

***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 °C en las estaciones de muestreo donde se observó esta asociación copépodo-diatomea.

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Gárate-Lizárraga, I. & G. María Esqueda-Escárcega. 2018. *Ditrichocorycaeus anglicus* (Copepoda; Poecilostomatoida), new basibiont of *Pseudohimantidium pacificum* (Bacillariophyceae) in Bahía de La Paz, Gulf of California. *CICIMAR Oceánides*, 33(1): 63-67.

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- μ m 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 & Muñetón-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).

Fecha de recepción: 21 de febrero 2018

Fecha de aceptación: 16 de marzo de 2018

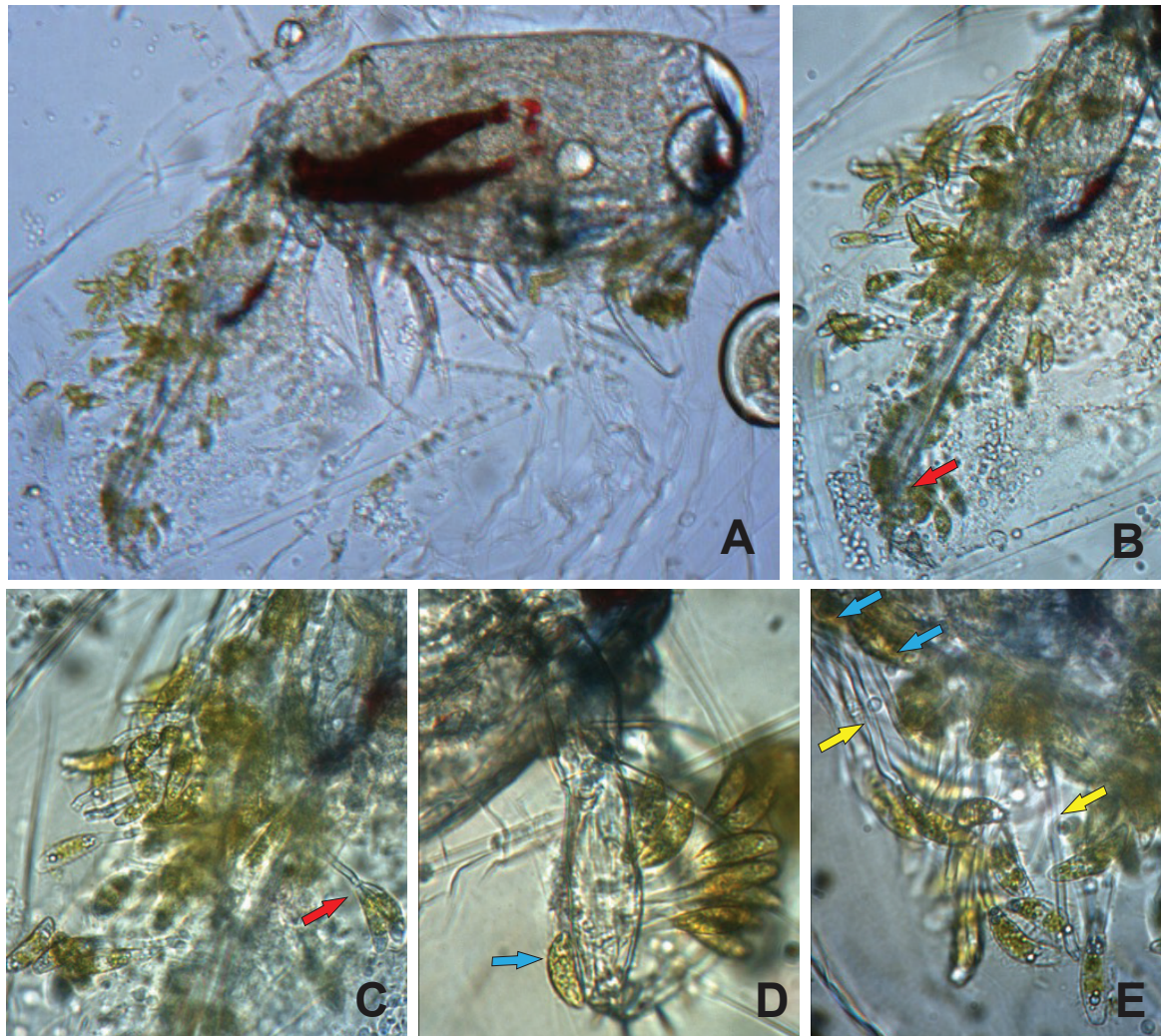


Figure 1. Different aspects of epibiosis of *Pseudohimantidium pacificum* diatoms on a live specimen of *Ditrichocorycaeus anglicus*. (A) Complete male specimen of *D. anglicus* with clusters of *P. pacificum* attached along the carapace. (B) *P. pacificum* epibion cells attached along the urosome, ending 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 exoskeleton 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 *Pseudohimantidium pacificum*

Copepod species	Sampling location	References
<i>Agetus flaccus</i> (Giesbrecht, 1891)	South Atlantic Ocean	Klevenhusen (1933)
<i>Agetus limbatus</i> (Brady, 1883)	Adriatic Sea	Giesbrecht (1892)
<i>Corycaeus crassiusculus</i> Dana, 1849 (= <i>Corycaeus elongatus</i>)	Gulf of Naples	Giesbrecht (1892)
<i>Corycaeus obtusus</i> Dana, 1849	Adriatic Sea	Steuer (1910)
<i>Corycaeus speciosus</i> Dana, 1849	Florida Current	Gibson (1978)
<i>Corycaeus subulatus</i> Herrick, 1887	Ft. Pierce Inlet, Florida	Gibson (1978; 1979)
<i>Ditrichocorycaeus affinis</i> (McMurrich, 1916)	Puget Sound Washington, Korean coastal waters, North Eastern Arabian Sea	Russell & Norris (1971), Lee <i>et al.</i> (1993), Padmakumar <i>et al.</i> (2015)
<i>Ditrichocorycaeus amazonicus</i> Dahl F. 1894	Brazil	Fernandes & Calixto-Feres (2012)
<i>Ditrichocorycaeus anglicus</i> Lubbock, 1857	Gulf of California	This study
<i>Ditrichocorycaeus brehmi</i> (Steuer, 1910)	Adriatic Sea	Steuer (1910)
<i>Euterpina acutifrons</i> (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 <i>et al.</i> (2015), Sahu <i>et al.</i> (2015)
<i>Farranula gibbula</i> (Giesbrecht, 1891)	Aru Islands, Indonesia, Bahía de La Paz, Gulf of California	Früchtl (1924), Gárate-Lizárraga & Muñetón-Gómez (2009)
<i>Farranula rostrata</i> (Claus, 1863)	Adriatic Sea	Steuer (1910)
<i>Onychocorycaeus giesbrechti</i> (F. Dahl, 1894)	Florida Current	Gibson (1978)
<i>Onychocorycaeus latus</i> (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 CO₂ supply for their cell growth (Totti *et al.*, 2011). The symbiotic relationship among tycho planktonic 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.

ACKNOWLEDGMENTS

The projects were funded by Instituto Politécnico Nacional (SIP-20130549, SIP-20130752, and SIP-20161235). The identification of *Ditrichocorycaeus anglicus* was corroborated by Ricardo Palomares-García (Departamento de Plancton y Ecología Marina-IPN-CICIMAR). Thanks are due to Y.B. Okolodkov (Universidad de Veracruz, Boca del Río, Veracruz, Mexico) and M.M. Gowing (University of California at Santa Cruz, California, USA) for improving the English style and to D. Ovie-

do-Juárez (ICMyL, UNAM, Mazatlán City) for helping us with the search of the scientific literature. We thank the anonymous reviewers for their constructive comments that helped us to improve the manuscript. The authors are COFAA fellows.

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