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Further record of the deep-sea euphausiid, *Thysanopoda cristata* G. O. Sars, 1883 (Euphausiacea, Euphausiidae) from the southwestern Atlantic: with comments on morphological variations

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Abstract :

Euphausiids are a diverse order of crustaceans that play a key role in pelagic food webs. The genus Thysanopoda H. Milne Edwards, 1830 is composed of 14 valid species, widely distributed in all oceans. However, some gaps remain in our knowledge of the geographic distribution of Thysanopoda cristata G. O. Sars, 1883, and its actual occurrence in Brazil. This study aims to expand the knowledge on krill diversity in Brazilian waters, confirming the occurrence of T. cristata and providing illustrations of its morphological variations. Four specimens, two males and two females, were collected on board R/V "Antea" in October 2015, using a micronekton net with 1 mm mesh size, at depths ranging between 10 and 1660 m. Before this study, reports of T. cristata from Brazil were provided only in species lists or unpublished data. Our study confirms the presence of the species from the southwestern Atlantic and brings new information on its morphology.

Keywords : - Krill, Brazil, zooplankton, pelagic habitat, Abracos Project

Zooplanktonic organisms are widely studied worldwide to assess their biodiversity, biology and role in the pelagic energy transport, food webs, carbon and nitrogen flow and indications of environmental conditions (Bonecker et al., 2014). Among these organisms, holoplanktonic crustaceans of the order Euphausiacea Dana, 1852, composed by organisms, commonly known as krill (Ramirez, 1971, 1973, 1977; Montú, 1977), play an important role in the dynamics of pelagic communities, participating in both top-down and bottom-up controls (Rissik et al., 1997; Verity et al., 2002; Champalbert et al., 2005).

Krill is indeed the main prey for a large number of cephalopods, fishes, seabirds, sea lions and whales, due to its great abundance and rich source of energy and nutrients (Mauchline & Fisher, 1969; Gibbons et al., 1999; Letessier et al., 2009; Vereshchaka et al., 2018). Krill is also used in the production of feed for the aquaculture industry, the production of pharmaceuticals, and has been used as human food in some regions of Antarctica, Russia and Japan, due to the high concentration of fatty acids, lipids, vitamin A, Omega-3 and fluorine (Gibbons et al., 1999; Atkinson et al., 2008). For several regions of the world, e.g., subtropical, subpolar and polar regions, krill can be a potential indicator of water masses, associated with their occurrence and migration only in specific masses (Montú & Cordeiro, 1986; Atkinson et al., 2008; Sutton & Beckley, 2017).

To date, the order Euphausiacea is composed of two families: (i) Bentheuphausiidae Colosi, 1917, which is monospecific, comprising only the genus *Bentheuphausia* G. O. Sars, 1885, represented by *B. amblyops* G. O. Sars, 1885; and (ii) the family Euphausiidae Dana, 1852, comprising 11 genera and 86 valid species (WoRMS, 2022), which is widely distributed in all oceans including

high latitudes, occurring in pelagic habitats from the surface to the deep ocean (>5000 m) (Boden et al., 1955; Antezana & Brinton, 1981; Gibbons et al., 1999; Vereshchaka et al., 2018).

Around 60 species of krill are reported in the South Atlantic, from neritic to oceanic zones, including islands, archipelagos and atolls (Montú, 1977; Muxagata et al., 2019). In Brazilian waters, 22 species are currently recorded, distributed among *Euphausia* Dana, 1850 (6 species), *Nematobrachion* Calman, 1905 (3 species), *Nematoscelis* G. O. Sars, 1883 (4 species), *Stylocheiron* G. O. Sars, 1883 (4 species) and *Thysanopoda* (5 species) (Ramirez, 1971; Antezana & Brinton, 1981; Montú & Cordeiro, 1986; Gibbons et al., 1999; Lansac-Tôha & Freire, 1999). Large parts of these records are concentrated in only a few regions of Brazil, such as: the Saint Peter and Saint Paul as well as the Fernando de Noronha archipelagos and in the states of Espírito Santo, Rio de Janeiro (Campos Basin), São Paulo, Paraná and Rio Grande do Sul (Ramirez, 1971; Gibbons et al., 1999).

Regarding Euphausiidae, the genus *Thysanopoda* H. Milne Edwards, 1830 is composed of 14 valid species with a broad distribution in all oceans (including Arctic and Antarctic regions), especially in meso- and bathypelagic zones (∼200 to 4000 m) (Brinton, 1962; Baker et al., 1990; Gibbons et al., 1999). According to Lansac-Tôha & Freire (1999) and Muxagata et al. (2019), only five species of *Thysanopoda* have been recorded in the South Atlantic (*T. aequalis* Hansen, 1905; *T. monacantha* Ortmann, 1893; *T. obtusifrons* G. O. Sars, 1883; *T. orientalis* Hansen, 1910; and *T. tricuspidata* H. Milne Edwards, 1837). However, reports of *T. cristata* G. O. Sars, 1883 from the South Atlantic can only be found as elements in species lists in grey literature, and in Silva et al. (2019). In view of that surprisingly basic condition, this study aims to improve knowledge on krill diversity in Brazilian waters with the confirmation of *T. cristata* collected during the Acoustic Along the Brazilian Coast 1 (Abraços 1) survey in 2015, providing illustrations, morphological variations and deposited material.

MATERIAL AND METHODS

The specimens of *Thysanopoda cristata* were collected in October 2015 during the Abraços 1 survey, covering Northeastern Brazil between the states of Alagoas and Rio Grande do Norte and encompassing the Fernando de Noronha Archipelago, Rocas Atoll and the Fernando de Noronha Chain (Bertrand, 2015). Sampling was performed in the water column, using a micronekton trawl net with a 1 mm mesh at depths ranging between 10 and 1170 m.

After sampling, specimens were sorted out. In the laboratory, all individuals were measured with a digital calliper (0.01 mm) for total length (TL) and carapace

width (CW), and were next preserved in formalin 4% and thereafter identified to species level according to Boden et al. (1955) and Lozano Soldevilla & Lozano Soldevilla (1991). The appendages were dissected and mounted on semi-permanent excavated glass slides with glycerin and observed under an optical microscope Leica DM E and a stereomicroscope Nikon SMZ 800, both with camera lucida, for illustration. The drawings were digitized with CorelDRAW® Graphics Suite 2018. All specimens examined were deposited in the Museum of Oceanography Prof. Petrônio Alves Coelho of the Federal University of Pernambuco, Recife, Brazil (MOUFPE).

RESULTS AND DISCUSSION

Specimens collected

Four specimens of *Thysanopoda cristata*, 2 females and 2 males, were collected from Rocas Atoll, "Abraços 1" Station 22/ Leg. 1, initial trawl coordinates: 4°07′S 33°47′W, final trawl coordinates: 4°07′S 33°48′W, 8 October 2015, at a depth of 525 m, MOUFPE 20050.

Descriptive notes

The specimens' size (TL) ranged from 51.5 to 67.8 mm, while the carapace width (CW) ranged between 15 and 21 mm. *T. cristata* is characterized by a rostrum with an acute main spine and a shorter one above it (fig. 1A); carapace with a longitudinal groove above the inferior margin and a posterolateral denticle on the inferior margin (fig. 1A); first segment of the peduncle of first antenna bearing a hood-like lappet with dorsal setae, second segment dorsally produced as an acute spine (fig. 1B, C); fourth and fifth abdominal somites with a dorsal spine (fig. 1D, E); sixth abdominal somite slightly longer than fifth (fig. 1F); petasma with spinous process almost straight to curved, terminal process curved, proximal process longer than terminal and tapering distally, lateral process long and very curved distally, additional process short and somewhat rounded (fig. 1G); uropod extending beyond distal end of telson, protopod bearing short lateral plumose setae, with a produced dorsal spine, exopod with plumose setae, smooth on the lateral margin and slightly serrate on medial margin, bearing a distolateral projection forming an acute spine, endopod shorter than exopod, with plumose setae, margins slightly crenulate (fig. 1H); telson with up to 10 pairs of stout dorsal setae (fig. 1I). Thoracopods 1-8 with regular shape and structurally similar, bearing plumose, pectinate and/or serrate setae on the endopods and densely plumose setae on exopods (fig. 2A-H); seventh thoracopod (fig. 2G) like the sixth thoracopod (fig. 2F); eighth thoracopod (fig. 2G) with rudimentary endopod.

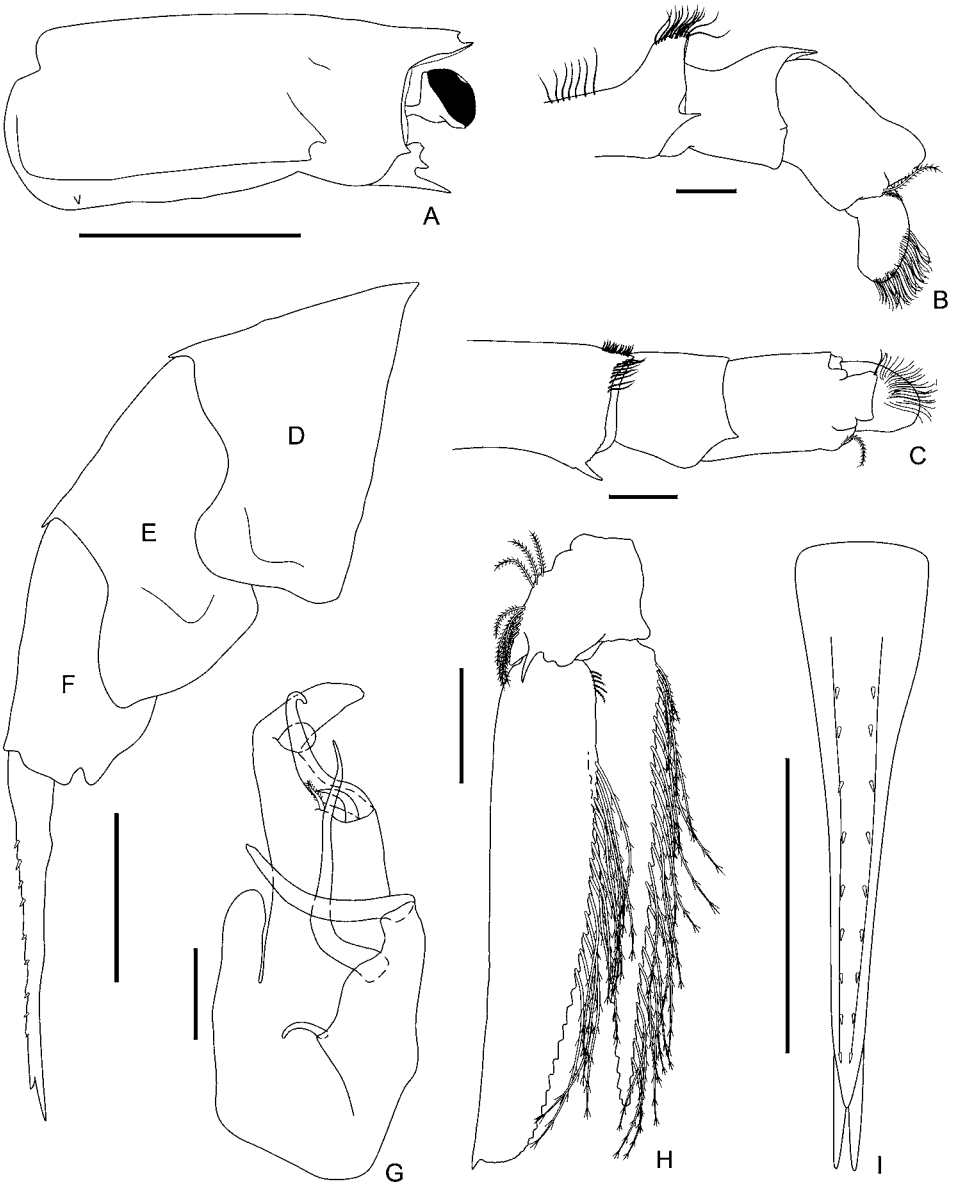

Fig. 1. *Thysanopoda cristata* G. O. Sars, 1883, (MOUFPE 20050). Female, 67.8 mm in length: A, carapace; D, fourth abdominal somite; E, fifth abdominal somite; F, sixth abdominal somite; H, uropod; I, telson. Male, 52.1 mm in length: B, first antennal peduncle in lateral view; C, first antennal peduncle in dorsal view; G, petasma. Scale bars = 10 mm for A; 1 mm for B-C; 5 mm for D-F and I; 0.5 mm for G; 2 mm for H.

Fig. 2. *Thysanopoda cristata* G. O. Sars, 1883, (MOUFPE 20050). Female, 67.8 mm in length: A-H, thoracopods 1-8, respectively. Scale bars = 0.05 mm.

Remarks and general discussion

The individuals of *T. cristata* analysed herein present some morphological differences from others described in the literature, such as: inferior margin of carapace with a denticle (vs. carapace without inferior denticle in G. O. Sars'

(1883) original description). Boden et al. (1955) and Lozano Soldevilla & Lozano Soldevilla (1991) provided an identification key in which the denticle is present, leading us to suppose that this character was overlooked by Sars (1883) as it can be often shortened. Additionally, the denticle does not exceed the carapace inferior margin, while it does in the illustration by Boden et al. (1955). The rostrum in our individuals has the main spine slightly longer than the shorter one and is weakly curved upwards, whereas it seems to be longer and deflexed in the description by Sars (1883), and straight in that of Boden et al. (1955). The sixth abdominal somite of our individuals presents a strong notch near the posterodistal corner, not observed, nor reported, in other literature. In our specimens, it is also possible to see the telson with up to 10 pairs of stout dorsal setae (vs. 6 pairs and 7 pairs described, respectively, in the works of Sars, 1883, and Boden et al., 1955).

Thysanopoda cristata was described by Sars (1883) based only on one adult male from off Mindanao in the Philippines (Pacific Ocean) (Station 213 at 3750 m), but it is known to be widely distributed in the Indo-Pacific (between 30°N and 40°S), South Africa (Natal coast), Baja California in Mexico, and in the Polar Arctic and Antarctic oceans (Boden, 1955; Brinton, 1962; Grindley & Penrith, 1965; Taniguchi, 1974; Youngbluth, 1975). For the Atlantic Ocean, this species was reported only in the Sargasso Sea, Azores and possible observations in the tropical western Atlantic (covering the North and South Atlantic) (Gibbons et al., 1999; Lansac-Tôha & Freire, 1999; Muxagata et al., 2019). However, several of these records were provided in unpublished reports (dissertations and theses) containing only species lists, without taxonomic descriptions, and specimens not deposited in a zoological collection, nor included an estimate of a possible region of occurrence for the *T. cristata* found. Based on those data, some geographic information included in the literature may contain dubious records from some marine areas around the world.

According to Vereshchaka et al. (2018), *T. cristata* is reported from mesopelagic zones, performing nictemeral migration between the depths of 800 and 2000 m, in addition, the occurrence of this species in shallow waters can be associated with upwelling regions, especially around oceanic islands. In this context, many species of krill are used as indicators of fish stocks, due to their direct predation by commercial fish (Champalbert et al., 2005). For example, in oceanic waters near the Saint Peter and Saint Paul Archipelago, the distribution of *T. cristata* displays seasonal movements that are indicative of the presence of *Thunnus albacares* (Bonnaterre, 1788) and *T. obesus* (Lowe, 1839) (Silva et al., 2019).

In Brazil, knowledge on krill diversity is still far from complete, with the main papers published between 1971 and 1999 (Ramirez, 1971, 1973, 1977; Antezana & Brinton, 1981; Montú & Cordeiro, 1986; Gibbons et al., 1999; Lansac-Tôha & Freire, 1999). However, new surveys along the Brazilian oceanic waters are

providing new materials for new records of known species. Thus, the new record of *T. cristata* increases the knowledge on krill diversity in the southwestern Atlantic, thereby providing an insight that the species might be widespread in the region.

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