CICIMAR Oceánides
ISSN 2448-9123
https://oceanides.ipn.mx
Centro Interdisciplinario de Ciencias Marinas
https://doi.org/10.37543/oceanides.v27i2.115

Vol. 27 No.2
Julio - Diciembre
2012

PROLIFERATION OF *Amphidinium carterae* (GYMNODINIALES: GYMNODINIACEAE) IN BAHÍA DE LA PAZ, GULF OF CALIFORNIA

Gárate-Lizárraga, I.

Instituto Politécnico Nacional, Centro Interdisciplinario de Ciencias Marinas, Departamento de Plancton y Ecología Marina, Apartado postal 592, La Paz, Baja California Sur 23096, México. Email: igarate@ipn.mx

ABSTRACT. During a sampling on 15 December 2011 in Bahía de La Paz, a bloom of the benthic dinoflagellate *Amphidinium carterae* was detected. Its abundance ranged from 28.2 to 64.8 × 10^3 cells L^{-1}. Cells of *A. carterae* varied in length from 18 to 28 µm and 13 to 18 µm in wide (*n* = 30). The presence of *A. carterae* and benthic species of diatoms and dinoflagellates at the surface could be an indicator of upwelling water generated by northwestern winds. Seawater temperature during the bloom was 20 °C. Also, new records of dinoflagellates for the Mexican coast of the Pacific are here reported: *Amphidiniopsis hirsuta*, *Amphidiniopsis* sp., *Amylax buxus, Cochlodinium pulchellum*, *Cochlodinium virescens*, *Durinskia* cf. *baltica*, *Gyrodinium* sp., *Thecadinium* sp., and *Prorocentrum minimum* var. *triangulatum*.

Keywords: Proliferation, *Amphidinium carterae*, benthic dinoflagellates, Gulf of California

Proliferación de *Amphidinium carterae* (Dinophyceae: Gymnodiniales) en Bahía de La Paz, Golfo de California

RESUMEN. Durante un muestreo realizado el 15 de Diciembre de 2011 en Bahía de La Paz se detectó un florecimiento del dinoflagelado bentónico *Amphidinium carterae*. Los valores de abundancia variaron de 28.2 a 64.8 × 10^3 céls L^{-1}. Los especímenes de *A. carterae* presentaron un intervalo de tallas de 18 a 28 µm de longitud y de 13 a 18 µm de ancho (*n* = 30). La presencia de *A. carterae*, así como de especies bentónicas de diatomeas y dinflagelados en superficie podrían indicar aguas de surgencia debido a la influencia de los vientos del noroeste en esta temporada. La temperatura del agua durante el florecimiento fue de 20 °C. También se reportan nuevos registros de dinoflagelados para la costa pacífica de México: *Amphidiniopsis hirsuta*, *Amphidiniopsis* sp., *Amylax buxus, Cochlodinium pulchellum*, *Cochlodinium virescens*, *Durinskia* cf. *baltica*, *Gyrodinium* sp., *Thecadinium* sp. y *Prorocentrum minimum* var. *triangulatum*.

Palabras claves: Proliferación, *Amphidinium carterae*, dinoflagelados bentónicos, Golfo de California.

Gárate-Lizárraga, I. 2012. Proliferation of *Amphidinium carterae* (Gymnodiniales: Gymnodiniaceae) in Bahía de La Paz, Gulf of California. *CICIMAR Oceánides*, 27(2): 37-49.

INTRODUCTION

Microalgae blooms are frequent and periodic throughout the year in Bahía de La Paz, at the southwestern part of the Gulf of California. Harmful blooms cause negative impacts to marine fauna through poisoning, mechanical damage, or other media (Gárate-Lizárraga *et al*., 2001). Naked dinoflagellates that form red tides have only recently received attention (Gárate-Lizárraga *et al*., 2004; 2006, 2009a; 2011). Many of these have been underestimated because they are normally deformed or destroyed by sampling nets, storage, and by traditional preservation solutions used in routine phytoplankton sampling (Okolodkov & Gárate-Lizárraga, 2006; Gárate-Lizárraga *et al*., 2011).

Gymnodiniales are unarmored dinoflagellates that lack cellulose plates, but have a membranous outer covering of small vesicles. Most of the studies of gymnodinioid dinoflagellates focus on the species responsible for harmful algal blooms, which are abundant in coastal waters (Gárate-Lizárraga *et al*., 2001; 2009a; 2011).

The genus *Amphidinium* Claparède and Lachmann emend. Flø Jørgensen, Murray & Daugbjerg belongs to the order Gymnodiniales Lemmermann, 1910, although the placement of *Amphidinium* in the Gymnodiniales was not supported by the molecular analyses done by Flø Jørgensen *et al*. (2004). *Amphidinium* definition was emended by Flø Jørgensen *et al*. (2004) as follows: Athecate benthic or endosymbiotic dinoflagellates with minute irregular triangular- or crescent- shaped epicones. Epicone overlays anterior ventral part of hypocone. Epicone deflected to the left. Cells are dorsoventrally flattened, with or without chloroplasts.

Members of *Amphidinium* are among the most abundant and diverse benthic dinoflagellates worldwide (Fukuyo, 1981; Dodge, 1982; Sampayo, 1985; Ismael *et al*., 1999; Hoppenrath, 2000; Okolodkov *et al*., 2007; Steidinger *et al*., 2009; Hallegraeff *et al*., 2010). Twelve species of *Amphidinium* have been found in Pacific coastal waters of Mexico (Okolodkov & Gárate-Lizárraga, 2006; Gárate-Lizárraga *et al*., 2007). According to Murray *et al*. (2004), there are several distinct genotypes. This report describes the first proliferation of *Amphidinium carterae* Claparède and Lachmann, 1859 in the southwestern Gulf of California. The stages of sexual fusion are also reported, and the micro-

Fecha de recepción: 7 de febrero de 2012 Fecha de aceptación: 13 de agosto de 2012

algae community present during this bloom is also described.

MATERIAL AND METHODS

Bahía de La Paz is the largest bay on the peninsular side of the Gulf of California. It has constant exchange of water with the Gulf of California via a northern and a southern broad channel (Gómez-Valdés *et al*., 2003). The main northern channel is wide and deep (up to 300 m), while the southern mouth is shallow and associated with a shallow basin about 10 m deep. There is a shallow lagoon, the Ensenada de La Paz, connected to the bay by a narrow inlet (1.2 km wide and 4 km long) with an average depth of 7 m. The sampling station (24.23°N; 110.34°W; 25 m depth) is located in the shallow basin of the southernmost region of Bahía de La Paz.

Phytoplankton bottle samples were collected at sampling station 1 (off PEMEX) in Bahía de La Paz (Fig. 1) December 15, 2011.Samples were fixed with Lugol´s solution. Identification and cell counts were made in 5 ml settling chambers under an inverted Carl Zeiss phase-contrast microscope (Germany). Surface and vertical tows from 15 m were made with a 20 µm phytoplankton net mesh. A portion of each tow was immediately fixed with acid Lugol´s solution and later preserved in 4% formalin. These samples were used to properly identify some uncommon species found in the bottle samples. Sea surface temperature was measured with a bucket thermometer (Kahlsico International Corp., El Cajon, CA, USA). Scientific names of microalgae species were updated using the algae data base (http://www.algaebase.org/) (Guiry & Guiry, 2012). An Olympus CH2 compound microscope (Japan) was used to measure cells, and a digital Konus camera and a SONY Cyber shot camera (8.1MP) were used to record the phytoplankton images.

RESULTS AND DISCUSSION

A total of 107 microalgae taxa were identified: 56 were diatoms, 46 dinoflagellates, 2 silicoflagellates, 1 raphydophyte, 1 cyanobacteria and 1 coccolithophorid. This survey revealed the presence of benthic diatoms and dinoflagellates, as well as dinoflagellate cysts in the surface water samples, which is an indicator of upwelled water generated by northwest winds (Gárate-Lizárraga & Muñetón, 2008; Gárate-Lizárraga *et al*., 2009a). The species list and abundance are summarized in Table 1. Microphytoplankton was numerically more important than nano-phytoplankton, and diatoms were the most important group followed by dinoflagellates; in this last group *Amphidinium carterae* was the most abundant.

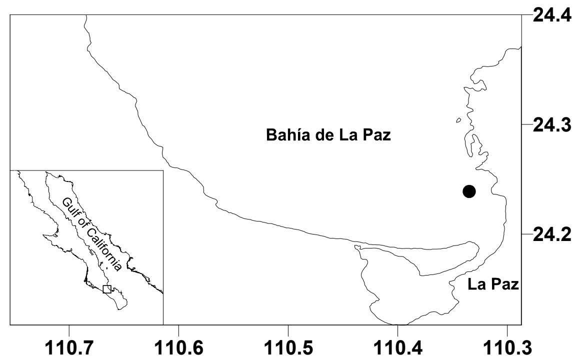
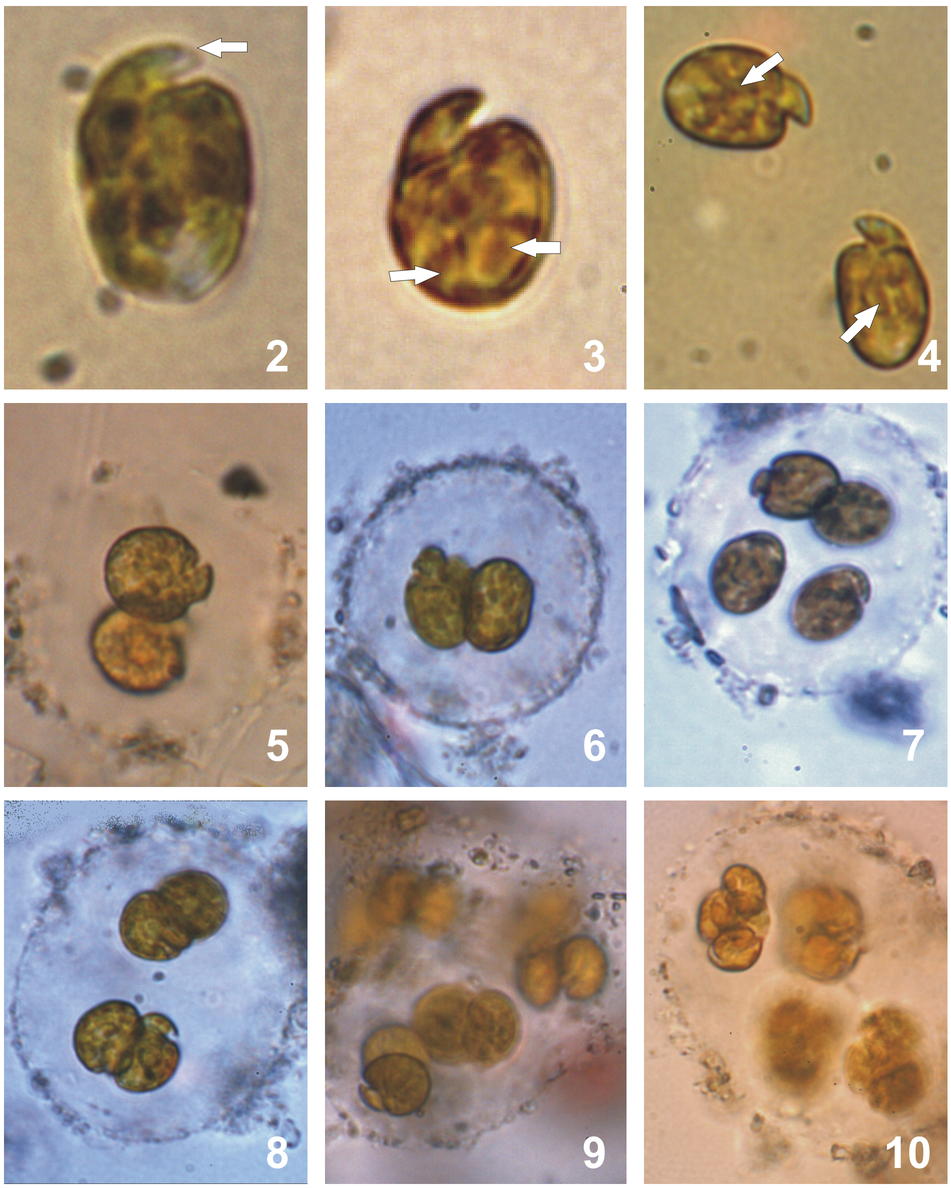


Figure 1. Sampling station (●) in the Bahía de La Paz, Gulf of California.

The abundance of *A. carterae* in three samples was 28.2, 42.0, and 64.8 × 10^3 cells L^{-1}. These are the highest quantitative data of *A. carterae* recorded for the Gulf of California, with a seawater temperature of 20 °C. Although this is the first recorded bloom of *A. carterae* in the Gulf of California, it was registered in Bahía de La Paz by Núñez-Vázquez (2005) and Okolodkov & Gárate-Lizárraga (2006). Only a few specimens were found in February 12, March 24, April 28 and May 24 of 2011, in the net phytoplankton samples (unpublished data). Cells of *A. carterae* were oval from the ventral side and flattened dorsoventrally, as shown in Figs. 2–5. Cells range from 18 to 28 µm in length and 13 to 18 µm in wide (n = 30). The epitheca is asymmetric and directed to the left (Fig. 2). Girdle is v-shaped ventrally and runs higher on the dorsal side of the cell. The cell contains one large, multilobed chloroplast (Fig. 3) with a central pyrenoid structure (Fig. 4). The chloroplast is located at the cell periphery and can be obscured by other organelles. The nucleus is large and ovoid and located in the posterior part of the cell.

When live phytoplankton samples were examined vegetative cells or gametes of *A. carterae* were swimming close to each other, simulating recognition (Fig. 4). Gametes of *A. carterae* were described to have the same size and shape as vegetative cells (Cao Vien, 1967). This occurred about one hour after the samples were collected and, about a half hour later, specimens of *A. carterae* were surrounded by a mucilaginous membrane. Inside this membrane the cells swam close to each other (Figs. 5, 6) until they fused (Figs. 6, 8). In most of these cases four cells of *A. carterae* were aggregated (Figs. 7, 8), while in a few cases, 12 cells were aggregated (Fig. 9). Inside another mucilaginous membrane, four cells were joined (Fig. 10).

The term "pellicle" is more appropriately used to describe single-layered-wall stages (Bravo *et al*., 2010). Kofoid and Sweezy (1921) mentioned that encystment of *Amphidinium* members occurs within a thin-walled membrane and that binary fission takes place within a cyst or in freely-swimming forms. Fusion of *A. carterae* cells have been observed as mentioned by Cao Vien (1967), at the same time, zygotes germination in culture was detected (Cao Vien, 1968). This author mentioned that only the act of fusion between gametes reveals their role in sexual recombination. Barlow and Triemer (1988) observed formation of cysts as part of the life cycle in *A. klebsii* Carter, 1937. These cysts contain 2-8 cells and are sites of multiple vegetative divisions. An encysted stage has important implications for species ecology because they survive conditions that would destroy the motile stage, enabling the species to repeatedly occur in a local region year after year (Sampayo, 1985).



Figures 2–10. Two specimens of *Amphidinium carterae*; Ventral view; arrow indicates the epicone (2) and Dorsal view; arrows indicate the multilobed chloroplast (3). Two cells of *Amphidinium carterae* swimming near each other; arrows indicate the pyrenoid (4). Two cells of *Amphidinium carterae* inside a just made pellicle. (5). Two clearly joined (matched) cells (6). A sequence of four cells of *Amphidinium carterae* recognizing each other (7) and later they matched (8). Two pellicicles with 16 cells of *Amphidinium carterae* (9, 10).

Table 1. Abundance of microalgae species recorded in Bahía de La Paz, Gulf of California during the proliferation of *Amphidinium carterae* in December 2011.

Microalgae species **Diatoms**	Sample A cells L^{-1}	Sample B cells L^{-1}	Sample C cells L^{-1}
Actinoptychus adriaticus Grunow, 1863	200	0	0
Asterionellopsis glacialis (Castracane) Round, 1990	3000	1400	600
Asteromphalus heptactis (Brébisson) Ralfs, 1861	0	400	400
Auliscus coelatus Bailey, 1854	0	200	0
Azpeitia nodulifer (Schmidt) Fryxell &Sims, 1986	200	0	0
Bacillaria paxillifera (O.F.Müller) T. Marsson, 1901	0	200	4200
Bellerochea malleus (Brightwell) Van Heurck, 1885	1600	1200	0
Biddulphia aurita (Lyngbye) Brébisson, 1838	200	0	0
Biddulphia bidulphiana (J.E.Smith) Boyer, 1900	0	1200	0
Biddulphia tuomeyii (Bailey) Roper, 1859	0	600	0
Cerataulina pelagica (Cleve) Hendey, 1937	0	200	200
Cerataulus californicus Schmidt,1888	200	0	0
Chaetoceros affinis H.S. Lauder, 1864	92800	101200	41600
Chaetoceros atlanticus P.T. Cleve, 1873	14600	14200	21400
Chaetoceros coarctatus H.S. Lauder, 1864	4000	1400	3000
Chaetoceros compressus H.S. Lauder,1864	10000	12200	6000
Chaetoceros curvisetus P.T. Cleve, 1889	36800	21400	42600
Chaetoceros didymus Ehrenberg, 1845	1400	0	800
Chaetoceros lorenzianus Grunow, 1863	0	1600	1800
Chaetoceros messanensis Castracane, 1875	400	600	800
Chaetoceros rostratus H.S. Lauder, 1864	4200	1200	600
Chaetoceros socialis H.S. Lauder, 1864	8200	15200	4400
Chaetoceros sp.	23200	18400	16600
Coscinodiscus asteromphalus Ehrenberg, 1844	200	0	200
Coscinodiscus radiatus Ehrenberg, 1839	0	400	200
Coscinodiscus sp.	200	0	0
Cylindrotheca closterium (Ehrenberg) Reimann & J.C. Lewin, 1964	200	400	1800
Detonula pumila (Castracane) Gran,1900	800	5200	400
Ditylum brightwellii (T.West) Grunow in Van Heurck, 1885	400	200	200
Eucampia cornuta (Cleve) Grunow in Van Heurck, 1883	0	200	200
Eucampia zodiacus Ehrenberg, 1840	400	800	200
Eupodiscus radiatus J.W.Bailey, 1851	200	200	0
Fallacia nummularia (Greville) D.G.Mann, 1990	0	400	0
Fragilariopsis doliolus (Wallich) Medlin & P.A.Sims, 1993	0	1200	800
Grammatophora marina (Lyngbye) Kützing, 1844	0	0	400
Guinardia flaccida (Castracane) H.Peragallo, 1892	0	1400	400
Guinardia striata (Stolterfoth) Hasle, 1997	400	1200	400
Helicotheca tamesis Ricard, 1987	0	400	0
Lauderia annulata Cleve, 1873	0	600	0
Lioloma pacifica (Cupp) Hasle, 1996	1600	2000	4200
Lithodesmium undulatum Ehrenberg 1839	0	400	1200
Paralia fenestrata Sawai and Nagumo, 2005	800	800	600
Pleurosigma sp. A	200	200	0
Pleurosigma sp. B	400	0	200
Proboscia alata (Brightwell) Sundström, 1986	200	0	400
Pseudosolenia calcar-avis (Schultze) B.G.Sundström, 1986	0	200	800
Pseudo-nitzschia spp.	3600	4200	5600
Rhizosolenia bergonii H.Peragallo, 1892	0	0	400
Rhizosolenia hyalina Ostenfeld, 1901	0	1600	0
Rhizosolenia imbricata Brightwell, 1858	400	200	200

Table 1. Continued

Microalgae species **Diatoms**	**Sample A cells L^{-1}**	**Sample B cells L^{-1}**	**Sample C cells L^{-1}**
Rhizosolenia setigera, Brightwell 1858	0	0	400
Thalassionema nitzschioides (Grunow) Mereschkowsky, 1902	0	3000	1200
Thalassiosira eccentrica (Ehrenberg) Cleve, 1904	800	1800	200
Thalassiosira rotula Meunier, 1910	1200	800	800
Thalassiosira subtilis (Ostenfeld) Gran, 1900	1600	1200	1400
Stephanopyxis palmeriana (Greville) Grunow, 1884	0	1200	1600
Total abundance of diatoms	**214600**	**223000**	**169400**
Dinoflagellates			
Actiniscus pentasterias (Ehrenberg) Ehrenberg, 1854	200	0	200
Alexandrium tamiyavanichii Balech, 1994	800	200	400
Amphidiniopsis hirsuta (Balech) J.D.Dodge, 1982	0	200	0
Amphidiniopsis sp.	0	200	0
Amphidinium carterae Hulburt, 1957	28200	42000	64800
Amphidinium sphenoides Wülff, 1916	0	200	0
Amylax buxus (Balech) J.D. Dodge, 1989	800	0	200
Cochlodinium pulchelum Lebour, 1917	400	0	200
Cochlodinium virescens Kofoid & Swezy, 1921	0	0	200
Cochlodinium sp.	0	0	200
Coolia monotis Meunier, 1919	400	200	0
Dinophysis acuminata Claparède & Lachmann, 1859	0	1200	400
Dinophysis caudata Saville-Kent, 1881	200	400	200
Dinophysis tripos Gourret, 1883	0	0	200
Dinophysis ovum Schütt, F.,1895	0	400	200
Dissodinium pseudolunula E.V. Swift ex Elbrächter & Drebes, 1978	200	0	200
Durinskia cf. *baltica* (Levander 1892) Carty et Cox, 1986	*	*	*
Gonyaulax digitale (Pouchet) Kofoid, 1911	0	1200	1400
Gymnodinium coeruleum Dogiel, 1906	200	0	0
Gymnodinium gracile, Bergh 1881	0	200	400
Gymnodinium instriatum Freudenthal & Lee, 1963	0	200	200
Gyrodinium sp.	0	0	400
Katodinium glaucum (Lebour) Loeblich III, 1965	200	400	1600
Neoceratium azoricum (Cleve) F.Gómez, D.Moreira & P.López-Garcia, 2010	200	0	200
Neoceratium dens (Ostenfeld & Schmidt) F.Gomez, D.Moreira & P.Lopez-Garcia, 2010	0	400	200
Neoceratium fusus (Ehrenberg) F.Gomez, D.Moreira & P.Lopez-Garcia, 2010	0	400	0
Neoceratium furca (Ehrenberg) F.Gomez, D.Moreira & P.López-García, 2010	200	0	200
Ornithocercus magnificus Stein, 1883	200	0	200
Phalacroma favus Kofoid & J.R.Michener, 1911	0	0	400
Prorocentrum compressum (J.W.Bailey) Abé ex Dodge, 1975	800	0	1200
Prorocentrum emarginatum Fukuyo, 1981	400	400	200
Prorocentrum gracile Schütt, 1895	200	400	200
Prorocentrum micans Ehrenberg, 1833	200	200	600
Prorocentrum minimum var. *triangulatum* (Martin) Hulburt, 1965	0	400	0
Prorocentrum rhathymum Loeblich, Sherley & Schmidt,1979	400	200	0
Protoperidinium abei (Paulsen) Balech, 1974	200	200	0
Protoperidinium compressum (Abé) Balech, 1974	1600	400	200
Protoperidinium excentricum (Paulsen, 1907) Balech, 1974	400	0	200
Protoperidinium oblongum (Aurivillius) Parke & Dodge, 1976	200	200	0
Protoperidinium pentagonum (Gran) Balech, 1974	0	200	200
Protoperidinium subinerme (Paulsen) Loeblich III, 1969	200	0	200
Ptychodiscus noctiluca Stein, 1883	200	0	200

Table 1. Continued

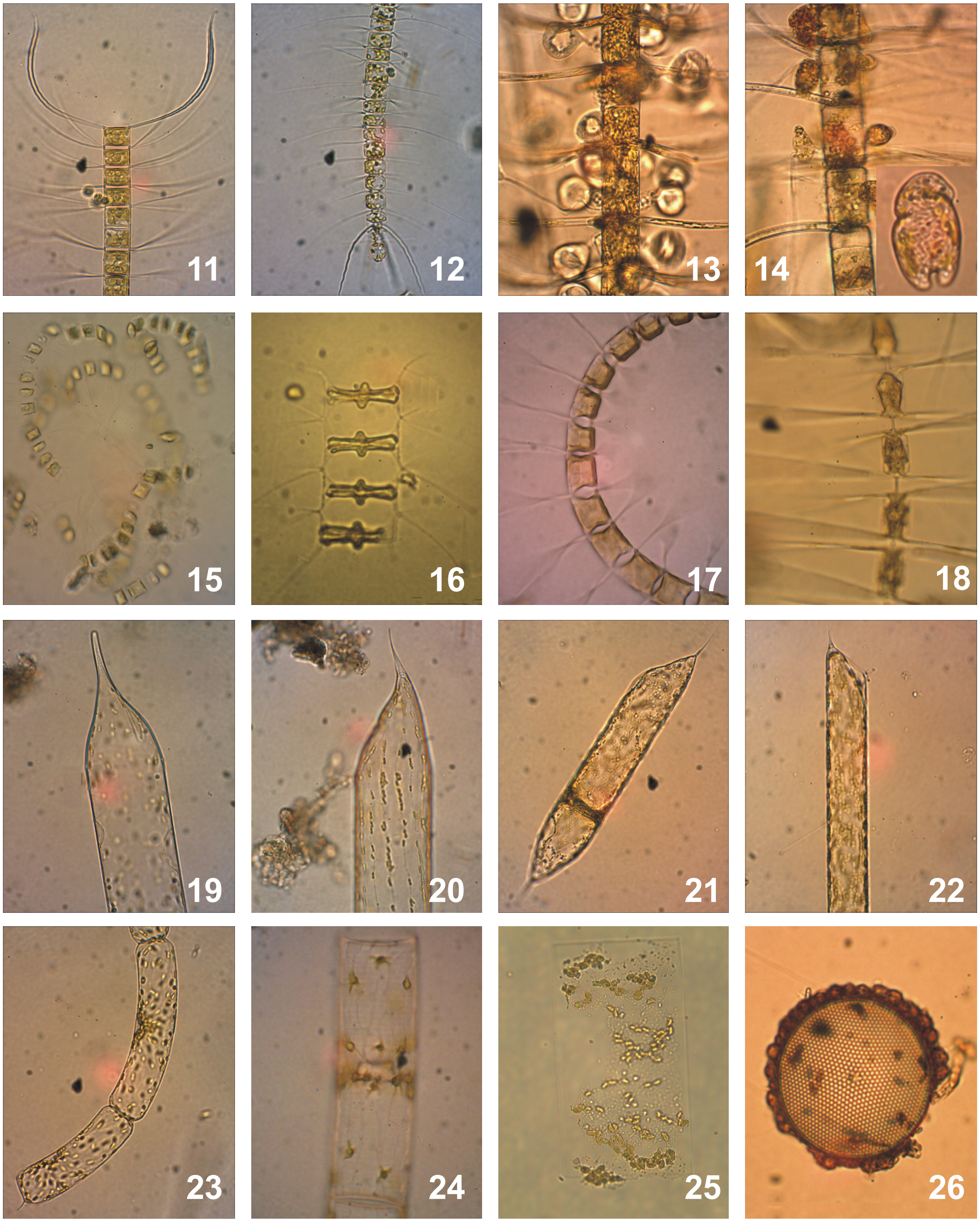
Microalgae species Dinoflagellates	cells L^{-1}	cells L^{-1}	cells L^{-1}
Pyrocystis fusiformis var. *fusiformis* (Wyville-Thomson ex Haeckel) V. H. Blackmann, 1902	0	200	200
Pyrocystis noctiluca Murray ex Haeckel, 1890	400	200	0
Pyrocystis robusta Kofoid, 1907	0	0	200
Thecadinium sp.	200	0	0
Total abundance of dinoflagellates	**37600**	**50800**	**76200**
Silicoflagellates			
Octactis octonaria (Ehrenberg) Hovasse, 1946	400	200	200
Dictyocha fibula var. *robusta* Schrader &Murray, 1985	0	0	400
Rhaphydophytes			
Chattonella marina var. *ovata* (Y. Hara & Chihara) Demura & Kawachi, 2009	0	0	200
Cyanobacteria			
Trichodesmium erythraeum Ehrenberg ex Gomont, 1892	8200	4200	16800
Total abundance of the other groups	**8600**	**4400**	**17600**
Micro-phytoplankton	**260800**	**278200**	**263200**
Nano-phytoplankton	**312400**	**211200**	**245800**
Total phytoplankton abundance	**573200**	**489400**	**509000**

At least 48 species of dinoflagellates form thin-walled cysts as part of their life cycle, associated with very different conditions, both in culture and nature (Bravo *et al*., 2010). Pellicle cysts of *Cochlodinium pulchellum* Lebour, 1917 (Fig. 60), *Cochlodinium virescens* Kofoid & Swezy, 1921 (Fig. 61), *Cochlodinium convolutum* Kofoid & Swezy, 1921 (Fig. 64), *Gyrodinium instriatum* Freudenthal & Lee, 1963 (Fig. 65), *Prorocentrum compressum* (J.W.Bailey) Abé ex Dodge, 1975 (Fig. 54), and *P. rhathymum* Loeblich, Sherley & Schmidt, 1979 (not shown) were observed in our study. Other species reported to produce pellicle cysts in Bahía de La Paz are *Gymnodinium falcatum* Kofoid & Swezy, 1921, *C. helicoides* Lebour, 1925, *C. helix* Schütt 1895, and *C. polykrikoides* Margalef, 1961 (Gárate-Lizárraga *et al*., 2004; 2009a, 2011); even these encysted species can have movement. Further studies are needed to characterize the life history of *Amphidinium* members.

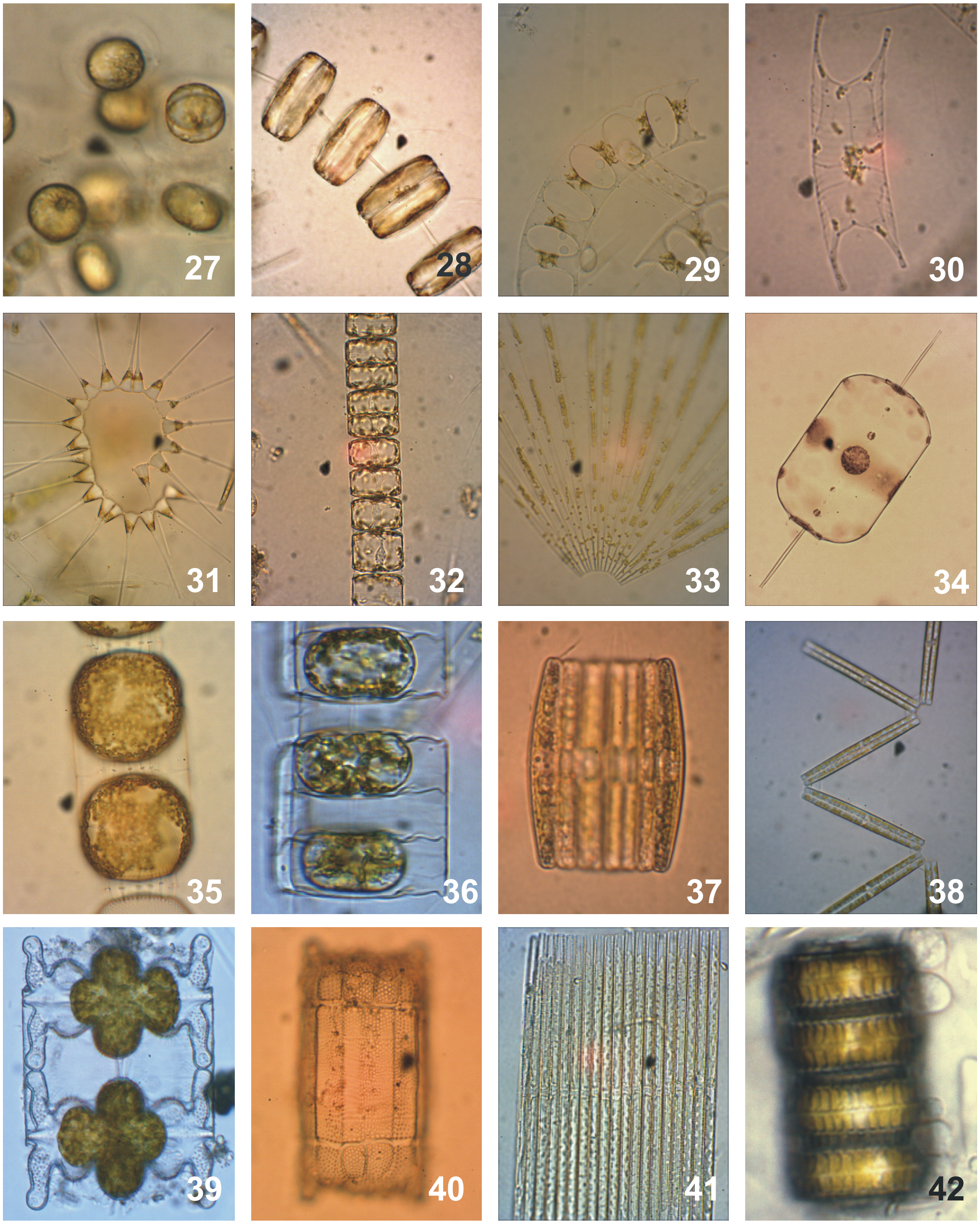
In the Sado estuary of Portugal, *A. carterae* blooms seasonally in fish ponds, causing fish die-offs (Sampayo, 1985). Mortality is most prevalent among caged fish which are unable to avoid algal blooms (Gárate-Lizárraga *et al*., 2004). Intertidal pools in the North Arabian Sea along the coast of Pakistan have blooms with concentrations of 12 × 10^3 cells mL^{-1} (Baig *et al*., 2006). In our study, densities were higher than in intertidal pools, however, no fish die-offs were observed. Although *A. carterae* is considered a benthic or epiphytic species, it makes daily upward migrations in the water column from the benthos (Kamykowski & Zentara, 1977) and this favors formation of blooms. The occurrence of outbreaks of *A. carterae* in shrimp ponds in Bahía de La Paz could pose a risk to aquaculture activities because proliferations of microalgae are common in shrimp ponds (Gárate-Lizárraga *et al*., 2009b).

Amphidinium carterae has been recognized as a producer of powerful ichthyotoxins and hemolytic substances (Yasumoto *et al*., 1987; Tindall & Morton, 1998; Echigoya *et al.,* 2005; Rhodes *et al.,* 2010). It has a variety of deleterious effects on adults and larvae of several invertebrates and is implicated as a causative agent in human ciguatera (Baig *et al.,* 2006). Both wild and cultured *A. carterae* cells were tested for ciguatera toxicity by exposure to brine shrimp nauplii and albino mice. Pharmacological effects on mice include muscle contraction in lower back area, increased respiration, immobility, and paralysis in hind limbs for 2 h. These effects appeared to be reversible and gradually disappeared within 24h.

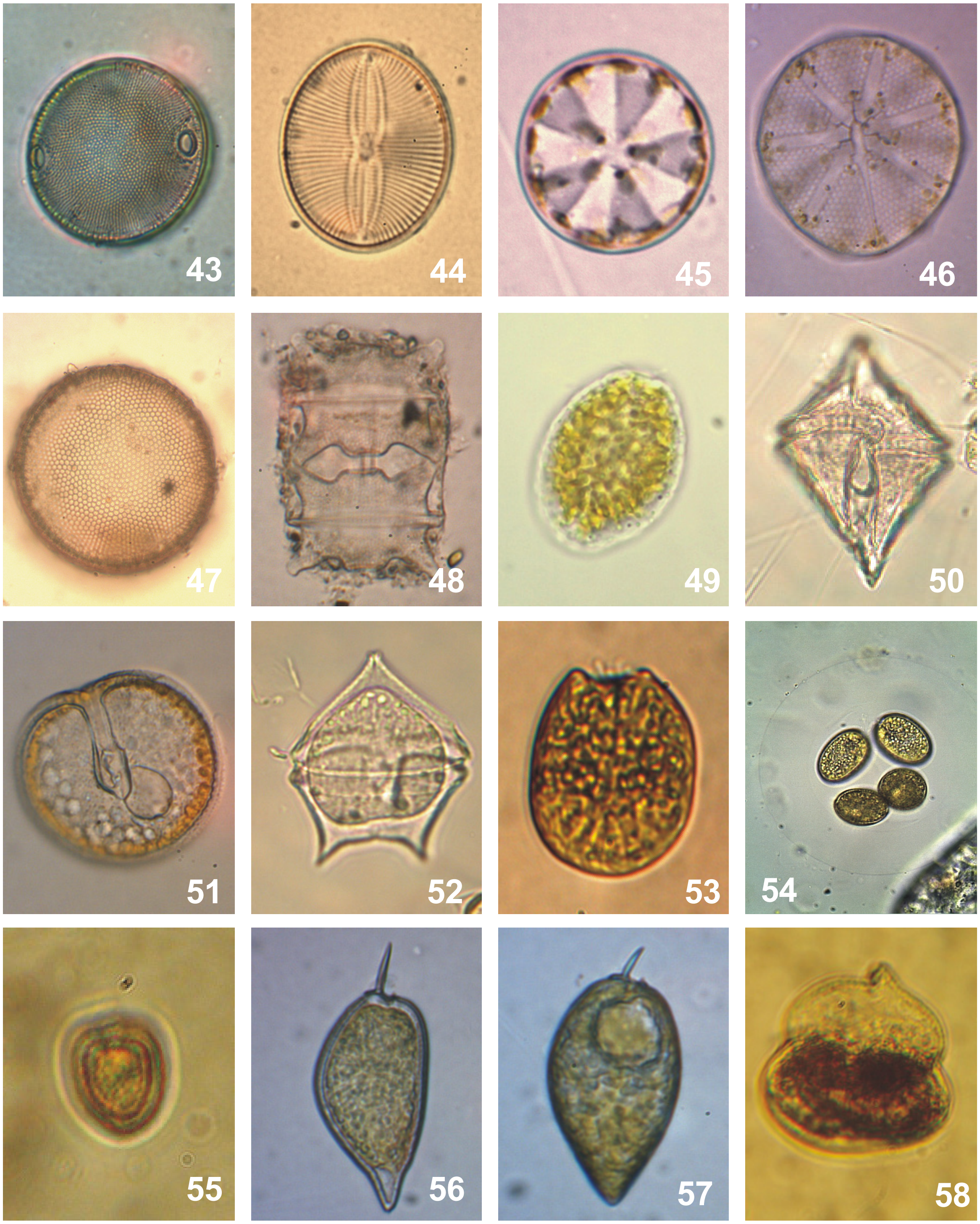
In this survey, three species of microalgae producers of okadaic acid were observed (*Dinophysis acuminata*, *D. caudata*, and *D. tripos*), one produces venerupin (hepatotoxin) (*Prorocentrum minimum*), one generates neurotoxins and hepatotoxins (*Trichodesmium erythraeum*), and one produces haemolytic toxins (*P. rhathymum*). Although these species occurred in low densities during this bloom, they could be a health hazard if they proliferate. Monitoring of bloom forming, and toxin-producing microalgae species in Bahía de La Paz and other coasts of the Baja California Sur is an on-going activity.



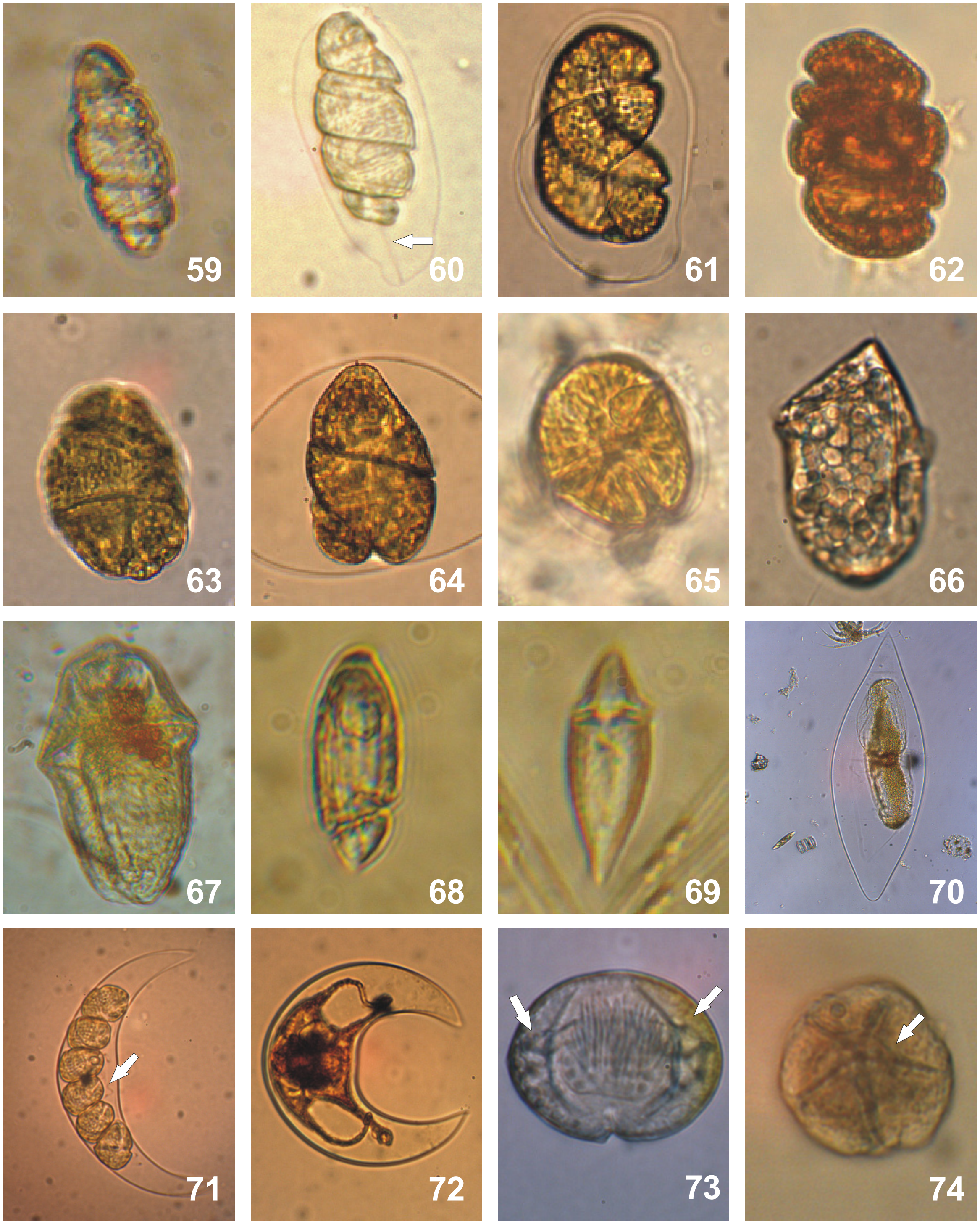
Figures 11–26. *Chaetoceros affinis* (11), *Chaetoceros compressus* (12), *Chaetoceros coarctatus* (with *Vorticella oceanica*) (13), *Chaetoceros coarctatus* (with a microalgae attached; inset is the free-microalgae) (14), *Chaetoceros socialis* (15), *Chaetoceros didymus* (16), *Chaetoceros curvisetus* (17), *Chaetoceros rostratus* (18), *Proboscia indica* (19), *Pseudosolenia calcar-avis* (20), *Rhizosolenia hyalina* (21), *Rhizosolenia imbricata* (22), *Guinardia striata* (23), *Guinardia flaccida* (24), *Helicotheca tamesis* (25), and *Thalassiosira* sp. with *Reticulofenestra sessilis* attached to the frustule (26).



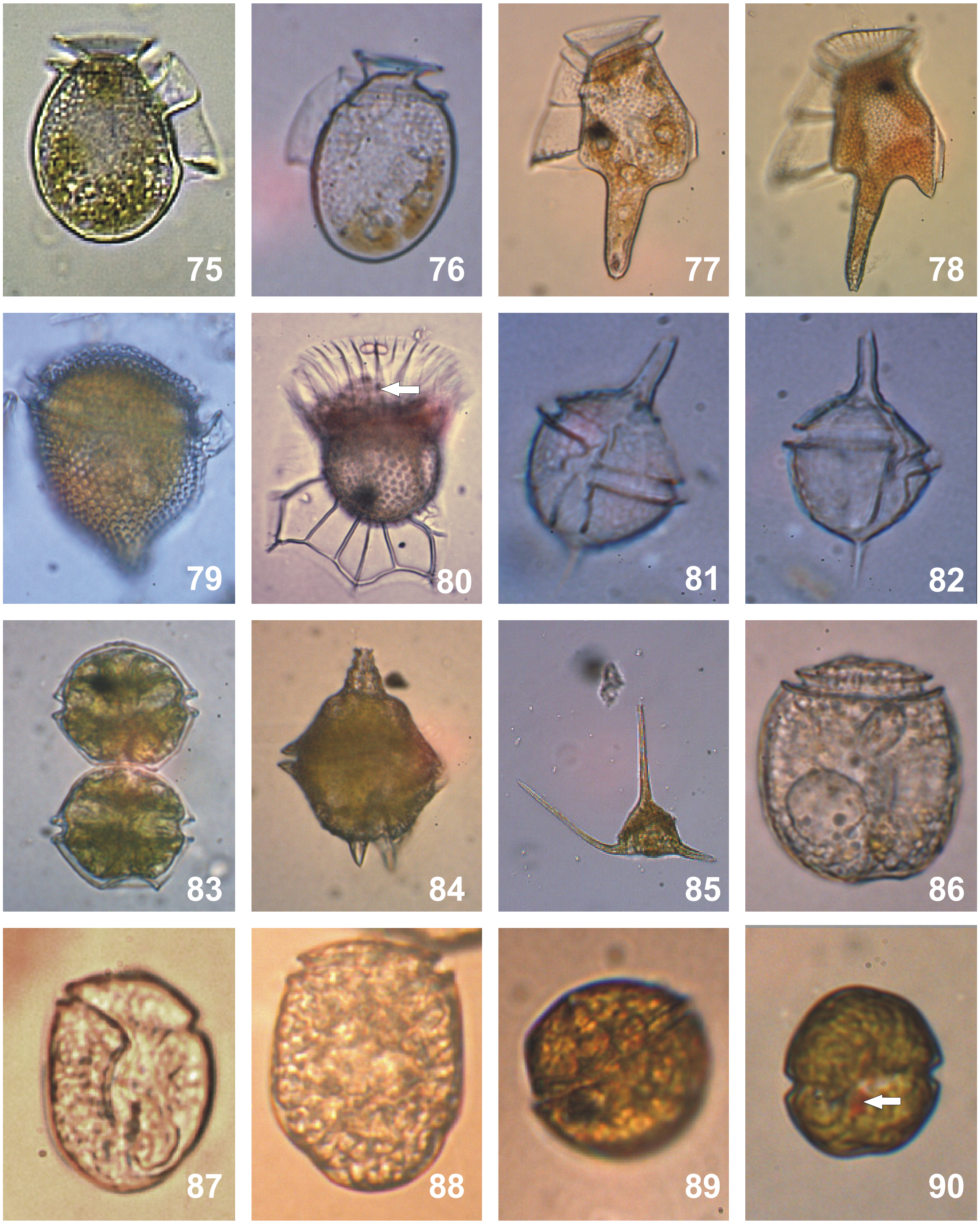
Figures 27–42. *Thalassiosira subtilis* (27), *Thalassiosira rotula* (28), *Eucampia zodiacus* (29), *Eucampia cornuta* (30), *Asterionellopsis glacialis* (31), *Detonula pumila* (32), *Lioloma pacifica* (33), *Ditylum brightwelli* (34), *Stephanopyxis palmeriana* (35), *Lithodesmium undulatum* (36), *Fragilariopsis doliolus* (37), *Thalassionema nitzschioides* (38) *Biddulphia tuomeyii* (39), *Biddulphia biddulphiana* (40), *Bacillaria paxillifera* (41), and *Paralia fenestrata.* (42).



Figures 43–58. *Cerataulus californicus* (43), *Fallacia nummularia* (44), *Actinoptychus adriaticus* (45), *Asteromphalus heptactis* (46), *Eupodiscus radiatus* (47), *Odontella aurita* (48), *Chattonella marina* var. *ovata* (49) *Protoperidinium abei* (50), *Protoperidinium excentricus* (51), *Protoperidinium compressum* (52), *Prorocentrum emarginatum* (53), Four cells of *Prorocentrum compressum* inside a gelatinous membrane (Pellicicle) (54), *Prorocentrum minimum* var. *triangulatum* (55), *Prorocentrum gracile* (56), *Prorocentrum micans* (57), and *Ptychodiscus noctiluca* (58).



Figures 59–74. Cells of *Cochlodinium pulchellum* (59, 60), Pellicicle of *Cochlodinium pulchellum* showing the flagellum (60), Pellicicle of *Cochlodinium virescens,* (61), Cell *Cochlodinium virescens* fixed with Lugol (62), *Cochlodinium convolutum* (63), *Cochlodinium convolutum pellicicle* (64), *Gyrodinium instriatum* (65), *Gyrodinium* sp. (66), *Gymnodinium gracile* (67), *Katodinium glaucum* (68), *Amphidinium sphenoides* (69), *Pyrocystis fusiformis* var. *fusiformis* (70), *Dissodinium pseudolunula;* secondary cyst with 6 dinokont cells; arrow indicates the flagella (71), *Pyrocystis robusta* (72), *Actiniscus pentasterias*; Side view of the cell, arrow showing the two complete pentasters (73); cell showing one of the pentasters (74).



Figures 75–90. *Dinophysis ovum* (75), *Dinophysis acuminata* (76), *Dinophysis caudata* (77), *Dinophysis tripos* (78), *Phalacroma favus* (79) *Ornithocercus magnificus*, arrow indicates the symbiotic cyanobacteria harbourd in the region of the cingular list (80), *Amylax buxus* (81, 82) *Alexandrium tamiyanavichii* (83), *Gonyaulax digitale* (84), *Neoceratium dens* (85), *Amphidiniopsis hirsuta* (86), *Amphidiniopsis sp.* (87), *Thecadinium sp.* (88), *Coolia monotis* (89), and *Durinskia* cf *baltica*, arrow indicates the bright red stigma in the sulcal area of the cell (90).

New records

Several species of dinoflagellates shown in Figures 2-90, are new records for the Mexican Pacific coast: *Prorocentrum minimum* var. *triangulatum* (Martin) Hulburt, 1965 (Fig. 55), *Cochlodinium pulchellum* (Figs. 59–60), *Cochlodinium virescens* (Figs. 61–62), *Gyrodinium* sp. (Fig. 66), *Amylax buxus* (Balech) J.D. Dodge, 1989 (Figs. 81–82) *Amphidiniopsis hirsuta* (Balech) J.D.Dodge, 1982 (Fig. 86), for which the antapical row of spines was not visible under light microscopy, coinciding with those specimens collected from the French coasts (Gómez *et al*., 2011); *Amphidiniopsis* sp. (Fig. 87), *Thecadinium* sp. (Fig. 88), and *Durinskia* cf. *baltica* (Levander) Carty & Cox, 1986 (Fig. 90). Some others species are new records for the Gulf of California; *Ptychodiscus noctiluca* Stein, 1883 (Fig. 58), *Pyrocystis robusta* Kofoid, 1907 (Fig. 72), *Phalacroma favus* Kofoid & J.R. Michener, 1911 (Fig. 79), and *Coolia monotis* Meunier, 1919 (Fig. 89). Two interesting findings were observed in this study: the symbiosis between the coccolithophorid *Reticulofenestra sessilis* (Lohmann 1912) Jordan & Young 1990 and the diatom *Thalassiosira* sp. (Fig. 26), as well as the presence of the diatom *Paralia fenestrata* (Fig. 42) in Bahía de La Paz.

ACKNOWLEDGMENTS

Research projects were funded by Instituto Politécnico Nacional (SIP-20110281, SIP-20110590, and SIP-20121153). The author would like to thank the anonymous reviewers for their valuable comments and suggestions to improve the quality of the paper. I.G.L. is COFAA and EDI fellow.

REFERENCES

Baig, H.S., S.M. Saifullah & A. Dar. 2006. Occurrence and toxicity of *Amphidinium carterae* Hulburt in the North Arabian Sea. *Harmful Algae*, 5: 133–140. https://doi.org/10.1016/j.hal.2005.06.010

Barlow, S.B. & R.E. Triemer. 1988. Alternate life history stages in *Amphidinium klebsii* (Dinophyceae, Pyrrophyta). *Phycologia*, 27: 413–420. https://doi.org/10.2216/i0031-8884-27-3-413.1

Bravo, I., R.I. Figueroa, E. Garcés & S.F.A. Massanet. 2010. The intricacies of dinoflagellate pellicle cysts: The example of *Alexandrium minutum* cysts from a bloom-recurrent area (Bay of Baiona, NW Spain). *Deep Sea Research* II, 57: 166–174. https://doi.org/10.1016/j.dsr2.2009.09.003

Cao Vien, M. 1967. Sur l'existence de phénomènes sexuels chez un Péridinien libre, l'*Amphidinium carteri*. *C. R. Acad. Sci., Ser. D.*, 264: 1006-1008.

Cao Vien, M., 1968. Sur la germination du zygote et sur un mode particulier de multiplication végétative chez le péridinien libre, *l'Amphidinium carteri*. C. R. Acad. Sci., Ser. D., 267, 701–703.

Dodge, J.D. 1982. *Marine Dinoflagellates of the British Isles*. Her Majesty's Stationery Office, London, 303 p.

Echigoya, R., L. Rhodes, Y. Oshima & M. Satake. 2005. The structures of five new antifungal and hemolytic amphidinol analogs from *Amphidinium carterae* collected in New Zealand. *Harmful Algae*, 4: 383–389. https://doi.org/10.1016/j.hal.2004.07.004

Flø Jørgensen, M., S. Murray & N. Daugbjerg. 2004. *Amphidinium* revisited. I. Redefinition of *Amphidinium* (Dinophyceae) based on cladistic and molecular phylogenetic analyses. *J. Phycol*., 40: 351–365. https://doi.org/10.1111/j.1529-8817.2004.03131.x

Fukuyo, Y. 1981. Taxonomical study on benthic dinoflagellates collected on coral reefs. *Bull*. *Japan*. *Soc*. *Sci*. *Fish*., 47: 967–78. https://doi.org/10.2331/suisan.47.967

Gárate-Lizárraga, I. & M.S. Muñetón-Gómez. 2008. Bloom of *Peridinium quinquecorne* Abé in Ensenada de La Paz, Gulf of California (July 2003). *Acta Bot*. *Mex*., 83: 33−47. https://doi.org/10.21829/abm83.2008.1059

Gárate-Lizárraga, I., M. L. Hernández-Orozco, C. Band-Schmidt & G. Serrano-Casillas. 2001. Red tides along the coasts of Baja California Sur, México (1984 to 2001). *Oceánides*, 16(2): 127–134.

Gárate-Lizárraga, I., M.S. Muñetón-Gómez & V. Maldonado-López. 2006. Florecimiento del dinoflagelado *Gonyaulax polygramma* frente a la Isla Espíritu Santo, Golfo de California (Octubre-2004). *Rev. Inv. Mar.*, 27(1): 31–39.

Gárate-Lizárraga, I., C.J. Band-Schmidt, G. Verdugo-Díaz, M.S. Muñetón-Gómez & E.F. Félix-Pico. 2007. Dinoflagelados (Dinophyceae) del sistema lagunar Magdalena-Almejas, 141−170. *In*: R. Funes-Rodríguez, J. Gómez-Gutiérrez & J.R. Palomares-García (Eds.). *Estudios ecológicos en Bahía Magdalena*. CICIMAR-IPN, La Paz, Baja California Sur, México.

Gárate-Lizárraga, I., C.J. 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 Oceánides*, 24: 1−15. https://doi.org/10.37543/oceanides.v24i1.50

Gárate-Lizárraga, I., Band-Schmidt, C.J., López-Cortés, D.J. & M.S. Muñetón-Gómez. 2009b. Bloom of *Scrippsiella trochoidea* (Gonyaulacaceae) in a shrimp pond from the southwestern Gulf of California, Mexico. *Mar. Pollut. Bull.*, 58: 145–149. https://doi.org/10.1016/j.marpolbul.2008.09.016

Gárate-Lizárraga, I., F. García-Domínguez, B. Pérez-Cruz & J.A. Díaz-Ortiz. 2011. First record of *Cochlodinium convolutum* and *C. helicoides* (Dinophyceae: Gymnodiniaceae) in the Gulf of California. *Rev. Biol. Mar. Oceanogr.*, 46: 495–498. https://doi.org/10.4067/S0718-19572011000300020

Gómez, F., P. López-García & D. Moreira. 2011. Molecular phylogeny of the sand-dwelling dinoflagellates *Amphidiniopsis hirsuta* and *A. swedmarkii* (Peridiniales, Dinophyceae). *Acta Protozool.*, 50: 255–262.

Gómez-Valdés, J., J.A. Delgado & J.A. Dwora. 2003. Overtides, compound tides, and tidal-residual current in Ensenada de La Paz lagoon, Baja California Sur, Mexico. *Geof. Inter.*, 42: 623–634. https://doi.org/10.22201/igeof.00167169p.2003.42.4.316

Guiry, M.D. & G.M. Guiry. 2012. *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org.

Hallegraeff, G.M., C.J.S. Bolch, D.R.A. Hill, I. Jameson, J.M. LeRoi, A. McMinn, S. Murray, M.F. de Salas & K. Saunders. 2010. *Algae of Australia: Phytoplankton of temperate coastal waters.* CSIRO Publishing, Australia, 421 p.

Hoppenrath, M. 2000. *Taxonomische und o¨kologische Untersuchungen von Flagellaten mariner Sande*. Doctoral Thesis, Biologische Fakultät, Universität Hamburg, Germany, 311 p.

Ismael, A.A., H., Y. Halim & A.G., Khalil. 1999. Optimum growth conditions for *Amphidinium carterae* Hulburt from eutrophic waters in Alexandria (Egypt) and its toxicity to the brine shrimp *Artemia salina*. *Grana*, 38: 179–185. https://doi.org/10.1080/713786930 https://doi.org/10.1080/00173139908559226

Kamykowski, D. & S.J. Zentara. 1977. The diurnal vertical migration of motile phytoplankton through temperature gradients. *Limnol. Oceanogr.*, 22: 148–151. https://doi.org/10.4319/lo.1977.22.1.0148

Kofoid, C.A. & O. Swezy. 1921. *The free-living unarmored Dinoflagellata*. *Mem. Univ. Calif.*, University of California Press, Berkeley. V. 5, 562 p. + 12 pl.

Murray, S., M., Flo-Joergensen, N. Daugbjerg & L. Rhodes. 2004. *Amphidinium* revisited. II. Resolving species boundaries in the *Amphidinium operculatum* species complex (Dinophyceae), including the descriptions of *Amphidinium trulla* sp. nov. and *Amphidinium gibbosum* comb. nov. *J. Phycol.*, 40: 366–382. https://doi.org/10.1046/j.1529-8817.2004.03132.x

Núñez-Vázquez, E.J. 2005. *Biotoxinas marinas en peces comestibles de Baja California Sur, México: origen, identificación y cuantificación*. Bachelor's thesis. Centro de Investigaciones Biológicas del Noroeste, La Paz, Baja California Sur.

Okolodkov, Y.B. & I. Gárate-Lizárraga. 2006. An annotated checklist of dinoflagellates from the Mexican Pacific. *Acta Bot. Mex.*, 74: 1–154. https://doi.org/10.21829/abm74.2006.1008

Okolodkov, Y.B., G. Campos-Bautista, I. Gárate-Lizárraga, J.A.G. González-González, M. Hoppenrath & V. Arenas. 2007. Seasonal changes of benthic and epiphytic dinoflagellates in the Veracruz reef zone, Gulf of Mexico. *Aq. Micr. Ecol.*, 47: 223–237. https://doi.org/10.3354/ame047223

Rhodes L.L., K.F. Smith, R. Munday, A.I. Selwood, P.S. McNabb, P.T. Holland & M.Y. Bottein. 2010. Toxic dinoflagellates (Dinophyceae) from Rarotonga, Cook Islands. *Toxicon*, 56: 751–758. https://doi.org/10.1016/j.toxicon.2009.05.017

Sampayo, M.A. 1985. Encystment and excystment of a Portugese isolate of *Amphidinium carterae* in cultures, 125–130. *In*: Anderson, D.M., A.W. White, & D.G. Baden (Eds.). *Toxic Dinoflagellates*, Elsevier, Amsterdam.

Steidinger, K.A., A.M. Faust & D.U. Hernández-Becerril. 2009. Dinoflagellates (Dinoflagellata) of the Gulf of Mexico, 131-154. *In*: Tunnel, J. W. Jr., D. L. Felder & S.A. Earl (Eds.). *Gulf of Mexico origin, waters, and biota*. Vol.1, Biodiversity. 1st ed. Harte Research Institute for Gulf of Mexico Studies Series, Texas A & M University Press, Corpus Christi, TX.

Tindall, D.R. & S.L. Morton. 1998. Community dynamics and physiology of epiphytic/benthic dinoflagellates associated with ciguatera, 293–313. *In:* Anderson, D.M., A.D. Cembella & G.M. Hallegraeff (Eds.). *Physiological Ecology of Harmful Algal Blooms.* Proceedings of the NATO-ASI, volume 41. Springer Verlag, Heidelberg.

Yasumoto, T., N. Seino, Y. Murakami & M. Murata. 1987. Toxins produced by benthic dinoflagellates. *Biol. Bull.*, 172: 128–131. https://doi.org/10.2307/1541612