



West Side Story: A molecular and morphological study of *Caridina longicarpus* Roux, 1926 (Decapoda, Caridea, Atyidae) from New Caledonia reveals a new species

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COUVERTURE / COVER:

Typical habitat of *Caridina longicarpus* Roux, 1926, above Ciu waterfall, Canala, New Caledonia. Photograph: V. de Mazancourt. In medallion: *Caridina longicarpus* Roux, 1926: live coloration ovigerous female in left lateral view.

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ABSTRACT

Numerous specimens of freshwater shrimps identified as *Caridina longicarpus* Roux, 1926 were recently collected from New Caledonia. Following an integrative taxonomy approach, they were morphologically and genetically studied. Results of a 16S mtDNA analysis showed that the specimens initially identified as *C. longicarpus* were distributed in two geographically structured clades. Morphological study showed that the shrimps found in rivers draining to the east coast of the island belonged to *C. longicarpus sensu stricto*, whereas those from rivers draining to the west coast belonged to a new species, here described as *Caridina occidentalis* n. sp. Detailed redescription of *C. longicarpus* is provided and a lectotype is designated. The existence of both species in allopatry could be explained by local biogeographical factors such as the topography of the island or oceanic circulation impacting the dispersal of larvae during the planktonic stage.

KEY WORDS

Freshwater shrimp,
Amphidromy,
New Caledonia,
integrative taxonomy,
morphology,
16S,
new species.

RÉSUMÉ

West Side Story : Une étude moléculaire et morphologique de Caridina longicarpus Roux, 1926 (Decapoda, Caridea, Atyidae) de Nouvelle-Calédonie met en évidence une nouvelle espèce.

De nombreux spécimens identifiés comme *Caridina longicarpus* Roux, 1926 ont été collectés récemment en Nouvelle-Calédonie. Suivant une approche de taxonomie intégrative, ils ont été étudiés morphologiquement et génétiquement. L'analyse du marqueur 16S mtDNA a montré que les spécimens initialement identifiés comme *C. longicarpus* se répartissaient en deux clades distincts structurés géographiquement. L'étude morphologique a montré que les crevettes trouvées dans les rivières se jetant vers la côte est de l'île appartenaient à l'espèce *C. longicarpus sensu stricto*, tandis que celles des rivières de la côte ouest représentaient une espèce nouvelle, décrite ici sous le nom de *Caridina occidentalis* n. sp. Une redescription détaillée de *C. longicarpus* est fournie et un lectotype est désigné. L'existence de ces deux espèces en allopatrie peut s'expliquer par des facteurs biogéographiques locaux comme la topographie de l'île ou la circulation océanique qui influe sur la dispersion des larves lors de la phase planctonique.

MOTS CLÉS

Crevette d'eau douce,
Amphidromie,
Nouvelle-Calédonie,
taxonomie intégrative,
morphologie,
16S,
espèce nouvelle.

INTRODUCTION

New Caledonia is an archipelago situated between 164°E–168°E longitude and 20°S–23°S latitude with a surface area of 19 500 km². It is located 1500 km off the east coast of Australia, its nearest neighbours being Vanuatu (230 km northeast) and Fiji (800 km east). It mainly consists of a large island called “La Grande Terre” (16 890 km²) flanked by the Loyalty archipelago (1981 km²) (Choy & Marquet 2002).

Caridina weberi var. *longicarpus* was first described by Roux (1926). It was not represented in the collections from New Caledonia studied by Holthuis (1969). Later, Choy & Marquet (2002) and Marquet *et al.* (2003) reported it under the name *Caridina weberi* De Man, 1892. *Caridina longicarpus* Roux, 1926 is now considered a valid species (De Grave & Fransen 2011). The aim of the present study was to verify the status of *C. longicarpus* through an integrative taxonomic framework by combining morphological data with a 16S mtDNA analysis of recently collected specimens.

MATERIAL AND METHODS

COLLECTION OF SPECIMENS

Numerous specimens were collected in New Caledonia during specific inventories in 1991 by the “Pedcal” expedition, between 1997 and 2003 by one of us (GM), between 1999 & 2002 by the “Chloe” expeditions (Marquet *et al.* 2003) and in October 2010 by the RAP expedition (Conservation International & MNHN). More recently, new specimens were collected in September 2016 during a survey jointly funded by the Province Sud and the Observatoire de l'Environnement en Nouvelle-Calédonie (OEIL), and in November 2016 and November 2017 during the hydrobiological part of the “Our Planet Reviewed” program in New Caledonia. Specimens were collected by electrofishing. Rivers and sites are indicated in Figure 6. All samples preserved in 75–95% ethanol have been deposited in the collections of the Muséum national d'Histoire naturelle (MNHN) in Paris.

MORPHOLOGICAL COMPARISON

The rostrum, the cephalothorax, the pereopods 1, 2, 3 and 5 and the abdomen were observed using either an Olympus SZX7 stereomicroscope with an Olympus DP-20 camera or an Olympus BX51 microscope with a Leica MC170 HD camera, depending on the size of the observed character. The proportions of the various joints of the appendages were measured on microphotographs with the AnalySIS Works software (Olympus) or LAS (Leica Application Suite) software. Drawings were made using the “Digital Inking” method (Coleman 2003, 2006) by tracing vectorial paths on high-resolution photographs using Adobe Illustrator.

ABBREVIATIONS

Institutions

MNHN Muséum national d'Histoire naturelle, Paris;
NMB Naturhistorisches Museum Basel, Basel.

Morphological analyses

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

DNA EXTRACTION, AMPLIFICATION AND SEQUENCING

DNA was extracted from abdominal tissues using the semi-automatic Eppendorf ep-Motion 5075 robot. Fragments of the mitochondrial 16S rRNA (*c.* 520 bp) were amplified using newly designed primers, adapted from Palumbi *et al.* (1996) to our taxa: 16Sar-Lmod (TACTTCTGCCTGTT-TATCAAAAA) and 16Sbmod (GGTCTGAACTCAAAT-CATGTAAA). DNA amplification was performed in 20 µl PCR reactions, containing approximately 3 ng of template DNA, 2.5 mM MgCl₂, 0.26 mM of each nucleotide, 0.3 µM of each primer, 5% DMSO, 1 ng of BSA and 1.5 units of

TABLE 1. — List of the sequences included in the phylogenetic analysis of *Caridina* H. Milne-Edwards, 1837 species.

Species	Collection number	Status	DNA number	GenBank number	Reference
<i>C. occidentalis</i> n. sp.	MNHN-IU-2018-3309	Holotype	CA1657	ON555669	This study
	MNHN-IU-2018-3310	Paratype	CA1656	ON555668	This study
	MNHN-IU-2018-3311	Paratype	CA1611	MK189897	de Mazancourt <i>et al.</i> 2019a
	MNHN-IU-2018-3312	Paratype	CA1658	ON555670	This study
	MNHN-IU-2018-3313	Paratype	CA1883	ON555676	This study
	MNHN-IU-2018-3314	Paratype	CA1884	ON555677	This study
	MNHN-IU-2018-3315	Paratype	CA1885	ON555678	This study
	MNHN-IU-2018-3316	Paratype	CA1886	ON555679	This study
	MNHN-IU-2018-3317	Paratype	CA2049	ON555680	This study
	MNHN-IU-2018-3318	Paratype	CA2050	ON555681	This study
	MNHN-IU-2018-3319	Paratype	CA2051	ON555682	This study
	MNHN-IU-2018-3320	Paratype	CA2052	ON555683	This study
	MNHN-IU-2018-3321	Paratype	CA2053	ON555684	This study
	—	—	GUC908	DQ478535	Page <i>et al.</i> 2007
	—	—	GUC914	DQ478536	Page <i>et al.</i> 2007
<i>C. longicarpus</i> Roux, 1926	MNHN-IU-2018-3322	—	CA1557	MK189892	de Mazancourt <i>et al.</i> 2019a
	MNHN-IU-2018-3323	—	CA1558	ON555647	This study
	MNHN-IU-2018-3324	—	CA1594	ON555648	This study
	MNHN-IU-2018-3325	—	CA1595	ON555649	This study
	MNHN-IU-2018-3326	—	CA1599	MK189895	de Mazancourt <i>et al.</i> 2019a
	MNHN-IU-2018-3327	—	CA1600	ON555651	This study
	MNHN-IU-2018-3328	—	CA1640	ON555653	This study
	MNHN-IU-2018-3329	—	CA1641	ON555654	This study
	MNHN-IU-2018-3330	—	CA1642	ON555655	This study
	MNHN-IU-2018-3331	—	CA1643	ON555656	This study
	MNHN-IU-2018-3332	—	CA1644	ON555657	This study
	MNHN-IU-2018-3333	—	CA1646	ON555658	This study
	MNHN-IU-2018-3334	—	CA1647	ON555659	This study
	MNHN-IU-2018-3335	—	CA1648	ON555660	This study
	MNHN-IU-2018-3336	—	CA1649	ON555661	This study
	MNHN-IU-2018-3337	—	CA1650	ON555662	This study
	MNHN-IU-2018-3338	—	CA1651	ON555663	This study
	MNHN-IU-2018-3339	—	CA1652	ON555664	This study
	MNHN-IU-2018-3340	—	CA1653	ON555665	This study
	MNHN-IU-2018-3341	—	CA1654	ON555666	This study
	MNHN-IU-2018-3342	—	CA1655	ON555667	This study
	MNHN-IU-2018-3343	—	CA1659	ON555671	This study
	MNHN-IU-2018-3344	—	CA1879	ON555672	This study
	MNHN-IU-2018-3345	—	CA1880	ON555673	This study
	MNHN-IU-2018-3346	—	CA1881	ON555674	This study
	MNHN-IU-2018-3347	—	CA1882	ON555675	This study
<i>C. typus</i> H. Milne Edwards, 1837	MNHN-IU-2014-20778	—	CA1568	MK189893	de Mazancourt <i>et al.</i> 2019a
<i>C. tupaia</i> de Mazancourt, Marquet & Keith, 2019	MNHN-IU-2018-260	Holotype	CA2058	MK204717	de Mazancourt <i>et al.</i> 2019b

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 30s, annealing at 52°C for 40s, extension at 72°C for 60s and a final extension step at 72°C for 7 min.

PCR products were sequenced using the same primers and in both directions to ensure the accuracy of base calls. Chromatograms were edited using Geneious v.8 software (<http://www.geneious.com/>; Kearse *et al.* 2012). All sequences were deposited in GenBank (numbers ON555646 to ON555684, see Table 1).

MOLECULAR ANALYSES

DNA sequences were aligned using MEGA X software (Kumar *et al.* 2018) with Muscle algorithm (Edgar 2004). Using Bayesian information criterion in jModelTest (Darriba *et al.*

2012; Guindon & Gascuel 2003) we retained the GTR + G + I model. Best-scoring ML trees were estimated using RAxML HPC2 v.8.2.10 (Stamatakis 2014) and best-scoring Bayesian Inference (BI) trees were estimated using MrBayes v.3.2.7 (Ronquist & Huelsenbeck 2003), both methods implemented in Cyber Infrastructure for Phylogenetic Research (CIPRES) with the previously determined model, running for 10 000 000 generations, a sampling frequency of 2000 and a burn-in of 10%. Support for nodes was determined using posterior probabilities calculated by MrBayes implemented in the CIPRES portal v.3.1. (Miller *et al.* 2010, <https://www.phylo.org/>). One hundred independent searches, each starting from distinct random trees, were conducted. Robustness of the nodes was assessed using non-parametric bootstrapping (Felsenstein 1985) with 1000 bootstrap replicates. For the analysis, we included 39 specimens all initially identified

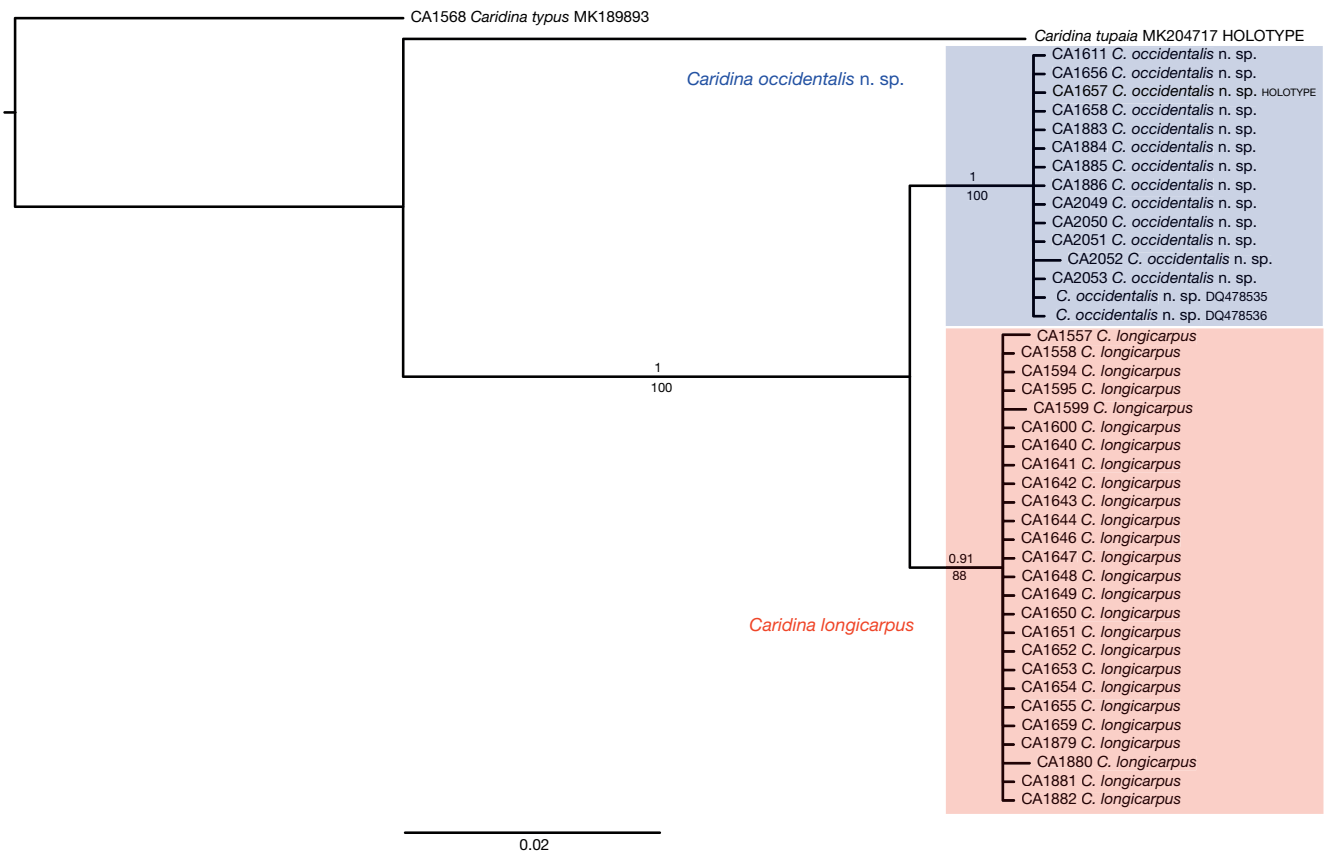


FIG. 1. — Phylogenetic tree of the studied specimens of *Caridina typus* H. Milne Edwards, 1837, *Caridina tupaia* de Mazancourt, Marquet & Keith, 2019 and *Caridina longicarpus* Roux, 1926) obtained by Bayesian Inference method. Numbers above branches indicate Bayesian posterior probabilities; numbers under branches indicate Maximum Likelihood bootstrap numbers.

as *C. longicarpus* collected during the authors' field trips, to which were added four sequences retrieved from GenBank, including one of *Caridina typus* H. Milne Edwards, 1837 from New Caledonia and one of *Caridina tupaia* de Mazancourt, Marquet & Keith, 2019 from Tahiti (French Polynesia) used as outgroups (Table 1), the latter being closely related to *C. longicarpus* as part of the *C. weberi* group (de Mazancourt *et al.* 2019b) while the former belongs to a different species group within the same genus (de Mazancourt *et al.* 2019a).

RESULTS

MOLECULAR ANALYSES

The sequenced specimens are distributed into two clearly separated clades (minimum inter-clade p-distance: 2.3%) (Fig. 1). One, containing sequences from specimens collected in rivers flowing to the west coast is strongly supported both in ML and BI, while its sister clade containing all the specimens collected from rivers flowing to the East coast shows lower support values (PP = 0.91; B = 88%). The p-distances between the two clades range between 2.4 and 2.6%. If we retain the substitution rate of 0.65-0.9% per My in 16S previously used in this genus (Wood *et al.* 2019), we can estimate the separation of these clades to date back to 2.6-4 mya.

MORPHOLOGICAL ANALYSES

Measures and observations made on the specimens allowed us to confirm the molecular results in recognizing the two clades as two different species, one being new for science (See thereafter).

TAXONOMY

Family ATYIDAE De Haan, 1849

Caridina longicarpus Roux, 1926 (Figs 2; 3)

Caridina weberi var. *longicarpus* Roux, 1926: 212, figs 37-39.

Caridina weberi longicarpus – Holthuis 1969: 103.

Caridina longicarpus – de Mazancourt *et al.* 2019a: 166 (part: CA1557 and CA1599), figs 2-5.

Non *Caridina weberi* – Marquet *et al.* 2002 (part); 2003: 72 (part). — Choy & Marquet 2002: 220, 209 (part). — Taillebois *et al.* 2013: 106.

TYPE MATERIAL. — **Lectotype** (here designated among the syntypes). **New Caledonia** • 1♂ cl 4.1 mm; above Oubatche, slopes of Mt. Ignambi; 600 m a.s.l.; IV.1911; F. Sarasin & J. Roux leg.; NMB 6.V.a.



FIG. 2. — *Caridina longicarpus* Roux, 1926, A-H, J, K, NMB 6.V.a, lectotype: first pereopod (A), second pereopod (B), third pereopod (C), fifth pereopod (D), dactylus of third pereopod (E), dactylus of fifth pereopod (F), telson (G), uropodal diaeresis (H), male first pleopod (J), male second pleopod (K); I, L-N, ovigerous female paralectotype: pre-anal carina (I), eggs (L), cephalothorax (M), rostrum (N). Scale bars: A-D, G, H, J-L, N, 0.05 mm; E, F, 0.01 mm; I, 0.2 mm; M, 1 mm.

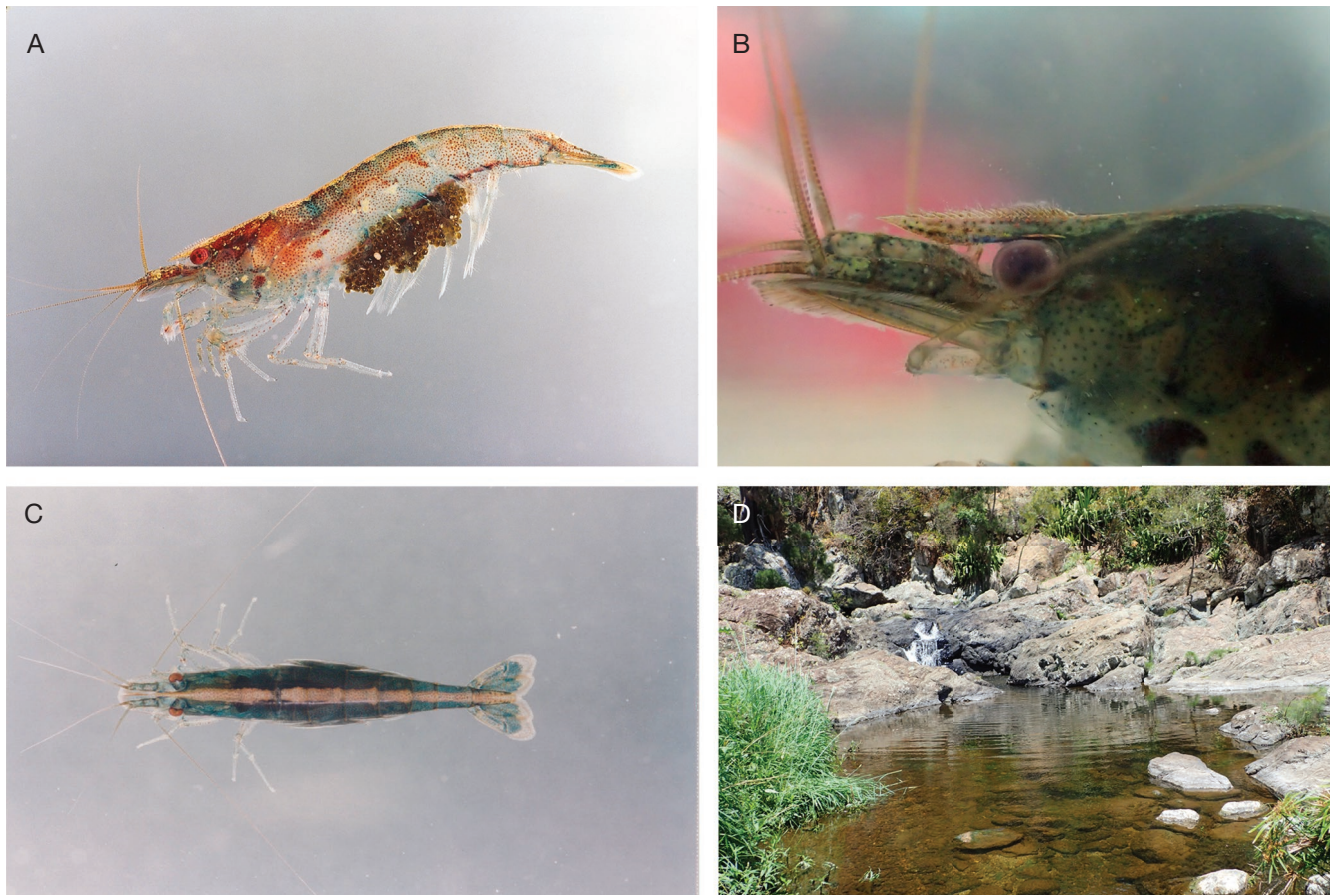


FIG. 3. — **A-C**, *Caridina longicarpus* Roux, 1926: live coloration ovigerous female in left lateral view (**A**), live coloration, ovigerous female, left lateral view of the rostrum (**B**); live coloration, ovigerous female in dorsal view (**C**); **D**, typical habitat, above Ciu waterfall, Canala, New Caledonia. Photographs: A, C, E. Vigneux; B, D, V. de Mazancourt.

Paralectotypes. New Caledonia • 1♂ cl 3.4 mm and 1♀ ovig. cl. 5.7 mm; same data as for lectotype • 1♀ cl 4.7 mm; Ciu, above Canala; 300 m a.s.l.; X.1911; F. Sarasin & J. Roux leg.; NMB 6.V.b.

OTHER MATERIAL EXAMINED. — New Caledonia • 1♀ ovig. cl 5.3 mm; Wewec river; 20°37.506'S, 164°44.637'E; 15.X.2010, G. Marquet & L. Taillebois leg.; DNA: CA1558; MNHN-IU-2018-3323 • 1♀ ovig. cl 5.8 mm; same collection data as preceding; MNHN-IU-2018-3383 • 1♀ cl 4.7 mm; same collection data as preceding; DNA: CA1557; MNHN-IU-2018-3322 • 1♀ cl 5.9 mm; same collection data as preceding; DNA: CA1642; MNHN-IU-2018-3330 • 1♀ cl 3.5 mm; same collection data as preceding; DNA: CA1647; MNHN-IU-2018-3334 • 1♀ cl 4.2 mm; same collection data as preceding; DNA: CA1643; MNHN-IU-2018-3331 • 1♂ cl 4.2 mm; same collection data as preceding; DNA: CA1640; MNHN-IU-2018-3328 • 1♂ cl 4.6 mm; same collection data as preceding; DNA: CA1641; MNHN-IU-2018-3329 • 1♂ cl 4.0 mm; same collection data as preceding; DNA: CA1644; MNHN-IU-2018-3332 • 1♂ cl 3.9 mm (MNHN-IU-2018-3333, DNA: CA1646), 1♂ cl 3.4 mm; same collection data as preceding; DNA: CA1648; MNHN-IU-2018-3335 • 1♀ ovig. cl 6.9 mm; Coula river; 21°21.656'S, 165°20.370'E; 240 m a.s.l.; 26.IX.2016; V. de Mazancourt, P. Tiberghien & G. Marquet leg.; DNA: CA1594; MNHN-IU-2018-3324 • 1♀ ovig. cl 7.3 mm; same collection data as preceding; DNA: CA1595; MNHN-IU-2018-3325 • 1♀ ovig. cl 6.9 mm; same collection data as preceding; DNA: CA1649; MNHN-IU-2018-3336 • 1♀ ovig. cl 5.4 mm; same collection data as preceding; DNA: CA1650; MNHN-IU-2018-3337 •

1♀ ovig. cl 5.9 mm; same collection data as preceding; DNA: CA1651; MNHN-IU-2018-3338 • 1♀ cl 5.0 mm; same collection data as preceding; DNA: CA1652; MNHN-IU-2018-3339 • 1♂ cl 4.0 mm; same collection data as preceding; DNA: CA1599; MNHN-IU-2018-3326 • 1♂ cl 3.7 mm; same collection data as preceding; DNA: CA1600; MNHN-IU-2018-3327 • 1♂ cl 3.4 mm; same collection data as preceding; DNA: CA1653; MNHN-IU-2018-3340 • 1♂ cl 3.9 mm; same collection data as preceding; DNA: CA1654; MNHN-IU-2018-3341 • 1♂ cl 3.9 mm; same collection data as preceding; DNA: CA1655; MNHN-IU-2018-3342 • 1♀ ovig. cl 4.9 mm; Creek Waxac (HYNC742); 20°39.789'S, 164°44.762'E; 310 m a.s.l.; 14.XI.2016; V. de Mazancourt leg.; DNA: CA1659; MNHN-IU-2018-3343 • 1♀ ovig. cl 6.3 mm; Diahot river (HYNC707); 20°31.285'S, 164°33.113'E; 100 m a.s.l.; 5.XI.2016; C. Pöllabauer, C. Huet & N. Charpin leg.; DNA: CA1879; MNHN-IU-2018-3344 • 1♀ cl 6.0 mm; same collection data as preceding; DNA: CA1880; MNHN-IU-2018-3345 • 1♀ cl 5.0 mm; same collection data as preceding; DNA: CA1881; MNHN-IU-2018-3346 • 1♀ cl 6.4 mm; same collection data as preceding; DNA: CA1882; MNHN-IU-2018-3347.

COMPARATIVE MATERIAL. — *Caridina weberi* De Man, 1892: Syntypes: Indonesia • 1♂ cl 4.5 mm, 1♀ ovig. cl 6.1 mm, 1♂ cl 4.4 mm; Kotting, Flores Island; XII.1888; M. Weber leg.; MNHN-IU-2015-1755.

Caridina parvirostris De Man, 1892: Syntypes: Indonesia • 2♂ cl 3.1-3.2 mm, 1♀ cl 4.2 mm; river near Bombang, Flores Island; I.1889; M. Weber leg.; MNHN-IU-2015-1748.

HABITAT. — This species is largely rheophile and prefers fresh and well-oxygenated waters from the middle to the higher courses (100–600 m) (Fig. 3D).

COLOUR PATTERN. — Variable, body dark brown or blue with sometimes a white dorsal line stretching from the rostrum to the telson and numerous reddish-brown spots all over the body (Fig. 3A–C).

DISTRIBUTION. — This species has been collected only in New Caledonia so far and seems endemic. It is only found in the rivers flowing to the East coast (Fig. 6).

DESCRIPTION

Cephalothorax

Suborbital angle indistinguishably fused with antennal spine. Pterygostomian margin rounded. Rostrum (Fig. 2M, N): bent, short, 0.2–0.6 of cl; 0.3–0.4, mean 0.39 ($n = 28$) reaching from base to slightly beyond middle of second segment of antennular peduncle, armed with 10–24 teeth on dorsal margin (mean 16, $n = 27$), 0–2 of them situated on carapace behind orbital margin (mean 0), ventral margin with 1–11 teeth (mean 4, $n = 26$).

Cephalic appendages

Eyes well developed, anterior end reaching to 0.55 length of basal segment of antennular peduncle. Antennular peduncle 0.49(♀)–0.57(♂) times as long as carapace. Anterolateral angle reaching 0.30 length of the second segment, second segment same length as the third. Stylocerite reaching just before the tip of the basal segment of antennular peduncle.

Pereiopods

Epipods on first four pereiopods. P1 (Fig. 2A): chela about 2.0–2.5 times as long as wide, movable finger 2.7–3.9 times as long as wide, 1.0–2.0 times length of palm; carpus 1.7–2.2 times as long as wide. P2 (Fig. 2B) more slender and longer than P1 with chela 2.2–3.2 times as long as wide: movable finger 4.0–5.4 times as long as wide, 1.4–1.9 times length of palm; carpus slender 5.0–7.4 times as long as wide. P3 (Fig. 2C): stout, dactylus (Fig. 2E) 2.6–3.4 times as long as wide (terminal spiniform seta included) with 5–8 spiniform setae on flexor margin in addition to the terminal spiniform seta; propodus 8.7–14.6 times as long as wide, 3.8–6.0 times as long as dactylus. P5 (Fig. 2D): dactylus (Fig. 2F) 3.3–4.9 times as long as wide with 27–72 spiniform setae on flexor margin (52, $n = 17$); propodus 11.9–18.2 times as long as wide, 4.1–5.4 times as long as dactylus (mean 4.5, $n = 18$).

Abdomen

Third abdominal somite with moderately convex dorsal profile. Sixth abdominal somite about half of carapace length, 1.2 times as long as fifth somite, reaching 0.8 times length of telson.

Telson (Fig. 2G)

2.7 times as long as wide, with 5–8 pairs of dorsal spinules and one pair of dorsolateral spinules; posterior margin with a median process, rounded with 5–10 (mean 7, $n = 21$) very long intermediate setae longer than lateral ones.

Pl1 (Fig. 2J)

Endopod of male subrectangular, 2.3 times as long as wide, reaching 0.37 times of exopod, with an appendix on the subdistal outer margin which reaches beyond distal end of endopod on a short length.

Pl2 (Fig. 2K)

Appendix masculina on second pleopod reaching 0.50 times length of endopod; appendix interna reaching 0.50 of appendix masculina.

Preanal carina (Fig. 2I)

High, unarmed.

Uropodal diaeresis (Fig. 2H)

With 17–23 spinules.

Eggs (Fig. 2L)

0.41–0.52 × 0.24–0.32 mm.

REMARKS

According to Roux (1926), *C. longicarpus* looks like *C. parvirostris* De Man, 1892 by its downward bent rostrum and its long P2 carpus 5.0–7.4 times as long as wide (vs 6.0–7.4 in *C. parvirostris*) but the rostrum bears more teeth 10–24 (vs 8–10 in *C. parvirostris*) like *C. weberi* De Man, 1892 (vs 11–15 in *C. weberi*). But this latter species has a shorter P2 carpus 4.9–5.4 (vs 5.0–7.4 in *C. weberi*).

Our specimens fit well with the types described by Roux (1926) from New Caledonia: a short bent rostrum, 0.2–0.5 of cl (vs 0.2–0.4), armed with 10–24 teeth on dorsal margin (vs 13–25), 0–2 of them situated on carapace behind orbital margin (vs 0–2); ventral margin with 1–11 teeth (vs 3–7); P1 carpus 1.7–2.2 times as long as wide (vs. 1.5–1.9) and P2 carpus 5.0–7.4 times as long as wide (vs 5.2–5.6); P3 dactylus 2.6–3.4 times as long as wide (terminal spiniform seta included) (vs 3.1–3.5) with 5–8 spiniform setae on flexor margin in addition to the terminal one (vs 6–7); propodus 8.7–14.6 times as long as wide (vs 9.5–11.4), 3.8–6.0 times as long as dactylus (vs 4.1–4.6); by its P5 dactylus 3.3–4.9 as long as wide (vs 3–4.5) with 27–72 spiniform setae on flexor margin (vs 46–69), P5 propodus 3.4–5.1 times as long as dactylus (vs 4.1–4.7).

Caridina occidentalis n. sp. (Figs 4; 5)

[urn:lsid:zoobank.org:act:2B9014C4-ACBB-44A4-B5BC-A4D3475D2493](https://zoobank.org/act:2B9014C4-ACBB-44A4-B5BC-A4D3475D2493)

Not *Caridina weberi* – Choy & Marquet 2002: 220.

Not *Caridina weberi* – Marquet *et al.* 2003: 72–73.

Not *Caridina weberi longicarpus* (sp. Ncal A / Ncal 1) – Page *et al.* 2007: 649 (GenBank: DQ478535 and DQ478536). — de Mazancourt *et al.* 2017: fig. 4.

Not *Caridina longicarpus* – de Mazancourt *et al.* 2019a: 166 (part: CA1611), figs 2–5.

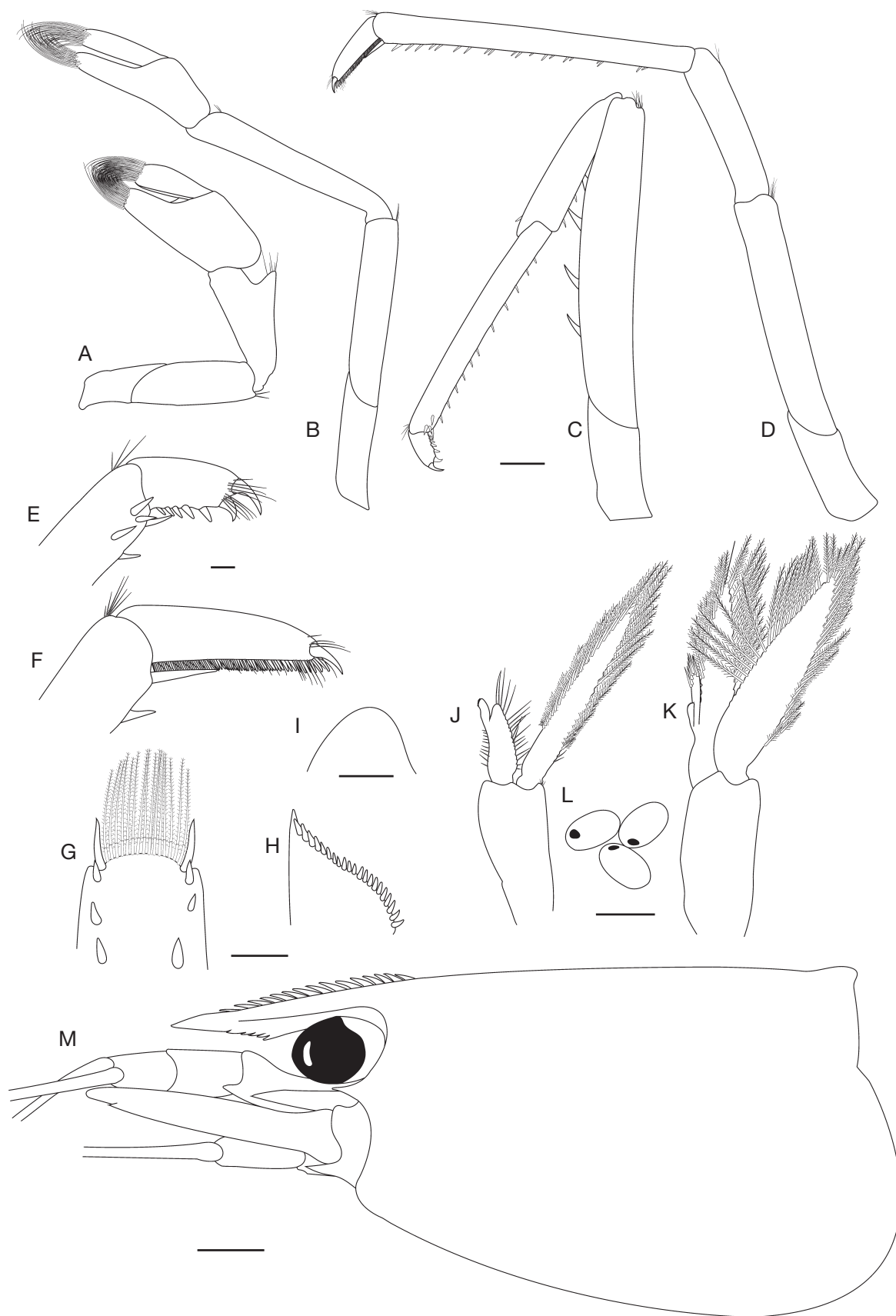


FIG. 4. — *Caridina occidentalis* n. sp.: **A-G, I, L, M**, MNHN-IU-2018-3311: first pereopod (**A**), second pereopod (**B**), third pereopod (**C**), fifth pereopod (**D**), dactylus of third pereopod (**E**), dactylus of fifth pereopod (**F**), telson (**G**); pre-anal carina (**I**), eggs (**L**); cephalothorax (**M**); **H**, MNHN-IU-2018-3312: uropodal diaeresis; **J, K**, holotype MNHN-IU-2018-3309: male first pleopod (**J**), male second pleopod (**K**). Scale bars: A-D, G, J-L, 0.5 mm; E, F, 0.1 mm; M, 1 mm.

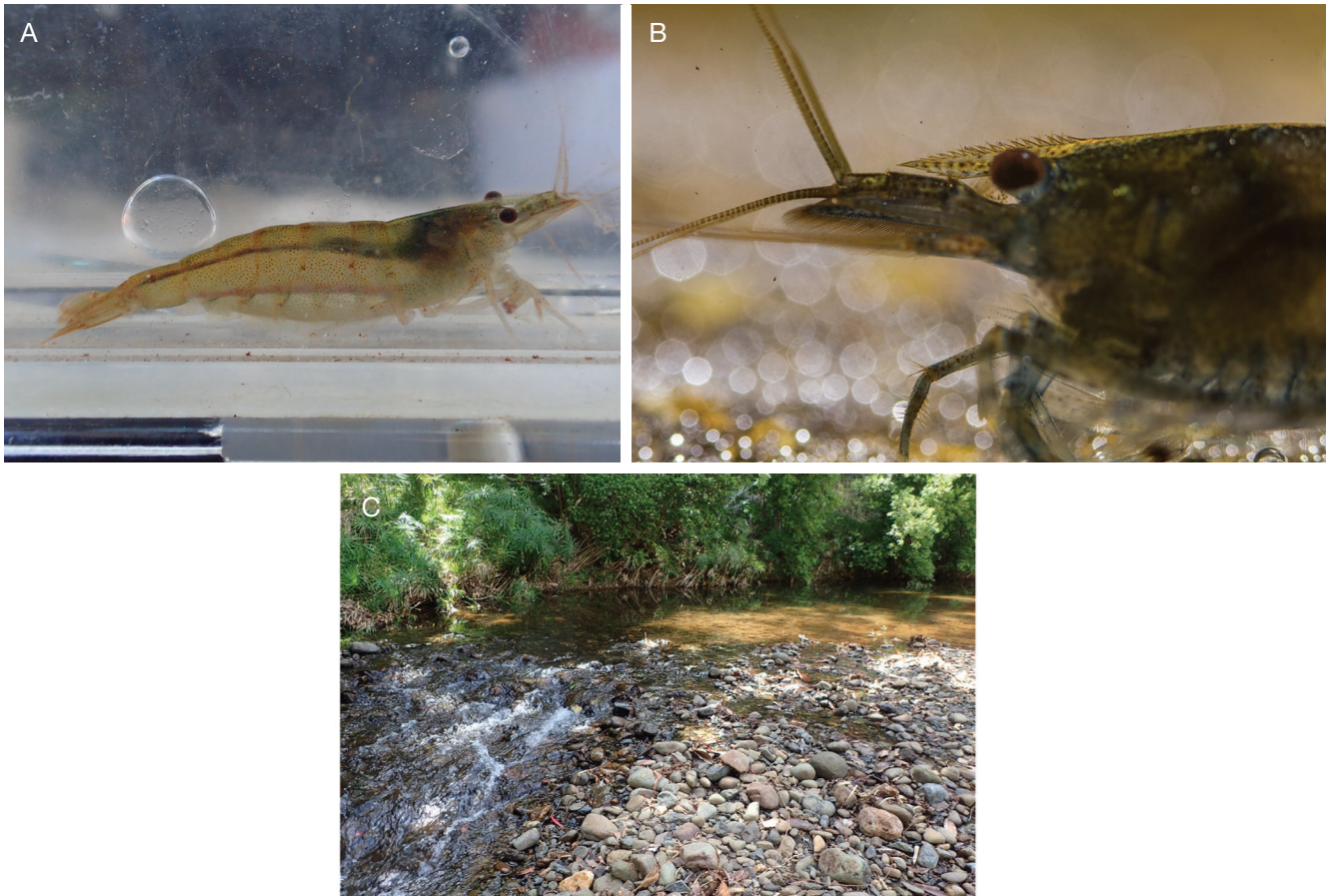


FIG. 5. — **A, B**, *Caridina occidentalis* n. sp.: live coloration, female in right lateral view (**A**); live coloration, female, left lateral view of the rostrum (**B**); **C**, typical habitat, Nékouri river, Bourail, New Caledonia. Photographs: A, C, V. de Mazancourt; B, N. Charpin.

MATERIAL EXAMINED. — **Holotype.** New Caledonia • 1♂ cl 4.0 mm; Pouéo river; 21°26.326'S, 165°31.909'E; 180 m a.s.l.; 28.IX.2016; V. de Mazancourt, P. Tiberghien & G. Marquet leg.; DNA: CA1657; [MNHN-IU-2018-3309](#).

Paratypes. New Caledonia • 1♀ cl 7.0 mm; same collection data as for holotype; DNA: CA1611; [MNHN-IU-2018-3311](#) • 1♀ cl 7.7 mm; Pouéo river (HYNC797); 12.XI.2017; 21°29.931'S, 165°30.701'E; 25 m a.s.l.; V. de Mazancourt & N. Charpin leg.; DNA: CA1656; [MNHN-IU-2018-3310](#) • 1♂ cl 4.4 mm; same collection data as preceding; DNA: CA1658; [MNHN-IU-2018-3312](#) • 1♀ cl 5.3 mm; same collection data as preceding; DNA: CA2050; [MNHN-IU-2018-3318](#) • 1♀ cl 5.7 mm; Voh river; 20°54.884'S, 164°46.275'E; 38 m a.s.l.; VI.2016; N. Charpin leg.; DNA: CA1886; [MNHN-IU-2018-3316](#) • 1♀ cl 5.0 mm; same collection data as preceding; DNA: CA1884; [MNHN-IU-2018-3314](#) • 1♀ ovig. cl 5.9 mm; same collection data as preceding; DNA: CA1883; [MNHN-IU-2018-3313](#) • 1♀ ovig. cl 5.4 mm; same collection data as preceding; DNA: CA1883; DNA: CA1885; [MNHN-IU-2018-3315](#) • 1♀ cl 6.0 mm; Ouaméni river (HYNC778); 21°49.546'S, 165°56.714'E; 37 m a.s.l.; 5.XI.2017; V. de Mazancourt & N. Charpin leg.; DNA: CA2049; [MNHN-IU-2018-3317](#) • 1♀ cl 5.0 mm; Nekouri river (HYNC1892); 21°34.805'S, 165°36.568'E; 44 m a.s.l.; 15.XI.2017; V. de Mazancourt & N. Charpin leg.; DNA: CA2053; [MNHN-IU-2018-3321](#) • 1♀ cl 5.7 mm; same collection data as preceding; DNA: CA2052; [MNHN-IU-2018-3320](#) • 1♀ ovig. cl 6.3 mm; same collection data as preceding; DNA: CA2051; [MNHN-IU-2018-3319](#) • 1♂ cl 4.0 mm; Farino river; 21°39.717'S, 165°46.344'E; 250 m a.s.l.; 9.XI.2012; N. Mary leg.; [MNHN-IU-2018-3384](#) • 1♀ cl 6.5 mm; same collection data as preceding; [MNHN-IU-2018-3385](#) • 1♀ cl 6.8 mm; same collection data as preceding; [MNHN-IU-2018-3386](#).

COMPARATIVE MATERIAL. — *Caridina weberi* De Man, 1892: Syntypes: **Indonesia** • 1♂ cl 4.5 mm, 1♀ ovig. cl 6.1 mm, 1♂ cl 4.4 mm; Kotting, Flores Island; XII.1888; M. Weber leg.; [MNHN-IU-2015-1755](#).

Caridina parvirostris De Man, 1892: Syntypes: **Indonesia** • 2♂ cl 3.1-3.2 mm, 1♀ cl 4.2 mm; river near Bombang, Flores Island; I.1889; M. Weber leg.; [MNHN-IU-2015-1748](#).

HABITAT. — This new species is largely rheophile and prefers fresh and well-oxygenated waters from the lower to higher courses (25-250 m) (Fig. 5C).

ETYMOLOGY. — The name of this new species refers to its geographical distribution, restricted to the west coast of New Caledonia.

COLOUR PATTERN. — Similar to *C. longicarpus*: variable, body dark brown or blue with sometimes a white dorsal line stretching from the rostrum to the telson and numerous reddish-brown spots all over the body (Fig. 5A, B).

DISTRIBUTION. — Like the previous species, this species has been collected only in New Caledonia so far and also seems endemic. It is only found in rivers flowing to the west coast (Fig. 6).

DESCRIPTION

Cephalothorax

Suborbital angle indistinguishably fused with antennal spine. Pterygostomial margin rounded. Rostrum (Fig. 4M): bent, short, 0.4-0.6 of cl (mean 0.5, n = 16), reaching from the

base to slightly beyond the middle of second segment of antennular peduncle, armed with 15-22 teeth on dorsal margin (mean 17, $n = 16$), 0-3 of them situated on carapace behind orbital margin (mean 2, $n = 16$), ventral margin with 2-7 teeth (mean 4, $n = 16$).

Cephalic appendages

Eyes well developed, anterior end reaching to 0.47 length of basal segment of antennular peduncle. Antennular peduncle 0.50(♀)-0.57 (♂) times as long as carapace. Anterolateral angle reaching 0.30 length of the second segment, second segment same length as the third. Stylocerite reaching just before the top of the basal segment of antennular peduncle.

Pereiopods

Epipods on first four pereiopods. P1 (Fig. 4A): chela about 2.1-2.5 times as long as wide, movable finger 2.5-4.3 times as long as wide, 0.9-1.4 times length of palm; carpus 1.8-2.5 times as long as wide. P2 (Fig. 4B): more slender and longer than P1 with chela 2.8-3.5 times as long as wide; movable finger 3.7-5.1 times as long as wide, 1.2-1.7 times length of palm; carpus slender 5.9-6.9 times as long as wide. P3 (Fig. 4C): stout, dactylus (Fig. 4E) 2.5-3.5 times as long as wide (terminal spiniform seta included) with 5-8 spiniform setae on flexor margin in addition to the terminal spiniform seta; propodus 7.3-10.3 times as long as wide, 3.7-5.8 times as long as dactylus. P5 (Fig. 4D): dactylus (Fig. 4F) 3.6-5.0 as long as wide with 55-90 spiniform setae on flexor margin (mean 68, $n = 14$); propodus 11.3-16.9 times as long as wide, 3.4-5.1 times as long as dactylus (mean 4.1, $n = 14$).

Abdomen

Third abdominal somite with moderately convex dorsal profile. Sixth abdominal somite about half of carapace length, 1.4 times as long as fifth somite, reaching 0.8 times length of telson.

Telson (Fig. 4G)

2.4 times as long as wide, with 4-6 pairs of dorsal spinules and one pair of dorsolateral spinules; posterior margin with a median process. Rounded with 7-15 (mean 11, $n = 15$) very long intermediate plumose setae, longer than lateral ones.

Pl1 (Fig. 4J)

Endopod of male subrectangular, 2.7 times as long as wide, reaching 0.40 times of exopod, with an appendix on the subdistal outer margin which reaches beyond distal end of endopod on a short length.

Pl2 (Fig. 4K)

Appendix masculina on second pleopod reaching 0.55 times length of endopod; appendix interna reaching 0.56 of appendix masculina.

Preanal carina (Fig. 4I)

High, unarmed.

Uropodal diaeresis (Fig. 4H)

With 17-24 spinules.

Eggs (Fig. 4L)

0.46-0.49 × 0.27-0.39 mm.

REMARKS

C. occidentalis n. sp. looks like *C. parvirostris* De Man, 1892 by its downward bent rostrum and its long P2 carpus 5.9-6.9 times as long as wide (vs 6.0-7.4 in *C. parvirostris*) but the rostrum has more teeth 15-22 (vs 8-10 *C. parvirostris*). This new species can be separated from *C. weberi* De Man, 1892 by its rostrum with more teeth 15-22 (vs 11-15 *C. parvirostris*) and a longer P2 carpus 5.9-6.9 times as long as wide (vs 4.9-5.4 *C. parvirostris*).

C. occidentalis n. sp. occurring in west coast rivers differs from *C. longicarpus* Roux, 1926, occurring in rivers of the East coast:

- by its rostrum: 0.4-0.6 of cl, mean 0.5 (vs 0.2-0.6, mean 0.39), armed with 15-22 teeth on dorsal margin (mean 17), (vs 10-24 in *C. longicarpus*, mean 16), 0-3 of them situated on carapace behind orbital margin (mean 2) (vs 0-2 of them situated on carapace behind orbital margin, mean 0);

- by its P5 dactylus with 55-90 spiniform setae, 63-90, mean 68 on flexor margin (vs 27-72, 27-59, mean 52) and its propodus 3.4-5.1 times as long as dactylus, mean 4.1 (vs 4.1-5.4, mean 4.5);

- by its telson with 7-15 (mean 11) very long intermediate setae longer than lateral ones (vs with 5-10 in *C. longicarpus*, (mean 7) very long intermediate setae longer than lateral ones).

DISCUSSION

In New Caledonia, the two closely related species, *C. longicarpus* and *C. occidentalis* n. sp., are found respectively in the rivers of the east and west coasts (Fig. 6). The relief of the island can explain their distribution. “Grande Terre” is a narrow-elongated island over 400 km long oriented north-west/south-east, the width of which does not exceed 50 km. It presents on its main axis a mountainous terrain often exceeding 1000 m above sea level. This chain divides to the north in two branches by surrounding the Diahot valley. As a result, the streams are oriented perpendicular to the coast except the Diahot, which is the only one to follow a direction parallel to the major axis (but seems to belong to the East coast from a biogeographical point of view since *C. longicarpus* is found in it). No terrestrial communications were possible between the east coast and west coast rivers and this potentially for several million years, as, the central mountain ridge seems to date back to the Oligocene (33.9-23 mya), formed by complex orogenic processes shortly after the emersion of the island (Chevillotte *et al.* 2006).

Since these species produce numerous small eggs and are likely amphidromous (Vogt 2013), the oceanic currents are also an important factor to take into account to explain the biogeographical differences between the two coasts. New

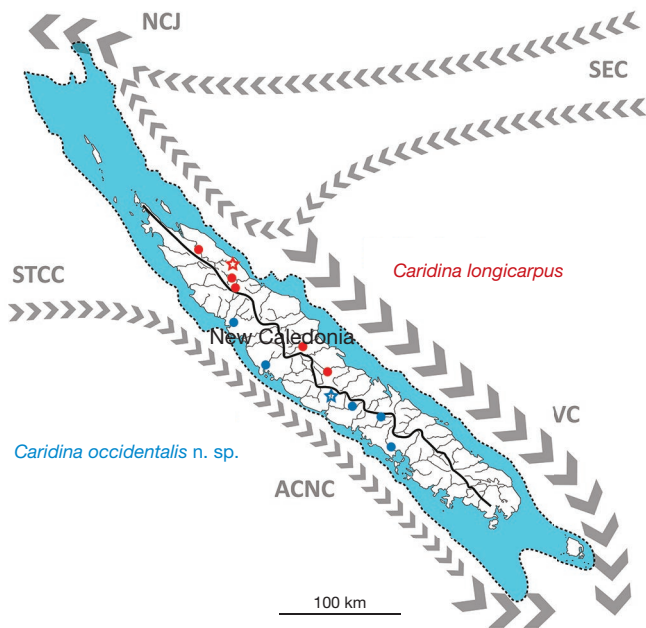


FIG. 6. — Distribution of *Caridina longicarpus* Roux, 1926 and *Caridina occidentalis* n. sp. in New Caledonia with the sampling localities of the present study. **Grey arrows** indicate the main oceanic currents: North Caledonian Jet (NCJ); South Equatorial Current (SEC); SubTropical CounterCurrent (STCC); Vauban Current (VC); Alis Current of New Caledonia (ACNC); **arrow widths** indicate the strengths of the currents (from Cravatte *et al.* 2015); **blue area** and **dashed line** represent the barrier reef and its lagoon; **black line** separates watersheds draining the East coast to those draining the West coast; **star** indicates Oubatche, the locality where the lectotype of *Caridina longicarpus* was collected.

Caledonia acts as an obstacle for the South Equatorial Current, which splits in two when encountering the East coast, a northwestward branch that becomes the North Caledonian Jet (NCJ) and a southeastward branch that is named the Vauban Current (VC). On the East coast, the Subtropical Countercurrent (STCC) becomes the Alis Current of New Caledonia (ACNC) as it flows southeastward along the barrier reef and meets the VC at the southern tip of the Grande Terre to form the westward South Caledonian Jet (Cravatte *et al.* 2015). Given the coastal circulation around the island, it appears that connectivity between the two coasts is difficult, with the marine planktonic larvae being carried along the same coast or away to the open ocean where no suitable habitat could allow them to recruit. The existence in New Caledonia of other endemic species of freshwater decapods with extended larval development such as *Caridina meridionalis* J. Roux, 1926, *Paratya bouvieri* J. Roux, 1926 or *Macrobrachium caledonicum* (J. Roux, 1926) could support the idea that planktonic larvae have difficulty reaching other neighboring islands.

Given the estimated date of separation of the two species (2.6–4 mya), the formation of the central chain cannot be the driving factor of a vicariance. One can suppose that two independent colonisation events occurred on each side of the island and their physical isolation prevented any kind of competition or hybridisation between them. It can be hypothesized that connectivity was once possible, e.g. when the sea level

was lower, or the currents circulation different and that subsequent changes due to climatic variations prevented further communication causing a vicariance (Grandcolas *et al.* 2008).

However, this pattern of speciation on each side of the island has not been observed in other amphidromous species like *Caridina typus* or *Caridina meridionalis* which populations are genetically homogeneous (de Mazancourt, unpub. data). It is likely that the (still largely unknown) life history of these species could explain these differences, such as for example a longer duration of the planktonic larval phase which would give more chance for the larvae to reach the other coast, or the location of the larval phase, i.e. inside or outside the lagoon, at which depth, facultative or obligatory amphidromy, etc. The case study of these two species is nevertheless a great example of insular evolutionary process in a place that is already known for its unique endemism (Grandcolas *et al.* 2008) and demonstrates once more how much is yet to discover in the biology of these amphidromous shrimps.

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