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Occurrence of *Ostreopsis lenticularis* (Dinophyceae: Gonyaulacales) from the Archipiélago de Revillagigedo, Mexican Pacific

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ABSTRACT

From December 2016 to May 2017, 22 phytoplankton surface samples were collected with a 20-μm mesh net at three islands of the Archipiélago de Revillagigedo (Partida, Socorro and San Benedicto), Mexican Pacific. The sites depth was approximately 20–80 m; the surface water temperature was 21–27 °C. The potentially toxic benthic dinoflagellate *Ostreopsis lenticularis* was present in all the samples. Cells had a lenticular to broadly oval shape, 65–100 μm long and 50–80 μm wide. The taxonomy of the genus *Ostreopsis* has been unclear due to equivocal ascribing some taxonomic features among species. The identification of specimens from the archipelago was made based on the most important taxonomic characteristics: the thecal plates, the presence of two types of thecal pores (larger and smaller), and the lack of cingulum undulation. The studied cells are compared with *O.* cf. *siamensis*, *O. labens* and *O. marina*. This is the first record of the species in the archipelago waters.

Marine benthic dinoflagellates are important as primary producers and play an important role in marine food webs (South and Whittick, 1987; Laza-Martínez et al., 2011). In both tropical and temperate waters three epibenthic dinoflagellate genera are commonly found (Fukuyo, 1981; Besada et al., 1982): *Coolia* Meunier 1919, *Gambierdiscus* Adachi and Fukuyo 1979, and *Ostreopsis* Schmidt 1901. The genus *Ostreopsis* belongs to the family Ostreopsidaceae Lindemann 1928, which comprises epiphytic or tychoplanktonic species. Since the description of the type species *Ostreopsis* cf. *siamensis* by Schmidt (1901), the genus *Ostreopsis* remained monospecific until 1981 (Hoppenrath et al., 2014). In 1981, Fukuyo (1981) described *O. lenticularis* and *O.* cf. *ovata* from French Polynesia and the Ryukyu Islands, Japan. In a phylogeographic study Leaw et al. (2001) demonstrated that *O. lenticularis* was genetically distinct from *O.* cf. *ovata*. Another eight *Ostreopsis* species were described during the following years: *O. heptagona* Norris, Bomber & Balech 1985, *O. mascarenensis* Quod 1994, *O. labens* Faust and Morton, 1995, *O. belizeana* Faust 1999, *O. caribbeana* Faust 1999, *O. marina* Faust 1999, *O. fattorussoi* Accoroni, Romagnoli & Totti 2016, and *O. rhodesae* Verma, Hoppenrath & S.A. Murray 2016, adding up to the 11 *Ostreopsis* species presently recognized. *Ostreopsis* species produce different toxins belonging to the potent neurotoxin palytoxin group. Toxicity has been demonstrated in seven *Ostreopsis* species: *O.* cf. *siamensis*, *O. heptagona*, *O. mascarenensis*, *O. lenticularis*, *O.* cf. *ovata*, *O. rhodesae* and *O. fattorussoi*, sometimes also in marine aerosols (Nakajima et al., 1981; Yasumoto et al., 1987; Holmes et al., 1988; Tindall et al., 1990; Mercado et al., 1995; Meunier et al., 1997; Lenoir et al., 2004; Ciminiello et al., 2012a, 2012b; Sechet et al., 2012; Uchida et al., 2013; Brissard et al., 2015; García-Altares et al., 2015; Accoroni et al., 2016; Verma et al., 2016a; Gómez et al., 2017). Palytoxin (PLTX) and its analogs (ostreocin, mascarenotoxins, ovatoxin) have been detected mainly in tropical and subtropical waters, but lately also from temperate waters, mainly the Mediterranean basin, Sea of Japan and the Tasman Sea (Pearce et al., 2001; Selina and Orlova, 2010; Sato et al., 2011; Selina et al., 2014; Accoroni and Totti, 2016; Verma et al., 2016b). No studies on benthic dinoflagellates have been conducted in the Pacific coastal waters of Mexico. The main records have been reported fortuitously (Okolodkov and Gárate-Lizárraga, 2006; Gárate-Lizárraga, 2012; Gárate-Lizárraga and González-Armas, 2017). *Ostreopsis* species reported from the Pacific Mexican coastal waters are: *O. heptagona*, *O. lenticularis*, *O. marina*, *O.* cf. *ovata*, and *O.* cf. *siamensis* that were collected in the water column (Sierra-Beltrán et al., 1998; Cortés-Lara et al., 2005; Okolodkov and Gárate-Lizárraga, 2006; Esqueda-Lara and Hernández-Becerril, 2010; Gárate-Lizárraga et al., 2014; Morquecho-Escamilla et al., 2016). The purpose of this study was to report the first occurrence of the toxigenic *O. lenticularis* in the Archipiélago de Revillagigedo.

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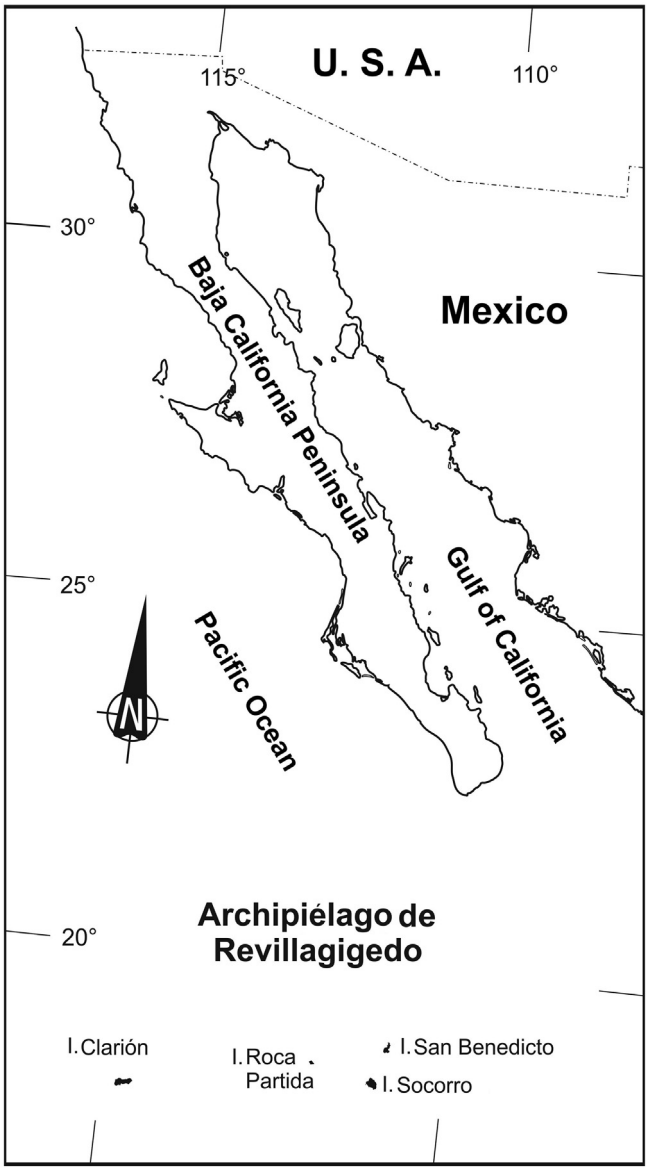

Fig. 1. Sampling area located in the Archipiélago de Revillagigedo in the Mexican Pacific.

The Archipiélago de Revillagigedo is located in the Eastern Pacific, 386 km southwest of the southernmost tip of the Baja California Peninsula and 720 to 970 km west of the Mexican mainland (Fig. 1). The Archipiélago de Revillagigedo is a serial nomination made up of four remote islands and their surrounding waters: Isla San Benedicto, Isla Socorro, Isla Roca Partida, and Isla Clarión (http://whc.unesco.org/en/list/1510). As part of a multidisciplinary study, several surveys were performed off three of the islands (Isla San Benedicto, Isla Socorro, and Isla Roca Partida) from December 2016 to May 2017 (Table 1). Sampling stations were located 50–100 m from the islands. Phytoplankton samples were collected in 250 ml plastic flasks and fixed with acid Lugol's solution and later preserved in 4% formalin. Surface tows were made with a manual 20-μm mesh phytoplankton net. Sea surface temperature was measured with a bucket thermometer (Brannan, Cumbria, England, UK). Examination and identification of the *Ostreopsis* were made under a Carl Zeiss Axiovert phase-contrast microscope. A digital Konus camera (8.1 MP) recorded the images.

Ostreopsis lenticularis was observed in all the sampling sites during five surveys carried out in the Revillagigedo islands. A total of 121 cells of *O. lenticularis* were identified from 22 phytoplankton net samples (Fig. 2A–P; Table 1). Surface seawater temperatures recorded at the same time as the collections ranged from 21 to 27 °C. Our specimens fit well in terms of cell shape and size with the descriptions of *O. lenticularis* reported by Fukuyo (1981: 970–972; Figs. 30–34, 52, 53), Tindall et al., (1990: 425, Fig. 1), Hansen et al. (2001: 65; pl. 10, Fig. 10 C-D), Larsen and Nguyen (2004: 112–114; pl. 18, figs. 1–4, pl. 21, Fig. 3), Mohammad-Noor et al. (2005: 668-670; Figs. 29a-h), and Omura et al. (2012: 41, Figs. a-c). However, they are not in agreement with Faust (1996: 456) and Faust et al. (1996: 1056-1057; Figs. 9–15) in terms of the presence of two sizes of the thecal pores (see below) that has been previously noted by various authors (Mohammad-Noor et al., 2005; Parsons et al., 2012; Hoppenrath et al., 2014). Cells of *O. lenticularis* vary from lenticulate to broadly oval-shaped and slightly pointed ventrally (Fig. 2A–H). The epitheca and hypotheca are nearly equal in size (Fig. 2A). Numerous yellow brown chloroplasts are present (Fig. 2B–D). The cell size ranges from 65 to 100 μm dorsoventrally and 50–80 μm in transdiameter (n = 30 cells). The Kofoidean plate formula is: Po, 3′; 7″; 6c, 7(8?)s, 5‴, 2⁗, lp (Hoppenrath et al., 2014). Ten epithecal plates are shown in Fig. 2E; the first apical plate (1′) is located almost in the center of the epitheca, although it has been reported as irregularly pentagonal, it is hexagonal and contacts the 2′, 3′, 1″, 2″ 6″ and 7″ plates and Po (Fig. 2E, I, H, L; Fukuyo, 1981; 978, Fig. 52). The second apical plate (2′) is narrow, and it is the smallest epithecal plate (Fig. 2E). Precingular plate 6″ is the largest epithecal plate (Fig. 2E). Plate 3′ is dorsocentered, hexagonal, and contacts the 1′, 2′, 3″, 4″, 5″, and 6″ plates. The thecal surface is smooth and perforated by numerous pores (Fig. 2M–N). Two different sizes of thecal pores were observed, and they are visible with a light microscope (Fig. 2H, I). The cingulum is narrow, deeply cavozone, slightly descending and lacks undulation (Fig. 2K). Eight hypothecal plates are shown in Fig. 2M. Plate 1p is not long, centrally located and touches plates 2‴, 3‴, 4‴, 5‴, 1⁗, and 2⁗ (Fig. 2M); this plate also has two types of pores of different sizes. According to Fukuyo (1981), the presence of two types of pores of different sizes densely scattered all over the thecal plates and the absence of undulation of the cingulum are the main taxonomical features for identifying *O. lenticularis*. These separate *O. lenticularis* from *O.* cf. *siamensis*, which has only one type of pore (Fukuyo, 1981; Hoppenrath et al., 2014). Some authors have reported cells of *O. lenticularis* with only one type of pore (Faust et al., 1996; Chang et al., 2000; Leaw et al., 2001). According to Penna et al. (2012), the taxonomy of the genus *Ostreopsis* has been unclear because the revision of the genus by Faust et al. (1996) described the characteristics of some species that contradict the original descriptions: 1) the larger size of *O.* cf. *siamensis*, 108–123 μm versus about 90 μm given by Schmidt (1901), and 2) the attribution of two sizes of thecal pores to *O.* cf. *siamensis*, whereas this is one of the features of *O. lenticularis* and differentiates it from *O.* cf. *siamensis* in its original description (Fukuyo, 1981). Faust et al. (1996) also reported that *O. lenticularis* had only one type of thecal pore. Recently, a third kind of pore only clearly visible with a scanning electronic microscope has been recently reported in *O. lenticularis* Hainan strains (Zhang et al., 2017). These authors concluded that the thecal pores of *O. lenticularis* were variable not only in number but also in shape (kidney-shaped pores) and size; however, this is not a stable characteristic for species discrimination.

On the other hand, *O. lenticularis* is also similar in shape to *O. marina*; however, in the latter the thecal surface is covered with small,