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FIRST REPORT OF AN ASSOCIATION OF THE DEEP-WATER HERMIT CRAB *PARAPAGURUS PILOSIMANUS* (DECAPODA, PARAPAGURIDAE) AND THE ZOANTHARIAN *EPIZOANTHUS* FROM MACARONESIA

BY

JOSÉ A. GONZÁLEZ[1,3]) and MANUEL BISCOITO[2])

[1]) EMAP — Applied Marine Ecology and Fisheries, i-UNAT, University of Las Palmas de Gran Canaria, Campus Universitario de Tafira, E-35017 Las Palmas de Gran Canaria, Spain

[2]) Funchal Marine Biology Station, MARE Sea and Environment Sciences Centre & OOM — Madeira Oceanic Observatory, Funchal Natural History Museum, Rua da Mouraria 31, P-9004-546 Funchal, Madeira, Portugal

Hermit crabs are important ecosystem engineers (Jones et al., 1994) in marine habitats, from the intertidal to the deep sea. The symbiotic associates of hermit crabs were reviewed worldwide by Williams & McDermott (2004), and over 550 invertebrates, from 16 phyla, were found associated with over 180 species of hermit crabs. Many studies have been focused on hermit crab-actiniarian associations, while hermit crab-zoantharian symbioses have received less attention (Kise et al., 2019).

Carcinoecium-forming species of *Epizoanthus* Gray, 1867 (Anthozoa, Hexacorallia, Zoantharia) are found in all oceans, ranging from the subtidal to almost 5000 m depth (Williams & McDermott, 2004). A few occur in the temperate eastern Atlantic, including the small *Epizoanthus papillosus* Johnston, 1842 [generally associated with the pagurid *Anapagurus laevis* (Bell, 1845)], in shallow (generally 2 to <1000 m) waters. At greater depths, *E. papillosus* is replaced by the much larger *Epizoanthus paguriphilus* Verrill, 1883 (500-2000 m) and *Epizoanthus abyssorum* Verrill, 1885 (>3000 m), both associated with the parapagurid *Parapagurus pilosimanus* Smith, 1879. In the Mediterranean, a similar relationship occurs between *Epizoanthus arenaceus* (Delle Chiaje, 1836) and the diogenid *Paguristes eremita* (Linnaeus, 1767) (Ryland & Ward, 2016). The taxonomic status of larger, deep-sea, carcinoecium-forming species of *Epizoanthus* is not totally clarified (e.g., Ryland & Ward, 2016) and this task is currently being undertaken with the help of molecular methodologies (e.g., Reimer et al., 2010; Kise et al., 2019).

[3]) Corresponding author; e-mail: pepe.solea@ulpgc.es

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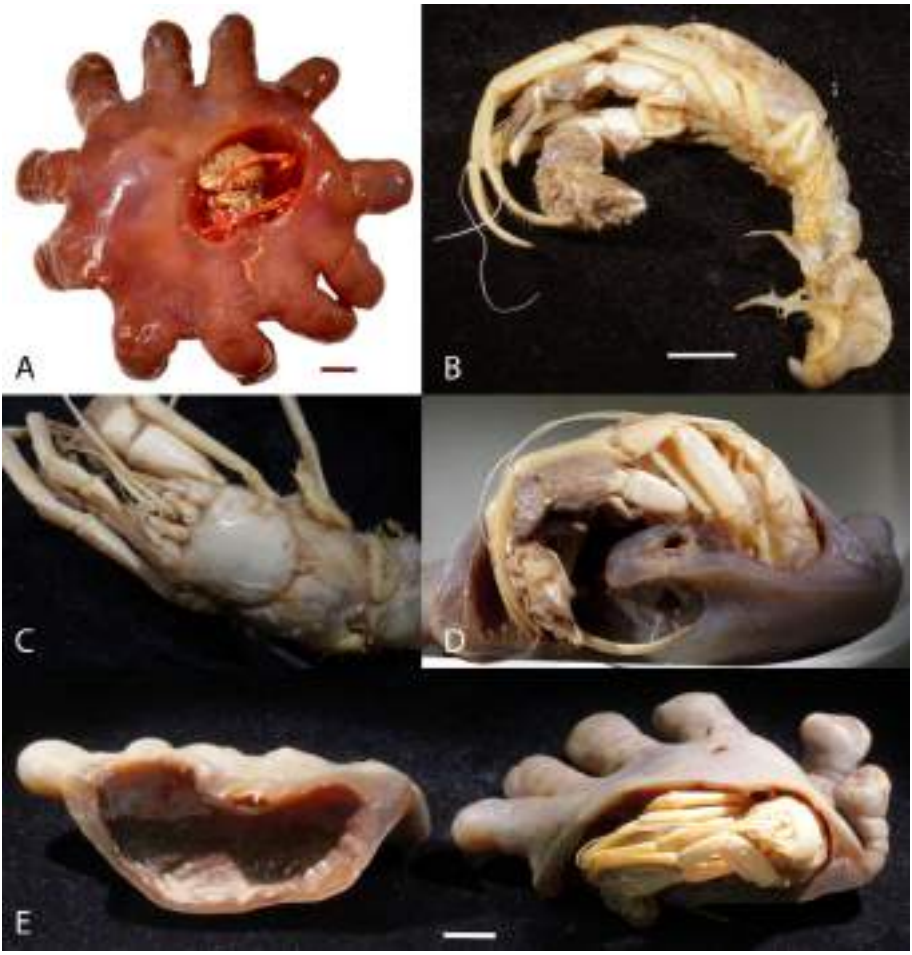

Fig. 1. A, Live colony of the zoantharian *Epizoanthus paguriphilus* Verrill, 1883 (MMF 47929) associated with the deep-water parapagurid hermit crab *Parapagurus pilosimanus* Smith, 1879 (MMF 47928) from the Canary Islands; B, lateral view of *P. pilosimanus* (ovigerous female, 15 mm shield length) once fixed and extracted from the shelter; C, dorsal view of the anterior part of *P. pilosimanus*, showing its shield in detail; D, the *Epizoanthus* colony sectioned, showing the position of the hermit crab inside its shelter; E, both parts of the *Epizoanthus* colony sectioned once. Scale bar: 1 cm.

Here we report for the first time, in the Macaronesia ecoregion, the association between the deep-water hermit crab *Parapagurus pilosimanus* Smith, 1879 (Decapoda, Parapaguridae) and the cnidarian epibiont *Epizoanthus paguriphilus* Verrill, 1883 (Hexacorallia, Zoantharia) (fig. 1A).

The specimens studied were obtained in the framework of the research project "Mariscomac". Sampling with benthic baited traps off the southeast coast of the island of Gran Canaria was focused on deep-water decapod crustaceans

and carried out on board the F/V "Juanfe" on 16 July 2017. Amongst the specimens, a zoanthid-hermit crab symbiosis was encountered (fig. 1A), which was photographed on board and then fixed in 80% ethanol for later morphological analysis and identification in the laboratory. Specimens were deposited in the collections of the Funchal Natural History Museum (MMF).

The house/shelter of the hermit crab was preliminarily identified as *Epizoanthus paguriphilus* with the assistance of experts in this cnidarian group. In fact, it is a colony of the zoanthid formed by 11 polyps.

Once the zoanthid was dissected at the laboratory (fig. 1D-E), the deep-water hermit crab was identified as *P. pilosimanus* according to Zariquiey Álvarez (1968), Lemaitre (1989) and Cardoso & Lemaitre (2012) (fig. 1B-C). Shield length (ShL) from the tip of the rostral spine to the end of the posterior border of the shield at mid-level, maximum shield width (ShW), right and left cheliped length (RChL and LChL), right and left maximum cheliped width (RChW and LChW) at level of the palm, and ocular peduncle length including cornea (OPL) were measured following Baba et al. (1986). The presence of eggs (fig. 1B) allowed an easy determination of sex.

The systematic classification for the anomuran follows the global data base WoRMS: http://www.marinespecies.org/ (Lemaitre & McLaughlin, 2020).

Suborder PLEOCYEMATA Burkenroad, 1963
Infraorder ANOMURA MacLeay, 1838
Superfamily PAGUROIDEA Latreille, 1802
Family PARAPAGURIDAE Smith, 1879
Genus *Parapagurus* Smith, 1879
Parapagurus pilosimanus Smith, 1879 (fig. 1A-E)

Material examined.— Voucher codes: MMF 47928, one ovigerous female (ShL 15 mm, ShW 14 mm, RChL 21 mm, LChL 13.5 mm, RChW 10 mm, LChW 7 mm, OPL 6.8 mm) (fig. 1B-C). Collection locality: SE of the island of Gran Canaria, off Castillo del Romeral, between 27°41.599′N 15°31.367′W and 27°41.977′N 15°30.578′W, 810-850 m depth; found in an eleven-polyp colony of *Epizoanthus paguriphilus* (MMF 47929); the anterior part of the carapace (shield) with eyes and antennules projecting from the colony of the cnidarian (fig. 1A).

Diagnosis.— Specific diagnostic features used for identifying the hermit crab are based on Zariquiey Álvarez (1968), Lemaitre (1989), Kazmi & Siddiqui (2006) and Cardoso & Lemaitre (2012). *P. pilosimanus* can be distinguished from other Atlantic congeners by the combination of the following characters: shape of the telson, with symmetrical posterior lobes; 2 or 3 rows of conical scales on the propodal rasp of pereiopod IV; and antennal acicles with the mesial margin unarmed or with 1 to 6 small tubercles (e.g., Lemaitre, 1989; Cardoso & Lemaitre, 2012). Another striking distinguishing character is: chelipeds unequal, right larger,

both covered by short pilosity (hence *pilosimanus*), especially the right one, and shorter than the walking legs (fig. 1B).

Distribution.— For many years, this rare deep-water hermit crab was considered as an amphi-Atlantic species with a wide distribution, occurring in the western Atlantic, from Nova Scotia, Canada to Guyana; the central Atlantic: Mid-Atlantic Ridge (near Tristan da Cunha) (Lemaitre, 1989); and in the eastern Atlantic, from southwest Iceland to the Gulf of Guinea and the southern Atlantic (Walvis Ridge, Cardoso & Lemaitre, 2012), including the Azores, the Canary and the Cape Verde Islands (e.g., d'Udekem d'Acoz, 1999; González, 2018). However, this species has also been recorded from two regions in the eastern Indian Ocean (Lemaitre & McLaughlin, 2020), e.g., in the Natal region, South Africa (Barnard, 1950) and in the northern Arabian Sea (Kazmi & Siddiqui, 2006). So, the species is currently referred to as cosmopolitan (Lemaitre & McLaughlin, 2020). In the Canary Islands it was first recorded by A. Milne-Edwards & Bouvier (1900).

Habitat and biology.— Benthic. Usually found living in shells of some gastropods and scaphopods covered by actiniarians (A. Milne-Edwards & Bouvier, 1900) on sand and shell remains (García-Raso, 1996), at depths between 102 and 3864 m, mainly at 400-1400 m (Lemaitre, 1989; d'Udekem d'Acoz, 1999; Cardoso & Lemaitre, 2012). The studied specimen was collected at 810-850 m depth, which is within the known depth range for the species. According to fishermen from the southeastern coast of Tenerife, this hermit crab is frequently caught entangled in gillnets used on shell remains bottoms at around 100-150 m depth (A. Brito, pers. comm.). The examined ovigerous female was carrying ca. 133 eggs (egg average diameter 0.8 mm) attached to 1st to 3rd left pleopods (*P. pilosimanus* females have 4 unpaired pleopods (Kazmi & Siddiqui, 2006)).

Remarks.— *Parapagurus* hermit crabs are commonly found living in association with either zoantharians or actiniarians, forming a carcinoecium (Muirhead et al., 1986), a chitin-like pseudo-shell (Kise et al., 2019). The studies of parapagurids living with cnidarians as housing suggest that the association may have evolved as a result of scarcity of shells in the deep sea, thus enabling these hermit crabs to survive and establish themselves (Cardoso & Lemaitre, 2012). Schejter & Mantelatto (2011) reported on a shelter association between the parapagurid hermit crab *Sympagurus dimorphus* (Studer, 1883) and *Epizoanthus paguricola* Roule, 1900 in the southwestern Atlantic, postulating an additional and non-exclusive hypothesis explaining this association due to the presence of non-adequate shells in the region.

Parapagurus pilosimanus has been found associated with the following Anthozoa, Hexacorallia cnidarians: *Paracalliactis consors* (Verrill, 1882) (as *Urticina consors*) (Actiniidae), *Calliactis polypus* (Forsskål, 1775) and *Paracalliactis stephensoni* Carlgren, 1928 (Hormathiidae), and *Palythoa eupaguri* Marion, 1882

(Sphenopidae) within the actiniarians, and *E. carcinophilus* Carlgren, 1923, *E. abyssorum*, *E. paguriphilus*, and *Epizoanthus* sp. (Epizoanthidae) within the zoantharians (Muirhead et al., 1986; Lemaitre, 1989; Ates, 2003; Cardoso & Lemaitre, 2012; Fernandez-Leborans, 2013).

Parapagurus pilosimanus is usually observed living in carcinoecia formed by large colonies of *Epizoanthus* spp., and associations with *E. abyssorum*, *E. carcinophilus* and *E. paguriphilus* are documented (Muirhead et al., 1986; Lemaitre, 1989; Ates, 2003; Cardoso & Lemaitre, 2012). The association between *P. pilosimanus* and *E. paguriphilus* was reported by Urzelai et al. (1990) in the Bay of Biscay at depths around 1000 m.

This is the first record of *E. paguriphilus*, as well as of the *P. pilosimanus*-*E. paguriphilus* symbiosis from the Canary Islands and indeed from the Macaronesia ecoregion sensu Spalding et al. (2007) (Azores-Madeira-Canaries), which enlarges the knowledge on distribution of this intriguing group.

A non-documented citation of *Epizoanthus* cf. *auronitens* Pax & Muller, 1956 was included in the checklist (annex) of the Cnidaria Anthozoa from the Canaries (Brito et al., 2003), but Prof. A. Brito (pers. comm.) has confirmed that this citation should rather refer to *Terrazoanthus* sp. Actually, no species of *Epizoanthus* were included in the monograph on corals of the Canary Islands by Brito & Ocaña (2004), although *Epizoanthus martinsae* Carreiro-Silva, Ocaña, Stanković, Sampaio, Porteiro, Fabri & Stefanni, 2017, associated with the antipatharian *Leiopathes* sp., has recently been described from the Azores (Carreiro-Silva et al., 2017).

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REFERENCES

ATES, R. M. L., 2003. A preliminary review of zoanthid-hermit crab symbioses (Cnidaria; Zoantharia/Crustacea; Paguridea). Zool. Verh., Leiden, **345**: 41-48.

BABA, K., K. I. HAYASHI & M. TORIYAMA, 1986. Decapod crustaceans from the continental shelf and slope around Japan. The intensive research of unexploited fishery resources on continental slopes: 1-336. (Japan Fisheries Resource Conservation Association, Tokyo).

BARNARD, K. H., 1950. Descriptive catalogue of South African decapod Crustacea (crabs and shrimps). Ann. South Afr. Mus., **38**: 1-837.

BRITO, A. & Ó. OCAÑA, 2004. Corals of the Canary Islands. Skeleton Anthozoa of the littoral and deep bottoms: 1-480. (F. Lemus Editor, La Laguna, Tenerife).

BRITO, A., Ó. OCAÑA & A. SANCHO, 2003. Cnidaria, Anthozoa. In: L. MORO, J. L. MARTÍN, M. J. GARRIDO & I. IZQUIERDO (eds.), Lista de especies marinas de Canarias. Algas, hongos, plantas y animales. Banco de datos de biodiversidad de Canarias: 40-43, 213 (anexo). (Gobierno de Canarias & Gesplan, La Laguna).

CARDOSO, I. & R. LEMAITRE, 2012. First reports of deep-water hermit crabs *Parapagurus* Smith, 1879 (Decapoda, Parapaguridae) and coelenterate associates from the Mid-Atlantic Ridge and South Atlantic. Crustaceana, **85**(4-5): 591-600.

CARREIRO-SILVA, M., Ó. OCAÑA, D. STANKOVIĆ, Í. SAMPAIO, F. M. PORTEIRO, M. C. FABRI & S. STEFANNI, 2017. Zoantharians (Hexacorallia: Zoantharia) associated with cold-water corals in the Azores region: new species and associations in the deep sea. Front. Mar. Sci., **4** [88]: 1-21. DOI:10.3389/fmars.2017.00088.

D'UDEKEM D'ACOZ, C., 1999. Inventaire et distribution des Crustacés Décapodes de l'Atlantique nord-oriental, de la Méditerranée et des eaux continentales adjacentes au nord de 25°N. Patrimoines naturels, Paris, **40**: i-x, 1-383.

FERNANDEZ-LEBORANS, G., 2013. A review of cnidarian epibionts on marine Crustacea. Oceanol. Hydrobiol. Stud., **42**(3): 347-357.

GARCÍA-RASO, J. E., 1996. Crustacea Decapoda (excl. Sergestidae) from Ibero-Moroccan waters. Results of Balgim-84 Expedition. Bull. Mar. Sci., **58**(3): 730-752.

GONZÁLEZ, J. A., 2018. Checklists of Crustacea Decapoda from the Canary and Cape Verde Islands, with an assessment of Macaronesian and Cape Verde biogeographic marine ecoregions. Zootaxa, **4413**(3): 401-448.

JONES, C. G., J. H. LAWTON & M. SHACHAK, 1994. Organisms as ecosystem engineers. Oikos, **69**: 373-386.

KAZMI, Q. B. & F. A. SIDDIQUI, 2006. An illustrated key to the Malacostraca (Crustacea) of the northern Arabian Sea. Part VI: Decapoda Anomura. Pakist. J. Mar. Sci., **15**(1): 11-79.

KISE, H., J. MONTENEGRO, M. EKINS, T. MORITAKI & J. D. REIMER, 2019. A molecular phylogeny of carcinoecium-forming *Epizoanthus* (Hexacorallia: Zoantharia) from the western Pacific Ocean with descriptions of three new species. Syst. Biodivers., **17**(8): 773-786. DOI:10.1080/14772000.2019.1693439.

LEMAITRE, R., 1989. Revision of the genus *Parapagurus* (Anomura: Paguroidea: Parapaguridae), including redescriptions of the western Atlantic species. Zool. Verh., Leiden, **253**: 1-106.

LEMAITRE, R. & P. MCLAUGHLIN, 2020. World Paguroidea & Lomisoidea database. *Parapagurus pilosimanus* Smith, 1879. Accessed through: World Register of Marine Species at: http://www.marinespecies.org/aphia.php?p=taxdetails&id=107248 on 2020-02-04.

MILNE-EDWARDS, A. & E. L. BOUVIER, 1900. Brachyures et Anomoures. In: Crustacés Décapodes, Première partie. Expéd. scient. Travailleur et Talisman, **6**: 1-396. (Paris).

MUIRHEAD, A., P. A. TYLER & M. H. THURSTON, 1986. Reproductive biology and growth of the genus *Epizoanthus* (Zoanthidea) from the north-east Atlantic. J. Mar. Biol. Assoc. U.K., **66**: 131-143.

REIMER, J. D., M. HIROSE, T. NISHISAKA, F. SINNIGER & G. ITANI, 2010. *Epizoanthus* spp. associations revealed using DNA markers: a case study from Kochi, Japan. Zool. Sci., **27**: 729-734.

RYLAND, J. S. & H. WARD, 2016. Carcinoecium-forming *Epizoanthus* [Hexacorallia: Zoantharia] and the biology of *E. papillosus* in the eastern Atlantic, with special reference to the cnidom. Zootaxa, **4088**(4): 489-514.

SCHEJTER, L. & F. L. MANTELATTO, 2011. Shelter association between the hermit crab *Sympagurus dimorphus* and the zoanthid *Epizoanthus paguricola* in the southwestern Atlantic Ocean. Acta Zool., **92**: 141-149.

SPALDING, M. D., H. E. FOX, G. R. ALLEN, N. DAVIDSON, Z. A. FERDAÑA, M. FINLAYSON, B. S. HALPERN, M. A. JORGE, A. LOMBANA, S. A. LOURIE, K. D. MARTIN, E. MCMANUS, J. MOLNAR, C. A. RECCHIA & J. ROBERTSON, 2007. Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. BioScience, **57**: 573-583.

URZELAI, A., M. ELIZALDE, T. CAPELLÁN, I. ESTEBAN, A. QUIROGA, I. ZABALA & M. IBÁÑEZ, 1990. Estudio preliminar de las comunidades de *Pagurus alatus* Fabricius, 1775 y *Parapagurus pilosimanus* S. I. Smith, 1879 (Crustacea Decapoda) y *Epizoanthus paguriphilus* Verrill, 1883 (Anthozoa Zoantarida) de la fosa de Cap Breton (Golfo de Vizcaya). Lurralde, **13**: 193-206.

WILLIAMS, J. D. & J. J. MCDERMOTT, 2004. Hermit crab biocoenoses: a worldwide review of the diversity and natural history of hermit crab associates. J. Exp. Mar. Biol. Ecol., **305**: 1-128.

ZARIQUIEY ÁLVAREZ, R., 1968. Crustáceos decápodos ibéricos. Inv. Pesq., Barcelona, **32**: i-xv, 1-510.

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