

First record of *Cochlodinium convolutum* and *C. helicoides* (Gymnodiniales: Dinophyceae) in the Gulf of California

Primer registro de *Cochlodinium convolutum* y *C. helicoides*
(Gymnodiniales: Dinophyceae) en el Golfo de California

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Abstract.- The naked marine dinoflagellates *Cochlodinium convolutum* and *C. helicoides* are reported for the first time in the Gulf of California. They occurred in seawater at 21-24.5°C. *Cochlodinium convolutum* was found in both bottle and net samples; its abundance ranged from 400-2200 cells L⁻¹. A total of 96 specimens of *C. convolutum* and 23 specimens of *C. helicoides* were examined from the net phytoplankton samples. A short description is given for each species, and photomicrographs provide information about the main morphological characteristics.

Key words: Dinoflagellates, phytoplankton, Mexico

INTRODUCTION

The genus *Cochlodinium* belongs to the order Gymnodiniales Lemmermann, 1910. *Cochlodinium* is an unarmored, marine planktonic dinoflagellate genus forming cell chains with a distinctive spiral-shaped cingulum of 1.5 or more gyres around the cell. According to the recent world-wide review on marine dinoflagellates by Gómez (2005), there are 35 species of *Cochlodinium*. *Cochlodinium fulvescens* Iwataki, Kawami & Matsuoka, 2007 was recently described as a new species (Iwataki *et al.* 2007). Most of the *Cochlodinium* species are heterotrophic or mixotrophic and have rarely been observed since their original descriptions (Iwataki *et al.* 2007, Gárate-Lizárraga *et al.* 2009a). Taxonomy and geographic distribution of *Cochlodinium* species have scarcely been studied in Mexico. Ten species of *Cochlodinium* have been found in Pacific coastal waters of Mexico (Gárate-Lizárraga *et al.* 2004, 2009a, 2009b, Cortés-Lara *et al.* 2004, Okolodkov & Gárate-Lizárraga 2006, Morquecho-Escamilla & Alonso-Rodríguez 2008). In these reports, massive blooms of *Cochlodinium polykrikoides* Margalef, 1961 have been recorded along the west coast (Gárate-Lizárraga *et al.* 2004, 2009b, Morales-Blake *et al.* 2001). *Cochlodinium fulvescens* blooms have also been recorded however only in the

Gulf of California (Morquecho-Escamilla & Alonso-Rodríguez 2008, Gárate-Lizárraga *et al.* 2009a). This report describes the presence of *Cochlodinium convolutum* Kofoid & Swezy, 1921 and *Cochlodinium helicoides* Lebour, 1925 for the first time in the Gulf of California.

MATERIALS AND METHODS

Phytoplankton was sampled at a fixed sampling station in Bahía de La Paz, Baja California Sur, Mexico (24°21'N, 110°31'W) on 24 March 2011, 28 April 2011, 24 May 2011, and 26 June 2011. Two surface horizontal tows and two vertical hauls from 15 m were performed using a 20 µm mesh net, 50 cm diameter. Each sample was immediately fixed with acid Lugol's solution and preserved with 4% formalin. Other set samples were used for live phytoplankton observations. Two samples were also collected during each sampling to estimate *Cochlodinium* abundance. Cell counts were made in 5 mL settling chambers under an inverted, phase-contrast microscope (Carl Zeiss, Germany). Sea surface temperature was recorded using a bucket thermometer. Microscopic images were taken in a compound microscope (Leica, Germany).

RESULTS AND DISCUSSION

Two *Cochlodinium* species were identified in the samples collected monthly from Bahía de La Paz during spring 2011. *Cochlodinium convolutum* was found in bottle and net samples; its abundance ranged between 400-2200 cells L⁻¹. A total of 35 and 42 specimens of *C. convolutum* were counted in horizontal and vertical net samples, respectively, on 24 March 2011. Five, ten and four specimens of *C. convolutum* were found in surface net phytoplankton samples collected on 28 April, 26 May and 26 June 2011, respectively. The specimens fit well with the diagnosis and descriptions of Kofoid & Swezy (1921) and Matsuoka *et al.* (2008). Cells of *C. convolutum* are elongated, ovoid to round and slightly fusiform in shape (Fig. 1A-F) with the anterior end rounded. The epicone becomes slender toward the apex. The Hypocone was rounded, with two broad lobes; the left lobe always larger than the right one. The cingulum circled the cell ~1.5 times. Cells range from 55-87 µm in length and from 34-50 µm in width. All specimens of *C. convolutum* occurred as solitary cells. As described in Matsuoka *et al.* (2008), no visible orange-pigmented body was noted. A rounded rectangular to ellipsoidal nucleus located in the center and the left ventral side of the cell was observed (Fig. 1D). The chloroplasts of *C. convolutum* are reticulate; many small grains regularly scattered in the cell surface (Figs. 1A, B and F). Twenty-one encysted cells of *C. convolutum* were in net phytoplankton samples (Fig. 1D-F). Some temporary cysts have two hyaline membranes (Fig. 1D). Salinity was 34.5 psu. Sea water temperature was 21.0-24.5°C, coinciding with that reported by Kofoid & Swezy (1921) off La Jolla, California when *C. convolutum* was found. Matsuoka *et al.* (2008) reported 26-27°C, suggesting that this taxon is a warm-temperate to tropical species.

There are few records of *Cochlodinium convolutum* in the literature. This species was first found in a surface net sample taken near La Jolla on 27 July 1914. Additional collections were made on 20 July 1917 in samples collected 23.6 miles off La Jolla (80 m vertical net haul) and on 6 August 1917, 4 miles offshore (60 m vertical net haul) (Kofoid & Swezy 1921). About 90 years later, *C. convolutum* was reported as a red tide in several coastal lagoons of western Japan (Matsuoka *et al.* 2008), and also this species has been recorded in Shimoda Bay, Japan (34°39.52N, 138°57E)¹.

Seventeen and six specimens of *Cochlodinium helicoides* were examined in the net phytoplankton samples collected on April 28 and May 26 2011,

respectively. This species was not found in bottle samples. *C. helicoides* cells are irregularly sub-ovoidal, broad, and posteriorly asymmetrical (Fig. 2A-D). The anterior end is tapering; the posterior end is broad, the postero-ventral face drawn out into a flap-like extension on its right side, giving the body a sinistro-ventral excavation, with the dorsal side strongly convex. The epicone and hypocone were subequal in size. The hypocone was broader than the epicone, less symmetrical with the dextroventral face drawn out into an outstanding flap or lobe, still further posteriorly marked by a deep sulcal notch. The girdle represents a descending left spiral of 1.5 turns. The sulcus invades the epicone in a short loop which may partly encircle the apex or may terminate below the right side of the cell. The nucleus is central. *C. helicoides* are yellow, usually with chloroplasts. All specimens of *C. helicoides* occurred as solitary cells. Three specimens were observed enclosed in a thin hyaline temporary cyst (Fig. 2C). Cells are 43-67 µm long and ≈30-36 µm wide.

There are few records of *C. helicoides* in the literature. This species was first defined by Lebour (1925) for the organism which was called *Cochlodinium helix* by Kofoid & Swezy (1921) and which was shown in one of Schütt's figures in 1895 (Dodge 1982). Kofoid & Swezy (1921) reported specimens of *C. helicoides* (as *C. helix*) collected on July 27 and August 15, 1917 off La Jolla, California. Lackey & Clendenning (1965) reported *C. helicoides* (as *Gymnodinium helicoides*) during an oceanographic survey in July-August 1959 off Ballast Point, near San Diego Bay, California. The species was reported elsewhere: in Plymouth Sound, England (Dodge 1982); in the South China Sea (Yan *et al.* 2002); Odessa Bay in the Black Sea (Terenko 2005); and Chesapeake Bay (Marshall *et al.* 2005). In this study, temperature was 21.0-24.5°C. This species has been reported in a temperature range between 0.5°C (Terenko 2005) to 21.9°C (Kofoid & Swezy 1921).

Monitoring microalgae species forming red tides, by studying live specimens, has been performed since 2000 in Bahía de La Paz (Gárate-Lizárraga *et al.* 2004). Since that time, *C. helicoides* has been observed only on March 24, May 26 2011 and *C. convolutum* on March 24, April 28, May 26 and June 26 2011 in Bahía de La Paz. The morphology of *C. convolutum* and *C. helicoides* changes during observation under a light microscope. Likewise, cells tend to form a hyaline membrane around the cell or a temporary hyaline cyst, otherwise they explode. Lugol fixed specimens of these species could not be properly identified. Live phytoplankton samples are important in the study of naked dinoflagellates.

¹<http://www.biol.tsukuba.ac.jp/~algae/PS/Dinophyta/Cochlodinium_convolutum/index.html>

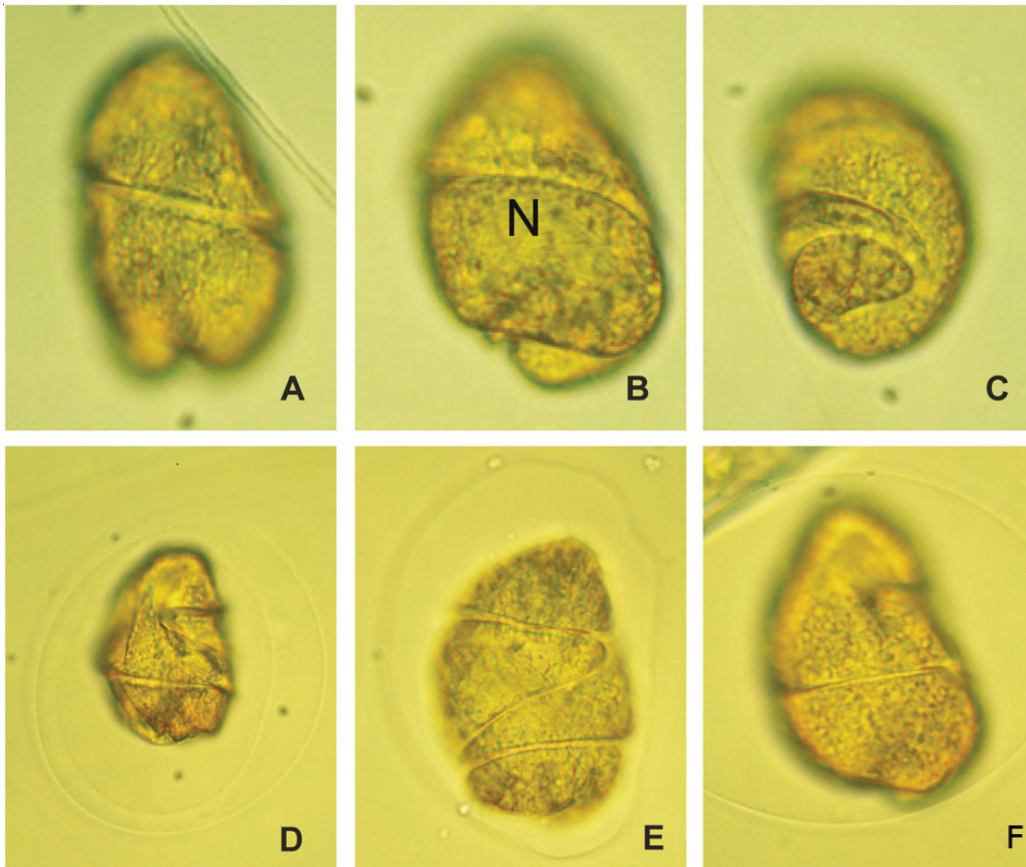


Figure 1. A-F. Microphotographs of *Cochlodinium convolutum* found in Bahía de La Paz during spring 2011. A) Specimen of *C. convolutum* in right lateral view. B) Cell showing the nucleus (N). C) Cell showing the antapical end. D) Temporary cyst clearly shows two hyaline membranes around the cell. E and F) Temporary cysts found on April 28 and May 24 2011, respectively / A-F. Microfotografías de especímenes de *Cochlodinium convolutum* encontrados en la Bahía de La Paz durante la primavera de 2011. A) Espécimen de *C. convolutum* en vista lateral derecha. B) Célula mostrando el núcleo (N). C) Célula mostrando el extremo antapical. D) Quiste temporal que muestra claramente dos membranas hialinas alrededor de la célula. E y F) Quistes temporales encontrados el 28 de abril y el 24 de mayo de 2011, respectivamente

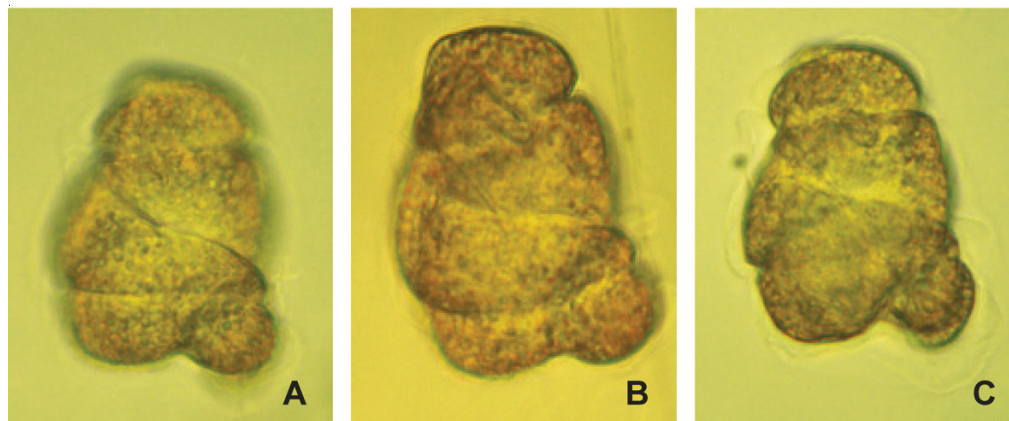


Figure 2. Microphotographs of *Cochlodinium helicoides*. A-B) Specimens viewed from right side. C) Specimen of *C. helicoides* showing the hyaline membrane around the cell (temporary cyst) / Microfotografías de *Cochlodinium helicoides*. A-B) Especímenes vistos de lado derecho. C) Espécimen de *C. helicoides* mostrando una membrana hialina alrededor de la célula (quiste temporal)

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LITERATURE CITED

- Cortés-Lara MC, R Cortés-Altamirano & AP Sierra-Beltrán. 2004.** Presencia de *Cochlodinium catenatum* (Gymnodinales: Gymnodinaceae) en mareas rojas de Bahía Banderas, Pacífico Mexicano. *Revista de Biología Tropical* 52(Supl. 1): 35-50.
- Dodge JD. 1982.** Marine dinoflagellates of the British Isles, 303 pp. Her Majesty's Stationery Office, London.
- Gárate-Lizárraga I, DJ López-Cortés, JJ Bustillos-Guzmán & FE Hernández-Sandoval. 2004.** Blooms of *Cochlodinium polykrioides* (Gymnodiniaceae) in the Gulf of California, Mexico. *Revista de Biología Tropical* 52 (Supl. 1): 51-58.
- Gárate-Lizárraga I, CJ Band-Schmidt, F Aguirre-Bahena & T Grayeb-del Álamo. 2009a.** A multi-species microalgae bloom in Bahía de La Paz, Gulf of California, Mexico (June 2008). *CICIMAR Oceanides* 24(1): 1-15.
- Gárate-Lizárraga I, JA Díaz-Ortiz, B Pérez-Cruz, M Alarcón-Tacuba, A Torres-Jaramillo, MA Alarcón-Romero & S López-Silva. 2009b.** *Cochlodinium polykrioides* and *Gymnodinium catenatum* in Bahía de Acapulco, Mexico (2005-2008). *Harmful Algae News* 40: 8-9.
- Gómez F. 2005.** A list of dinoflagellates in the world's oceans. *Acta Botanica Croatica* 64: 129-212.
- Iwataki M, H Kawami & K Matsuoka. 2007.** *Cochlodinium fulvescens* sp. nov. (Gymnodinales, Dinophyceae), a new chain forming unarmored dinoflagellate from Asian coasts. *Phycological Research* 55: 231-239.
- Kofoid CA & O Swezy. 1921.** The free-living unarmored dinoflagellata. *Memoirs of the University of California*, 562 pp. University of California Press, Berkeley.
- Lackey JB & KA Clendenning. 1965.** Ecology of the microbiota of San Diego Bay, California. *Transactions of the San Diego Society of Natural History* 14(2): 9-40.
- Lebour MV. 1925.** The dinoflagellates of Northern seas, 250 pp. Marine Biological Association of the United Kingdom, Plymouth.
- Marshall HG, L Burchardt & R Lacouture. 2005.** A review of phytoplankton composition within Chesapeake Bay and its tidal estuaries. *Journal of Plankton Research* 27: 1083-1102.
- Matsuoka K, M Iwataki & H Kawami. 2008.** Morphology and taxonomy of chain-forming species of the genus *Cochlodinium* (Dinophyceae). *Harmful Algae* 7: 261-270.
- Morales-Blake A, C Cavazos-Guerra & D Hernández-Becerril. 2001.** Unusual HABs in Manzanillo Bay, Colima, Mexico. *Harmful Algae News* 22: 6.
- Morquecho-Escamilla ML & R Alonso-Rodríguez. 2008.** First record of *Cochlodinium fulvescens* in Mexican Pacific. *Harmful Algae News* 37: 5-6.
- Okolodkov YB & I Gárate-Lizárraga. 2006.** An annotated checklist of dinoflagellates (Dinophyceae) from the Mexican Pacific. *Acta Botanica Mexicana* 74:1-154.
- Terenko L. 2005.** New dinoflagellate (Dinoflagellata) species from the Odessa Bay of the Black Sea. *Oceanological and Hydrobiological Studies* 37(Suppl. 3): 205-216.
- Yan T, Z Ming-Jiang & Z Jing-Zhong. 2002.** A national report on harmful algal blooms in China. In: Taylor FJR & VL Trainer (eds). *Harmful algal blooms in the PICES region of the North Pacific*. PICES Scientific Report 23: 119-128. North Pacific Marine Science Organization, Sidney.

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