "Pinocchio-shrimp effect": first evidence of rostrum length variation with the environment in *Caridina* H. Milne Edwards, 1837 (Crustacea: Decapoda: Atyidae). *Journal of Crustacean Biology* 37 (3): 249–257. https://doi.org/10.1093/jcbiol/rux025

Mazancourt V. de, Marquet G., Rogers D.C. & Keith P. 2018. Description of a new species of *Caridina* (Crustacea: Decapoda: Atyidae) from two Micronesian islands (Guam and Babeldaob). *Zootaxa* 4377 (1): 39–50. https://doi.org/10.11646/zootaxa.4377.1.3

Miller M., Pfeiffer W. & Schwartz T. 2010. Creating the CIPRES Science Gateway for Inference of Large Phylogenetic Trees. http://www.phylo.org/sub_sections/portal/sc2010_paper.pdf

Nelson S.G., Camacho F.A., Parham J.E., Tibbats R.B., Leberer T. & Smith B.D. 1996. Surveys of the macrofauna of the Nanpil Kiepw and Lehn Mesi rivers of Pohnpei. *South Pacific Regional Environment Programme. Technical Report 103.* University of Guam Marine Laboratory.

Page T.J. & Hughes J.M. 2011. Neither molecular nor morphological data have all the answers; with an example from *Macrobrachium* (Decapoda: Palaemonidae) from Australia. *Zootaxa* 2874: 65–68.

Page T.J., Choy S.C. & Hughes J.M. 2005. The taxonomic feedback loop: symbiosis of morphology & molecules. *Biology Letters* 1: 139–142. https://doi.org/10.1098/rsbl.2005.0298

Page T.J., Rintelen K. von & Hughes J.M. 2007. An island in the stream: Australia's place in the cosmopolitan world of Indo-West Pacific freshwater shrimp (Decapoda: Atyidae: *Caridina*). *Molecular Phylogenetics and Evolution* 43: 645–659. https://doi.org/10.1016/j.ympev.2006.08.007

Palumbi S.R. 1996. Nucleic acids II: the polymerase chain reaction. *In*: D.M. Hillis, B.K. Mable & C. Moritz (eds) *Molecular systematics* 205–247. Sinauer Associates, Sunderland, USA.

Pringle C.M., Blake G.A., Covich A.P., Buzby K.M. & Finley A. 1993. Effects of omnivorous shrimp in a montane tropical stream: sediment removal, disturbance of sessile invertebrates and enhancement of understory algal biomass. *Oecologia* 93: 1–11. https://doi.org/10.1007/BF00321183

Rehman H.U., Nakaya H. & Kawai K. 2013. Geological Origin of the volcanic islands of the Caroline Group in the Federated States of Micronesia, Western Pacific. *South Pacific Studies* 33 (2): 101–118.

Richard J. & Clark P.F. 2009. African *Caridina* (Crustacea: Decapoda: Caridea: Atyidae): redescriptions of *C. africana* Kingsley, 1882, *C. togoensis* Hilgendorf, 1893, *C. natalensis* Bouvier, 1925 and *C. roubaudi* Bouvier, 1925 with descriptions of 14 new species. *Zootaxa* 1995: 1–75.

Richard J. & Clark P.F. 2014. *Caridina simoni* Bouvier, 1904 (Crustacea: Decapoda: Caridea: Atyoidea: Atyidae) and the synonymy by Johnson, 1963. *Zootaxa* 3841 (3): 301–338. https://doi.org/10.11646/zootaxa.3841.3.1

Rintelen K. von & Cai Y. 2009. Radiation of endemic species flocks in ancient lakes: systematic revision of the freshwater shrimp *Caridina* H. Milne Edwards, 1837 (Crustacea: Decapoda: Atyidae) from the ancient lakes of Sulawesi, Indonesia, with the description of eight new species. *Raffles Bulletin of Zoology* 57: 343–452.

Ronquist F. & Huelsenbeck J.P. 2003. MRBAYES 3: Bayesian phylogenetic inference under mixed models. *Bioinformatics* 19: 1572–1574. https://doi.org/10.1093/bioinformatics/btg180

Wood L.E., Daniels S.R. & De Grave S. 2018. *Caridina susuroflabra* Richard & Clark, 2009 is a junior synonym of the widespread *Caridina africana* Kingsley, 1882 (Decapoda, Atyidae). *Crustaceana* 91 (2): 243–249. https://doi.org/10.1163/15685403-00003756

Manuscript received: 23 February 2018
Manuscript accepted: 21 June 2018
Published on: 3 August 2018
Topic editor: Rudy Jocqué
Desk editor: Eva-Maria Levermann