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Morphological abnormalities in *Corycaeus speciosus* Dana, 1849 (Copepoda, Cyclopoida) from the area of an Equatorial Atlantic Island

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Abstract: Taxonomic and ecological studies of a large number of specimens can lead to the finding of morphological anomalies. Thus, based on 800 specimens of *Corycaeus speciosus* in different developmental stages (juvenile and adult copepodites) this study was carried out to assess for the first time anomalies in Equatorial Atlantic specimens. Samples were collected around the St. Peter and St. Paul Archipelago (Equatorial Atlantic). Anomalies were found at the end of the prosome in two female specimens, one recorded in the juvenile copepodite stage V and was characterized by a left-side rounded prosome tip, while in the adult the anomaly was characterized by a rounded prosome inner the tip in the left-side. The causes of the malformations remain unknown, but the results are indicative that they are probably genetic in character, transmitted on reproduction. However, experimental tests are necessary to confirm such conclusions and their effect on the population structure of this ecologically important species.

Résumé : *Anomalies morphologiques chez* Corycaeus speciosus *Dana, 1849 (Copepoda: Cyclopoida) dans la region d'une île de l'Atlantique équatorial.* Les études taxonomiques et écologiques d'un grand nombre de spécimens peuvent conduire à la découverte d'anomalies morphologiques. Ainsi, à partir de 800 spécimens de *Corycaeus speciosus* de stades de développement différents (copepodites juvéniles et adultes), cette étude a été réalisée pour examiner, pour la première fois, des anomalies sur des spécimens d'Atlantique équatorial. Les échantillons ont été recueillis autour de l'archipel de St. Pierre et St. Paul (Atlantique équatorial). Des anomalies ont été trouvées à la pointe du prosome chez deux spécimens femelles, l'une sur le stade copepodite V, caractérisée par une pointe de prosome arrondie du côté gauche, tandis que chez une adulte l'anomalie était caractérisée par un prosome arrondi à l'intérieur de la pointe sur le côté gauche. Les causes de ces malformations restent encore inconnues, mais les résultats indiquent qu'elles sont probablement de nature génétique, transmises lors de la reproduction. Cependant, des tests expérimentaux sont nécessaires pour confirmer ces conclusions et leurs effets sur la structure de la population de ces espèces écologiquement importantes.

Keywords: Corycaeus speciosus ● Equatorial Atlantic ● Isolated island ● Marine copepods ● Morphological abnormalities

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Introduction

Copepods are one of the most important organisms among marine zooplankton, mainly because they dominate in biomass and density in the mesozooplankton community of the tropical South Atlantic Ocean (Bonecker, 2006). The copepod orders of greatest importance in terms of density and biomass among marine plankton are Calanoida, Cyclopoida (including Poecilostomatoida) and Harpacticoida (Bradford-Grieve et al., 1999). Copepods are central components of marine pelagic food webs as they mediate the energy flow from phytoplankton to higher trophic levels (Turner, 2004).

Descriptions of crustaceans with deformities of the entire body or individual body parts have been made by various authors (Barthélémy et al., 1998; Dias, 1999; Martinelli-Filho et al., 2009). These anomalies are recorded primarily for faunistic studies, and as their causes are not well known, they are referred to as idiopathic and there is no quantitative data available. In addition to the spontaneous anomalies of unknown etiology, there are also those that are related to exposure to toxic contaminants (Weis et al., 1992), somatic mutations (Klein & Koomen, 1993), intense exposure to ultraviolet (UV) radiation, specifically UVB from 280 to 320 nm (Naganuma et al., 1997), parasitic diseases (Primavera & Quinitio, 2000) and predators (Jagadeesan & Jyothibabu, 2016).

This work recorded for the first time an anomaly at the end of the prosome in two female specimens at different developmental stages (juvenile and adult copepodites) of *Corycaeus speciosus* Dana, 1849 (Copepoda, Cyclopoida), in samples collected around the St. Peter and St. Paul Archipelago, hereafter SPSPA (0°855’10”N-29°820’33”W) (Equatorial Atlantic).

Materials & Methods

A total of 48 zooplankton samples were collected through oblique hauls extending to a depth of 75% of the local depth or, at most, to 200 m, in oceanographic expeditions performed in July 2010, September 2012 and August 2014. After collections, the samples were transferred to plastic bottles and immediately preserved in formaldehyde solution (4%), buffered with sodium tetraborate.

In the laboratory, the samples were fractionated in aliquots of 1/32 or 1/64, using a Motoda splitter (Omori & Ikeda, 1984) containing on average 300 individuals (Frontier, 1981). The number of specimens of the species *C. speciosus* analysed was between two and 15 individuals per sample.

The specimens were identified and inspected under a Zeiss Discovery V8 stereomicroscope and a Zeiss Axio Scope A1 microscope and photographed with Zeiss AxioCam RMc and AxioCam 105 color cameras. Posteriorly, the specimens were deposited at the Carcinological Collection of the “Museu de Oceanografia Prof. Petrônio Alves Coelho” (MOUFPE) of the “Universidade Federal de Pernambuco” (UFPE), in Recife, Pernambuco state, Brazil.

Results & Discussion

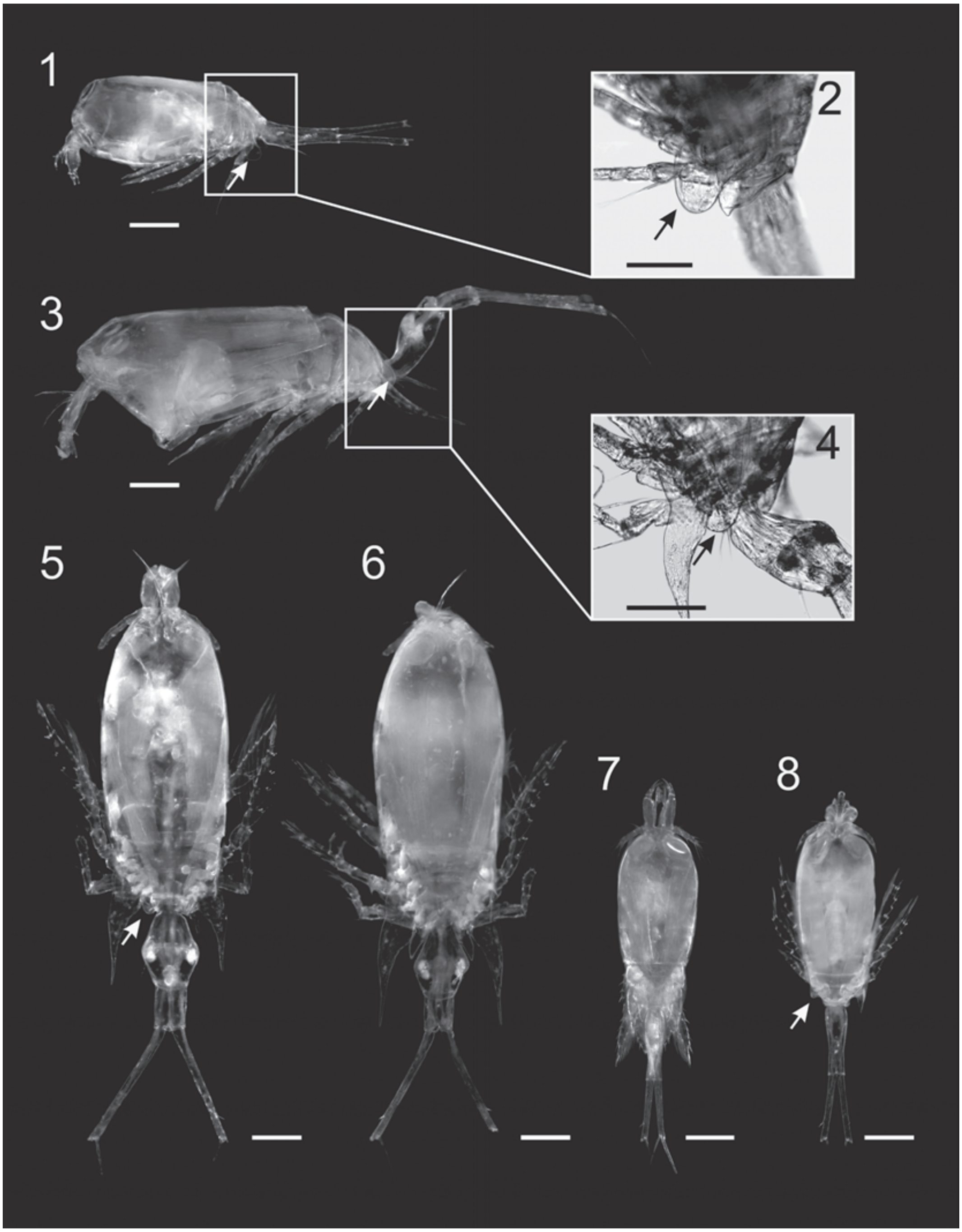
The Subclass Copepoda in the SPSPA was composed of 85 taxa (data not shown in this note) and the specie *C. speciosus* was found in 100% of the samples. The family Corycaeidae was represented by 6 species in the SPSPA, and has as its main features a cyclopiforme body, posteriorly pointed and two large eye lenses placed close together, sometimes adjoining in both sexes. The marine copepods of the genus *Corycaeus* are common and abundant in the oceans, mainly in tropical and subtropical seas (MOTODA, 1963). In the South Atlantic, this genus is represented by 17 species (Boltovskoy, 1999), among these *C. speciosus* is characterized as an epipelagic species, widespread and abundant in oceanic waters with temperatures close to 26°C and salinity of 35 (Bradford-Grieve et al., 1999).

Taxonomically, the adult females of *C. speciosus* (Figs 3-6) have the cephalosome and first pedigerous somite partially fused; prosome points longer than genital somite; divergent caudal rami longer than genital and anal somites combined; and basal setae on second antenna (A2) segment 1 are three times longer than the setae on second antenna (A2) segment 2 (Boltovskoy, 1999).

The Corycaeidae have six naupliar phases and six copepodite stages. In copepodite stage V (Figs 1-2 & 7-8), several particular features can be observed: 1) posterolateral angles of the third thoracic segment extended in fine point; 2) a third flow bristle added to each branch of furcation; 3) antennules with six segments; 4) four pairs of swimming legs, with a third segment in both exopodites and endopodites of the first three pairs; 5) as well as in the exopodite of the fourth pair. Males are slightly smaller than the females, which are distinguished by a swelling at the base of the antenna terminal thorn (Gibson & Grice, 1978).

In the present study, the anomaly recorded in the juvenile copepodite female (stage V) of *C. speciosus* (MOUFPE 18.543) was characterized by a left-side rounded prosome tip (see the arrows in Figs. 1, 2 & 8), while in the adult (MOUFPE 18.545) one the anomaly was characterized by a rounded prosome inner tip in the left-side (see the arrows in Figures 3-5). The other morphological characters of these specimens were investigated and confirm the general descriptions of the specie, available in Razouls et al. (2017).

The records of morphological anomalies in Cyclopoida



Figures 1-8. 1. Lateral view of *Corycaeus speciosus*, female in the Copepodite V stage of development, with anomaly at the tip of the third thoracic segment. **2.** Photo featured of the anomaly, characterized by a rounded tip on the left side at the end of the third thoracic segment in Copepodite female of *Corycaeus speciosus* V stage of development. **3.** Lateral view in adult female of *Corycaeus speciosus* with the presence of the anomaly at the prosome inner tip in the left-side. **4.** Photo featured of the anomaly, characterized by a rounded prosome inner tip in the left-side in adult female of *Corycaeus speciosus*. **5.** Dorsal view in adult female of *Corycaeus speciosus* with the presence of the anomaly at the prosome inner tip in the left-side. **6.** Dorsal view in adult female of *Corycaeus speciosus* without the presence of the anomaly at the prosome inner tip and at the end of the third thoracic segment. **7.** Dorsal view of *Corycaeus speciosus* female in the Copepodite V stage of development without the presence of the anomaly at the end of the third thoracic segment. **8.** Dorsal view of *Corycaeus speciosus*, female in the Copepodite V stage of development with anomaly at the tip of the third thoracic segment. All the specimens were collected on the St. Peter and St. Paul Archipelago, Tropical Atlantic Ocean. Figures 1 & 3-8 have a scalebar with length of 200 µm. Figure 2 with a scalebar length of 100 µm. The anomalies were indicated at figures by arrows. The figures 1, 3, 5-8 are proportional in size.

are rarely observed and discussed (Bhandare & Ingole, 2008; Mantha et al., 2013). However, for the order Calanoida these records are well documented (Brylinski, 1984; Behrends et al., 1997; Barthélémy et al., 1998; Omair, 1999; Gusmão & Mckinnon, 2009; Martinelli-Filho et al., 2009; Pombo & Martinelli-Filho, 2012; Melo et al., 2014). Different degrees of morphological alterations to the last pair of spines on the prosome were observed for both male and female in *Acartia lilljeborgii*. Some of these suggested that the anomalies registered are due to congenital defects, since the area of study (Caraguatatuba Bay, on the southeastern Brazilian coast) suffers from high anthropogenic disturbance, which increases the possibilities of induced morphological changes due to environmental factors (Pombo & Martinelli-Filho, 2012). Other species of calanoid copepods, such as those belonging to the family Candacidae, have different prosome extensions, considered secondary sex characters, indicating sexual dimorphism for this family (Boltovskoy, 1999). However, this is not the case for the Corycaeidae, since the characteristic of the family is to present both sides of the prosome sharply defined by Boltovskoy (1999), and these abnormalities are likely to occur equally in males and females.

The morphological malformations in these last stages of development in *C. speciosus* have never been reported before (Figs 2 & 4). It is unlikely that such anomalies arose during the ontogeny process, but rather during the process of embryonic development in the case of congenital defects (e.g., Björnberg, 1972; Crisafi & Crescenti, 1977). Abnormality affecting the embryonic stage, causing morphological deformities in the early stages of copepods (nauplius and copepodite), can have serious consequences for the survival of individuals and for the recruitment of any population with a high incidence of anomalies. These anomalies interfere in the process of development, hatching, swimming and reduction in physical fitness (Poulet et al., 1995).

Anomalies described in *Clausocalanus mastigophorus* occurring in the same area (SPSPA) are probably genetic in character, being transmitted on reproduction (Melo et al., 2014). The frequency of occurrence of these anomalies in *C. speciosus* and other specimens of copepods from the SPSPA need to be better investigated, and this alert for factors that need to be considered as a cause, since teratogenic anomalies have been observed in copepods (Pandourski & Evtimova, 2009).

Despite being an isolated archipelago that is not directly influenced by anthropogenic action, microplastics have been found in the SPSPA, which may have an indigenous origin, have been transported long distances by currents, or have originated from a fishing fleet of small boats (Ivar Do Sul et al., 2013). These microplastics can be a potential transfer vector of persistent organic compounds causing deleterious effects on marine biota (Thompson et al., 2004). Laboratory experiments have verified the intake of microplastics by calanoid copepods, reaffirming the ability of zooplankton to ingest microplastics (Wilson, 1973) and, consequently, perpetuate in the marine food web and attain predators such as *Corycaeus* species that can consume microplastic passively with prey (or in the prey itself) (Taylor et al., 2016). The diversity and anomalies of cyclopoid copepods were investigated along the hydrothermal vent at Kueishantao Island, north-eastern Taiwan and it was verified that pelagic cyclopoid copepods do ample vertical migrations along the water column (Lo et al., 2004). These migrations were related to additional searches of food sources in the form of bacteria (Burd & Thomson, 1994), being the pelagic copepods considered as opportunistic feeders that consume the excessive alimentary vent bacteria and organic carbon near hydrothermal vents. However, at these sites, these copepods were exposed to high concentrations of potentially toxic chemicals (Peng et al., 2011) and metals (Kondoh et al., 2003). Thus, pelagic cyclopoid copepods (eg, *Corycaeus* and *Oncaea*) can be transported to toxic environments through streams and may be exposed to toxic concentrations of metals and gases that weaken their exoskeletons (Mantha et al., 2013).

In this way, both the frequency of occurrence and the features of such morphological anomalies in isolated island areas can be tools for the assessment of impacts and to help distinguish between natural and anthropogenic changes, as well as assisting in environmental monitoring activities.

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