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FURTHER RECORDS OF THE ANCHIALINE SHRIMP *CARIDINA RUBELLA* FUJINO & SHOKITA, 1975 (DECAPODA, ATYIDAE)

BY

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ABSTRACT

Based on material collected during the mid- to late 1980s new distributional records for the anchialine shrimp, *Caridina rubella* Fujino & Shokita, 1975 are presented. Asides from the Ryukyus, Palawan and Sulawesi, the species is now also recorded from Tahiti, Niue, Tonga, Western Samoa, the Loyalty Islands, Solomon Islands, Bohol and Panglao. Attention is drawn to the considerable rostral variation in the species.

Key words. — Atyidae, *Caridina*, anchialine pools, caves

RÉSUMÉ

De nouvelles données sur la distribution de la crevette anchialine, *Caridina rubella* Fujino & Shokita, 1975, établies à partir d'un matériel collecté entre le milieu et la fin des années 1980, sont présentées. Hormis les îles Ryukyu, le Palawan et le Sulawesi, l'espèce est maintenant également signalée à Tahiti, Niue, Tonga, les Samoa occidentales, les îles Loyauté, les îles Salomon, Bohol et Panglao. Les variations rostrales considérables de l'espèce sont soulignées.

Mots clés. — Atyidae, *Caridina*, mares anchialine

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INTRODUCTION

Anchialine ecosystems include coastal, landlocked mixohaline pools and submerged caves, lacking a surface connection to the sea, but with a subterranean link, as evidenced by tidal fluctuations in water level and salinity (Holthuis, 1963, 1973; Stock et al., 1986). These unique habitats have been reported in low latitudes across the globe, from the Caribbean through to the Sinai Peninsula, the Philippines and Hawaii (Maciolek, 1983), with the total number of localities thought to number in the tens of thousands and with the highest concentration, an estimated 6000-10 000 pools and caves called cenotes, located in Mexico's Yucatan Peninsula. Despite their global distribution and unique faunal composition, these habitats are likely one of the most threatened, coastal habitats, with significant negative impacts from coastal development, water extraction, pollution, land fill and the introduction of invasive species (Santos, 2006; Malay et al., 2022). In order to understand and conserve these habitats, a deeper knowledge of their biology and a more accurate picture of the biogeography of the constituent species is needed.

Caridean and procaridean shrimps are among the more conspicuous components of the Indo-Pacific anchialine community, with to date 11 species described (Maciolek, 1983; De Grave & Sakihara, 2011). Several independent habitat invasions are evident, as the species are distributed in 10 genera, across five, unrelated, families and even two infra-orders. Their general biology remains relatively poorly known, but it is clear that they can be a very significant component of the community, reaching densities of up to 15-38 individuals/m^2 in some species (e.g. *Parhippolyte uveae* Borradaile, 1900, see Malay et al., 2022). In contrast, many species of shrimp are only known to occur in much lower densities, for example *Antecaridina lauensis* (Edmondson, 1935) at 0.3 individuals/m^2 (Malay et al., 2022) in the same pool as *P. uveae*, and *Periclimenes pholeter* Holthuis, 1973 in Hawaii, with only seven shrimps observed across four pools (Sakihara, 2012).

Despite this unique and fragmented habitat, several of the shrimp species have geographically broad distributions across vast stretches of the Indo-Pacific. For example, *A. lauensis* is known from Entedebir Island (Red Sea), Europa Island (Mozambique Channel), several islands in the Philippines, Solomon Islands, Fiji, the Ryukyu Archipelago, Guam and Hawaii (Maciolek, 1983; Cai et al, 2009; Malay et al., 2022). The exact role of passive oceanic dispersal to explain this distribution, as invoked by Smith & Williams (1981), versus the potential presence of cryptic species in several of these locations (see Weese et al., 2013) remains to be fully debated. *Parhippolyte uveae* is another example with a similar distribution (Wear & Holthuis, 1977; Fransen & Tomascik, 1996; De Grave & Sakihara, 2011), although currently not known from the Red Sea area.

Other species, have highly disjunct distributional patterns and are only known from a few locations, despite having a very broad overall distribution across the Indo-Pacific. It has, however, become clear that this is likely a sampling artefact, with significant intermediate records or range extensions reported for several species in the last decade or so. For example, Anker & Fujita (2014) reported *Calliasmata pholidota* Holthuis, 1973 from the Ryukyu Islands, a species until then only recorded from the Sinai (Egypt), Tuvalu and Hawaii. Equally, De Grave & Sakihara (2011) reported *Periclimenes pholeter* from Sulawesi, Lifou and Hawaii, with that species previously only known from the Red Sea and Fiji.

One such, highly disjunct species is *Caridina rubella* Fujino & Shokita, 1975, originally described from the Ryukyu Islands, and since, with certainty, only recorded further afield from Palawan (Philippines) and Maros (Sulawesi). Here, we report on additional material from this species, collected during the mid to late 1980's from several Indo-Pacific locations, considerably expanding the known geographical range of the species.

Specimens are deposited in the Zoological Collection of the Oxford University Museum of Natural History (OUMNH.ZC), Oxford, U.K. Postorbital carapace length (pocl) was measured in millimetres from the postorbital margin to the posterior margin of the carapace. The expression "fcn" refers to "field collection number".

TAXONOMY

Order DECAPODA Latreille, 1802
Infraorder CARIDEA Dana, 1852
Family ATYIDAE De Haan, 1849
Genus *Caridina* H. Milne Edwards, 1837
Caridina rubella Fujino & Shokita, 1975 (figs. 1-2)

Material examined.— One non-ov. female (pocl 6.4 mm), Victoria Memorial Park Cave, Taloto, Bohol Island, Philippines, 15 cm water depth, gravel mud bottom, 07.iv.1985 (fcn 85-073), OUMNH.ZC.2018-09-04; 1 non-ov. female (pocl 5.4), Underpass Cave, west of Hinagdanan Cave, Bingag, Panglao Island, Philippines, 1 m water depth, mud bottom, 08.iv.1985 (fcn 85-077), OUMNH.ZC.2018-09-05; 1 non-ov. female (pocl 6.3), Victoria Memorial Park Cave, Taloto, Bohol Island, Philippines, 0-30 cm water depth, still cave pool, 09.iv.1985 (fcn 85-080), OUMNH.ZC.2018-09-06; 1 male (pocl 5.5), Grotte de Vaipoiri, 10 km east of Teahupoo, Tahiti Iti, 1 m water depth, under rock ledge at rear of pool, 02.x.1987 (fcn 87-202), OUMNH.ZC.2018-09-07; 1 ov. female (pocl 6.2), Anatuku Chasm, 1 km southeast of Hakupu Village, Niue, 12 m water depth, just below halocline, water column, 12.ii.1988 (fcn 88-009), OUMNH.ZC.2018-09-08; 2 non-ov. females (damaged, not measured), Paduo Chasm, about 5 km south of Alofi, Niue, 2-10 m water depth, on logs, root masses and flowstone, 16.ii.1988 (fcn 88-010), OUMNH.ZC.2018-09-09; 1 ov. female (pocl 5.7) Easter Cave, 150 m inland from the coast at Tongatapu Island, near Oholei Beach, Tonga, 1 m water depth, 03.iv.1988 (fcn 88-025), OUMNH.ZC.2018-09-10; 1 ov. female (pocl 4.5), 2 non-ov. females (pocl 5.5, 5.7), 3 males (pocl 4.0-4.3), Ana Pe'ape'a at Tafatafa, about 1 km inland from the south coast of Upolu Island, Western Samoa, 0-0.8 m water depth, in main pool, 19.iv.1988

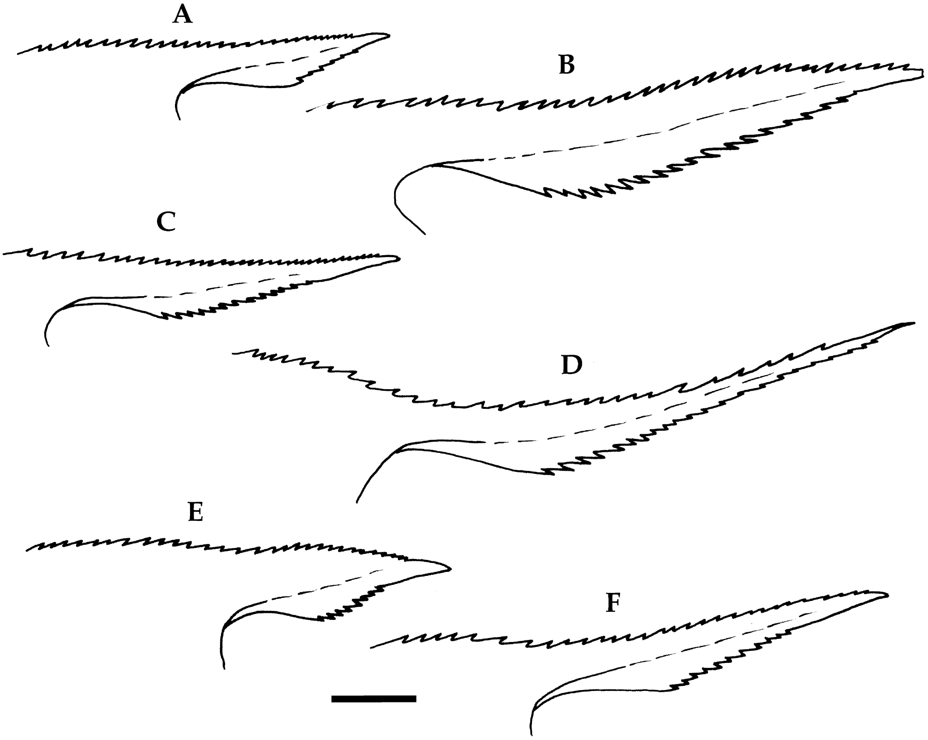

Fig. 1. Rostral variation in *Caridina rubella* Fujino & Shokita, 1975. A, Ov. female (pocl 4.5 mm), Western Samoa (OUMNH.ZC.2018-09-11); B, female (pocl not measured), Niue (OUMNH.ZC.2018-09-09); C, female (pocl 5.7), Western Samoa (OUMNH.ZC.2018-09-11); D, female (pocl 5.4), Philippines (OUMNH.ZC.2018-09-05); E, female (pocl 5.7), Western Samoa (OUMNH.ZC.2018-09-11); F, female (pocl 5.1), New Caledonia (OUMNH.ZC.2018-09-12). Scale bar indicates 1 mm.

(fcn 88-036), OUMNH.ZC.2018-09-11; 1 non-ov. female (pocl 5.1), Grotte de Péthoen, about 200 m inland from the coast and just inland of coastal road, 0.5 km north of Médu Village, Maré, Loyalty Islands, New Caledonia, 1 m water depth, 11.vi.1988 (fcn 88-053), OUMNH.ZC.2018-09-12; 1 non-ov. female (pocl 6.3), Anoubet, about 400 m from the ocean, near the sea cliffs to the east of Ouloup, Ouvéa, Loyalty Islands, New Caledonia, 3 m water depth, 22.vi.1988 (fcn 88-066), OUMNH.ZC.2018-09-13; 2 non-ov. females (pocl 4.8, 5.5), 2 males (pocl 5.0, 5.2); Nugubala Cave, 50 m from coast, west side of Matumab Bay, Nggela Pile Island, Solomon Islands, 0.5 m water depth, 16.viii.1988 (fcn 88-084), OUMNH.ZC.2018-09-14.

Remarks.— Although, in general morphology, the material reported herein closely adheres to the type description in Fujino & Shokita (1975), as well as the supplementary description and illustrations in Cai & Shokita (2006), considerable variation was noted in rostral shape and dentition (fig. 1). The rostrum of the present specimens is 0.47-1.42 times as long as the carapace length, with a median value of 0.91 and a mean value of 0.96. Both the dorsal and ventral margin harbour teeth throughout much of their length, but with a non-dentate distal part, which is

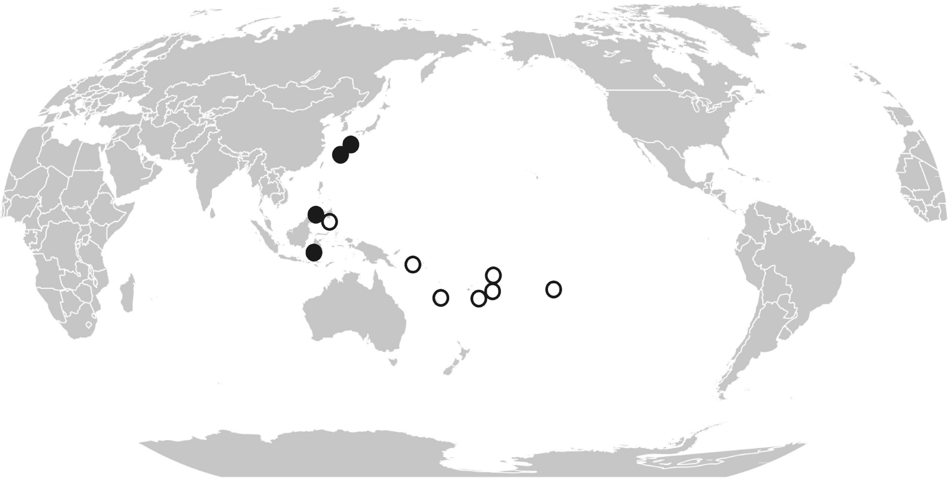

Fig. 2. Currently known distribution of *Caridina rubella* Fujino & Miyake, 1975 (filled circles are previous records; open circles are new records).

variable in length. The rostral formula of the present material is 5-12 + 17-31/6-22, comparable to the ratios provided by Cai & Shokita (2006), but with lower and higher end counts. Additionally, it was noted that the chelae of the first and second pereiopods displayed two morphs, akin to the gracile and robust forms noted for *Antecaridina lauensis* in Smith & Williams (1981), seemingly not correlated to the variation in rostral length. Unfortunately, in the majority of specimens, both pereiopods were detached or broken off, so this could only be cursorily examined.

Habitat.— The majority of specimens were collected by dip net, plankton net and suction bottle from shallow water depths (0-3 m), despite some of the caves being much deeper. Several of the collection sites had distinct haloclines, with the shrimps collected in salinities of 0.5-10 ppt above the halocline. However, in one instance (Anatuku Chasm, Niue) the specimens were collected just below the halocline, in an approximate salinity of 24 ppt, which is also the deepest record for the species at 12 m water depth. In contrast, one location (Grotte de Vaipoiri, Tahiti) is considered to be fully freshwater; further demonstrating the euryhaline tolerance of the species.

The live colouration of the majority of specimens was recorded as being colourless to pale red, with yellow to orange internal organs. However, a blood-red coloured specimen from Grotte de Péthoen, Maré, Loyalty Islands was collected from a dark pool in the rear of the cave.

Distribution.— Previously recorded from Okinoerabu-jima, Okinawa-jima, Minamidaito-jima, Miyako-jima and Yoron-jima, Ryukyus, Japan (Fujino & Shokita, 1975; Cai & Shokita, 2006; Weese et al., 2012; Fujita et al., 2019), as well as Palawan, Philippines (Cai & Anker, 2004) and Maros, Sulawesi, Indonesia

(Cai & Ng, 2009), with unconfirmed records from the Cook Islands (pers. comm. T. Page in Weese et al., 2012) and Java, Indonesia (pers. comm. T. von Rintelen in Weese et al., 2012). Herein also reported from Tahiti, Niue, Tonga, Western Samoa, the Loyalty Islands, Solomon Islands and Bohol and Panglao, Philippines.

DISCUSSION

Weese et al. (2012) in a genetic study of the populations from four locations on Miyako-jima (from where the species was initially described), found considerable COI divergence between a pool in which a long rostrum form occurred and three pools with short rostrum forms, amounting to approximately 17% between two, semi-isolated pools a mere 20 m away. They suggested that the short rostrum form corresponds to the type description of *C. rubella* and the long rostrum form, either represents an undescribed species or an already known anchialine *Caridina*, not yet recorded from the Ryukyu Islands. As there are no other described anchialine *Caridina* species to date, and all other *Caridina* species recorded from the Ryukyu Islands are epigeal forms, with well-developed cornea on their eyes (Cai & Shokita, 2006), the existence of an undescribed, pseudocryptic species is implicit in their statement. As the material reported herein did not yield any useable DNA, it remains unknown if the observed long rostrum specimens, also belong to this potentially undescribed species. In the majority of samples examined, only a single individual was collected per location, with the long rostrum form (as illustrated in fig. 1B, D, F; see also fig. 2B in Weese et al., 2012) being present in the material from Tonga, Niue, the Loyalty Islands and Bohol, Philippines; with the short rostrum form (as illustrated in fig. 1A, C, E; see also fig. 2A in Weese et al., 2012) present in Tahiti, Western Samoa and Panglao, Philippines). It is, however, noted, that in one location (Nggela Pile Island, Solomon Islands) both forms occur sympatrically, raising some doubts whether indeed an undescribed, pseudo-cryptic species is involved.

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REFERENCES

ANKER, A. & Y. FUJITA, 2014. On the presence of the anchialine shrimp *Calliasmata pholidota* Holthuis, 1973 (Crustacea: Decapoda: Caridea: Barbouriidae) in Shimoji Island, Ryukyu Islands, Japan. Fauna Ryukyuana, **17**: 7-11.

BORRADAILE, L. A., 1900. On the Stomatopoda and Macrura brought by Dr. Willey from the South Seas. In: A. Willey, Zoological results based on material from New Britain, New Guinea, Loyalty Islands and elsewhere, collected during the years 1895, 1896, and 1897, by Arthur Willey, D.Sc. Lond., Hon. M.A. Cantab.: 395-428, pls. 36-39. (University Press, Cambridge).

CAI, Y. & A. ANKER, 2004. On a collection of freshwater shrimps (Crustacea Decapoda Caridea) from the Philippines, with descriptions of five new species. Tropical Zoology, **17**: 233-266.

CAI, Y., S. CHOY & P. K. L. NG, 2009. Epigean and hypogean freshwater shrimps of Bohol Island, central Philippines (Crustacea: Decapoda: Caridea). Raffles Bulletin of Zoology, **57**: 65-89.

CAI, Y. & P. K. L. NG, 2009. The freshwater shrimps of the genera *Caridina* and *Parisia* from karst caves of Sulawesi Selatan, Indonesia, with descriptions of three new species (Crustacea: Decapoda: Caridea: Atyidae). Journal of Natural History, **43**: 1093-1114.

CAI, Y. & S. SHOKITA, 2006. Atyid shrimps (Crustacea: Decapoda: Caridea) of the Ryukyu Islands, southern Japan, with descriptions of two new species. Journal of Natural History, **40**: 2123-2172.

DE GRAVE, S. & T. S. SAKIHARA, 2011. Further records of the anchialine shrimp, *Periclimenes pholeter* Holthuis, 1973 (Crustacea, Decapoda, Palaemonidae). Zootaxa, **2903**: 64-68.

EDMONDSON, C. H., 1935. New and rare Polynesian Crustacea. Bernice P. Bishop Museum Occasional Papers, **10**: 3-40.

FRANSEN, C. H. J. M. & T. TOMASCIK, 1996. *Parhippolyte uveae* Borradaile, 1899 (Crustacea: Decapoda: Hippolytidae) from Kakaban Island, Indonesia. Zoologische Mededelingen, **70**: 227-233.

FUJINO, T. & S. SHOKITA, 1975. Report on some new atyid shrimps (Crustacea, Decapoda, Caridea) from the Ryukyu Islands. Bulletin of the Sciences and Engineering Division, University of the Ryukyus, (Mathematics and Natural Sciences) **18**: 93-113.

FUJITA, Y., D. UYENO, H. SUZUKI & K. TOGUKI, 2019. Three stygobiotic atyid shrimps from an anchialine cave in Yorin-jima Island, central Ryukyus, Japan. Cancer, **28**: 33-36. [In Japanese.]

HOLTHUIS, L. B., 1963. On red coloured shrimps (Decapoda, Caridea) from tropical land-locked saltwater pools. Zoologische Mededelingen, **38**: 261-279.

HOLTHUIS, L. B., 1973. Caridean shrimps found in land-locked saltwater pools at four Indo-West Pacific localities (Sinai Peninsula, Fuanfuti Atoll, Maui and Hawaii Islands), with descriptions of one new genus and four new species. Zoologische Verhandelingen, **128**: 1-48.

MACIOLEK, J. A., 1983. Distribution and biology of Indo-Pacific insular hypogeal shrimps. Bulletin of Marine Science, **33**: 606-618.

MALAY, M. C. M., K. C. S. EBREO, L. R. FELIX, J. N. DOMINGO & J. T. GERONA, 2022. Observations on anchialine-pool shrimps (Decapoda: Caridea: Atyidae, Barbouriidae) from the Philippines: a re-assessment after four decades and discovery of a second epigeal pool. Journal of Crustacean Biology, **42**: ruab077 [1-9].

SAKIHARA, T. S., 2012. A diel comparison of the unique faunal assemblage in remote anchialine pools on Hawai'i Island. Pacific Science, **66**: 83-95.

SANTOS, S. R., 2006. Patterns of genetic connectivity among anchialine habitats: a case study of the endemic Hawaiian shrimp *Halocaridina rubra* on the island of Hawaii. Molecular Ecology, **15**: 2699-2718.

SMITH, M. J. & W. D. WILLIAMS, 1981. The occurrence of *Antecaridina lauensis* (Edmondson) (Crustacea, Decapoda, Atyidae) in the Solomon Islands. An intriguing biogeographical problem. Hydrobiologia, **85**: 49-58.

STOCK, J. H., T. M. ILIFFE & D. WILLIAMS, 1986. The concept "anchialine" reconsidered. Stygologia, **2**: 90-92.

WEAR, R. G. & L. B. HOLTHUIS, 1977. A new record for the anchialine shrimp *Ligur uveae* (Borradaile, 1899) (Decapoda, Hippolytidae) in the Philippines with notes on its morphology, behaviour and ecology. Zoologische Mededelingen, **51**: 125-140.

WEESE, D. A., Y. FUJITA, M. HIDAKA & S. R. SANTOS, 2012. The long and short of it: genetic variation and population structure of the anchialine shrimp *Caridina rubella* on Miyako-jima, Japan. Journal of Crustacean Biology, **32**: 109-117.

WEESE, D. A., Y. FUJITA & S. R. SANTOS, 2013. Multiple colonizations lead to cryptic biodiversity in an island ecosystem: comparative phylogeography of anchialine shrimp species in the Ryukyu Archipelago, Japan. Biological Bulletin, **225**: 24-41.

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