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Ditrichocorycaeus anglicus (COPEPODA; POECILOSTOMATOIDA), NEW BASIBIONT OF *Pseudohimantidium pacificum* (BACILLARIOPHYCEAE) IN BAHÍA DE LA PAZ, GULF OF CALIFORNIA

Ditrichocorycaeus anglicus (Copepoda; Poecilostomatoida), nuevo basibionte de *Pseudohimantidium pacificum* (Bacillariophyceae) en Bahía de La Paz, Golfo de California

RESUMEN. En muestras recolectadas en la Bahía de La Paz se observó que copépodos de la especie *Ditrichocorycaeus anglicus* son utilizados como basibiontes por la especie de diatomeas *Pseudohimantidium pacificum*. Un espécimen de *D. anglicus* de nueve recolectados en la bahía, presentó una alta intensidad epibionte por *P. pacificum* (108 células de adheridas a lo largo del cuerpo); tres especímenes tuvieron baja intensidad epibionte (5-7 diatomeas por individuo). La temperatura superficial del mar presentó un intervalo de 19–23 ºC en las estaciones de muestreo donde se observó esta asociación copépodo–diatomea.

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There is little information about the associations of epibiotic diatoms with marine crustaceans in Mexican waters. However, this is a widespread and well-documented phenomenon in other regions of the world. Marine zooplankton are often common basibionts or hosts for a variety of parasitic and epizoic animals and plants (Russell & Norris, 1971). The exoskeleton of copepods constitutes a favorable habitat for a variety of epibiotic bacteria, microalgae, and protozoans (Round, 1981; Carman & Dobbs, 1997; Walkusz & Rolbiecki, 2007). Pennate diatoms are among the most common epibiont microalgae that have been found growing on the body surface of copepods. Giesbrecht (1892) was likely the first to discover the epibiotic association of benthic microalgae attached to marine invertebrates. He noted the presence of stalked epibiont diatoms on the marine planktonic copepods *Agetus limbatus* (=*Corycaeus limbatus*) (Giesbrecht, 1891) collected in the Adriatic Sea. Gibson (1979) confirmed that diatoms *Pseudohimantidium pacificum* was the species recorded in that previous report of epibiosis. Interactions between marine copepods and their epibiont diatoms offer several interesting examples of host specificity (Totti *et al*., 2011). *P. pacificum* lives on a few marine crustaceans belonging to cyclopoid and harpacticoid copepods from a wide range of marine areas, attaching to the host exoskeleton by a mucus stalk (Simonsen, 1974; Gibson, 1979; Rivera *et al*., 1986; Ohtsuka *et al*., 2004; Skovgaard & Saiz, 2006; Tiffany, 2011; Totti *et al*., 2011; Fernandes & Calixto-Feres, 2012; Sahu *et al*., 2015).

The main epizoic diatoms reported on copepods are: *Pseudohimantidium pacificum* Hustedt & Krasske in Krasske, 1941, *Falcula hyalina* Takano, 1983, *Protoraphis atlantica* R.A. Gibson, 1978, *Sceptronema orientale* Takano, 1983, *Licmophora unidenticulata* Takano, 1983, and *Cylindrotheca closterium* (Ehrenberg) Reimann & J.C. Lewin, 1964 (Gibson, 1978; Takano, 1983; González & Vergara, 1984; Hiromi *et al*., 1985; Gárate-Lizárraga & Muñetón-Gómez, 2009; Tiffany, 2011; Fernandes & Calixto-Feres, 2012; Gárate-Lizárraga & Esqueda-Escárcega, 2016). Among these, *P. pacificum* has a worldwide distribution (Belyaeva, 1973; Hiromi *et al*., 1985; Gárate-Lizárraga & Muñetón-Gómez, 2009). The present study is the first record of the copepods *Ditrichocorycaeus anglicus* Lubbock, 1857 as basibionts of diatom, as well as the first record of epibiosis of the diatoms *P. pacificum* on this copepod species.

As a part of a long-term microalgal monitoring program, phytoplankton samples were collected at two sampling stations located at Bahía de La Paz, Baja California Sur, México (Fig. 1; Station 1: 24°8240.363N, 110°20240.293W, and Station 2: 24°10236.473N, 110°21231.623W) (Gárate-Lizárraga & Esqueda-Escárcega, 2016). Phytoplankton was sampled with a phytoplankton net (20-µm mesh, at Station 1 collected on February 12, 2013 and at Station 2 collected on March 2, 2016. Samples were fixed with acidified Lugol's solution and later preserved with 4% formalin. Sea surface temperature was measured with a bucket thermometer. The observation and taxonomic identification of the epibiont diatoms and copepods were made under a Carl Zeiss Axioscope 40 phase-contrast microscope. References for identification of the diatoms were: Gibson (1978, 1979), Hiromi *et al*. (1985), Rivera *et al*. (1986), Gárate-Lizárraga & Muñeton-Gómez (2009), Fernandes & Calixto-Feres (2012), and Sunesen *et al*. (2015). Copepods were identified to species level using standard taxonomic keys (Dahl, 1912; Sars, 1918). Taxonomy of the copepod species reported in the literature was updated using the World Register of Marine Species database (WoRMS, 2018).

A total of nine specimens of the copepods *Ditrichocorycaeus anglicus* (Lubbock, 1857) were counted in different phytoplankton samples (n=4 in February 2013 and n=5 in March 2016). Four specimens (two specimens from each sampling date) showed *Pseudohimantidium pacificum* cells on the carapace. About 108 cells of *P. pacificum* were observed along the body of a male specimen of *D. anglicus* collected in March 2016 (Fig. 1A-E).

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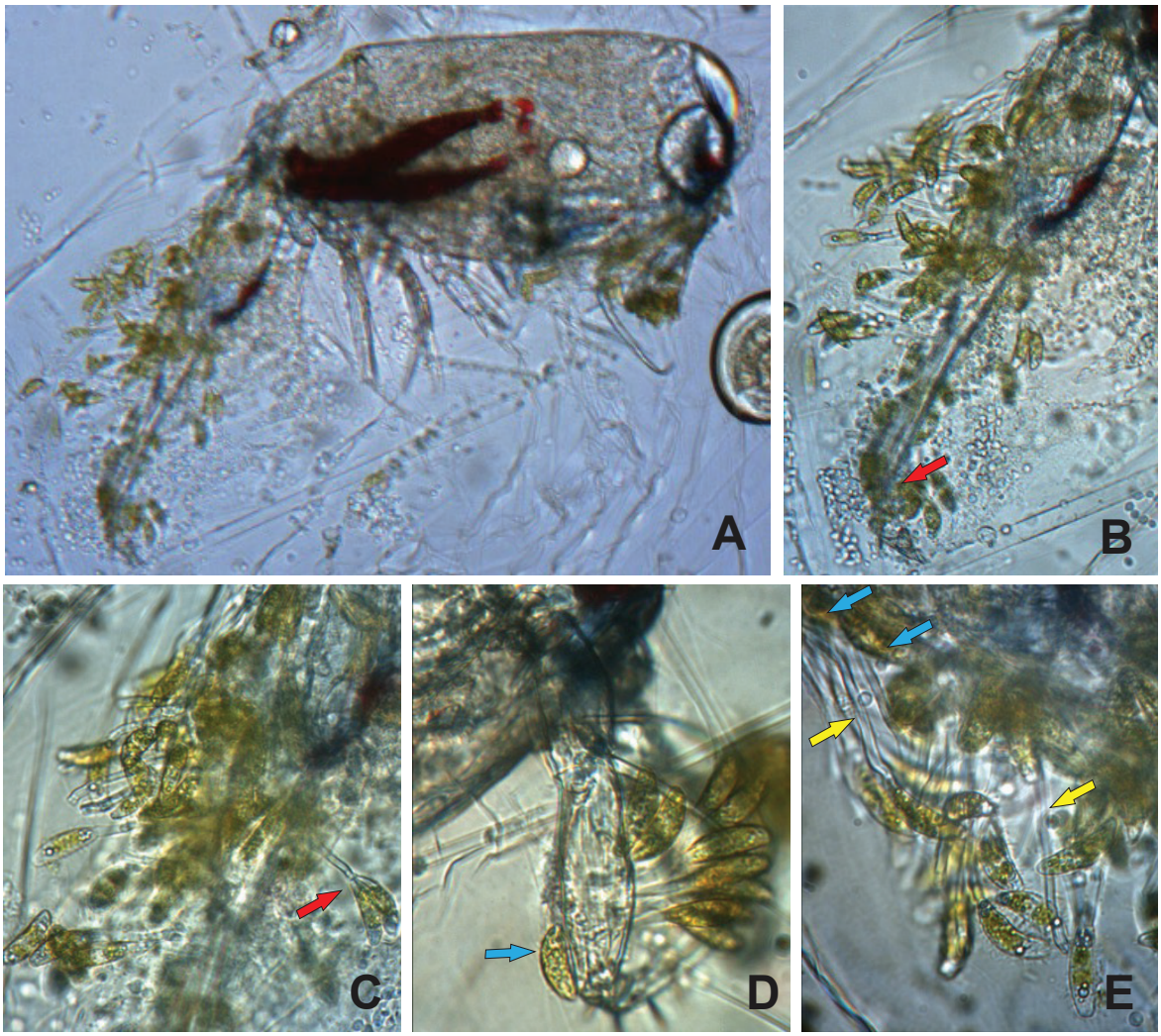

Figure 1. Different aspects of epibiosis of *Pseudohimantidium pacificum* diatoms on a live specimen of *Ditrichocorycaeus anglicus*. (A) Complete male specimen of *D. anglicus* with clusters of *P. pacificum* attached along the carapace. (B) *P. pacificum* epibion cells attached along the urosome, ending in the furca (red arrowhead) of *D. anglicus*. (C) Close up of the colonized urosome. (D) Second antenna of *D. anglicus* with epibiont *P. pacificum*. (E) Cells of *P. pacificum* showing the long mucilage stalks (yellow arrowheads). Blue arrowheads show cells of *P. pacificum* attached without mucilage stalks on the cuticle of the copepod.

The other three specimens of *D. anglicus* were colonized by few small bouquets of 5-7 cells of *P. pacificum* adhering to the urosome. The diatom frustule is wedge-shaped, markedly dorso-ventral and attached to the marine copepod exosqueleton by mucilaginous stalks (Figs. 1D-E; yellow arrowheads). Other cells of *P. pacificum* were attached directly to the copepod cuticle (Figs. 1D-E; blue arrowheads). One cell at the end of the stalk was commonly observed (two cells were rare) (Fig. 1C red color arrowhead). *P. pacificum* cell length measured 40-48 µm and 8.5-12 µm in width. Many small chloroplasts were observed distributed throughout the cell, conferring a green color to the cells (Fig. 1A-E). Temperature range recorded at the two sampling locations was 19-23 °C. These sea surface temperatures were lower than those reported by Gárate-Lizárraga & Muñetón-Gómez (2009) in the case of the epibiosis of *P. pacificum* attached to *Farranula gibbula* (Giesbrecht, 1891). Table 1 shows the worldwide records of the copepod basibiont species of *P. pacificum*.

Although marine copepods have been broadly studied along the Mexican Pacific, there are few records of *D. anglicus*. Alvarez-Cadena (1985) is the only previous report on *D. anglicus* for the Gulf of California. Hernández-Alfonso *et al*. (1987) and Lavaniegos & Jiménez-Pérez (2006) found this species along the west coast of the Baja California Peninsula. Our record of *D. anglicus* is the first for this copepod in Bahía de La Paz. The mesh size (20 µm) of our phytoplankton net allowed us to collect small copepods. Adult specimens of *D. anglicus* were 1.2–1.4 mm long; they have not been frequently collected by most zooplankton nets (300 or 500 µm mesh) used in the study region (Palomares-García, 1996; Paloma-

Table 1. Worldwide records of copepod species colonized as basibionts of the epibiont diatom *Pseudohimantidinium pacificum*

Copepod species	Sampling location	References
Agetus flaccus (Giesbrecht,1891)	South Atlantic Ocean	Klevenhusen (1933)
Agetus limbatus (Brady, 1883)	Adriatic Sea	Giesbrecht (1892)
Corycaeus crassiusculus Dana, 1849 (=*Corycaeus elongatus*)	Gulf of Naples	Giesbrecht (1892)
Corycaeus obtusus Dana, 1849	Adriatic Sea	Steuer (1910)
Corycaeus speciosus Dana, 1849	Florida Current	Gibson (1978)
Corycaeus subulatus Herrick, 1887	Ft. Pierce Inlet, Florida	Gibson (1978; 1979)
Ditrichocorycaeus affinis (McMurrich,1916)	Puget Sound Washington, Korean coastal waters, North Eastern Arabian Sea	Russell & Norris (1971), Lee *et al*. (1993), Padmakumar *et al*. (2015)
Ditrichocorycaeus amazonicus Dahl F. 1894	Brazil	Fernandes & Calixto-Feres (2012)
Ditrichocorycaeus anglicus Lubbock, 1857	Gulf of California	This study
Ditrichocorycaeus brehmi (Steuer, 1910)	Adriatic Sea	Steuer (1910)
Euterpina acutifrons (Dana, 1847)	Florida Current, Mission Bay, California, Brazil, coastal waters of Argentina, Bay of Bengala, India	Gibson (1978), Tiffany (2011), Fernandes & Calixto-Feres (2012), Sunesen *et al*. (2015), Sahu *et al*. (2015)
Farranula gibbula (Giesbrecht, 1891)	Aru Islands, Indonesia, Bahía de La Paz, Gulf of California	Früchtl (1924), Gárate-Lizárraga & Muñetón-Gómez (2009)
Farranula rostrata (Claus, 1863)	Adriatic Sea	Steuer (1910)
Onychocorycaeus giesbrechti (F. Dahl, 1894)	Florida Current	Gibson (1978)
Onychocorycaeus latus (Dana, 1849)	South Atlantic Ocean	Klevenhusen (1933)

res-García *et al*., 1998).

Round (1981) suggested several benefits for microalgae when being attached to copepods (epizoic habit), such as protection against grazing for herbivores that feed on free-swimming phytoplankton cells, and a nutritional advantage from absorption of nutrients through the basibiont copepod. It is also likely that the epibiontic microalgae can exploit the host catabolites and the CO_2 supply for their cell growth (Totti *et al*., 2011). The symbiotic relationship among tychoplanktonic diatoms and copepods could be a spatial distribution strategy. Likewise, copepod molts fully colonized by diatoms could sink and reach the sea floor where benthic diatoms can also develop (Gárate-Lizárraga & Esqueda-Escárcega, 2016). Blooms of *P. pacificum* have been related to juvenile lobster mortality (Hargraves & Maranda, 2002); however, no damage to copepods was observed in the present study.

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