

## Bloom of *Gymnodinium catenatum* in Bahía Santiago and Bahía Manzanillo, Colima, Mexico

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**Abstract:** *Gymnodinium* bloom events are of concern, since they produce toxins, which have unfavorable consequences to marine ecosystems, human health and the economy. This report describes the physico-chemical conditions that were present during the algal bloom event on May 2010 in Bahía Manzanillo and Bahía Santiago, Colima, Mexico. For this, seawater nutrient analysis, phytoplankton counts, identification, and toxicity tests were undertaken. Nutrients in seawater were determined using colorimetric techniques, the higher concentrations (8.88µM DIN, 0.78µM PO<sub>4</sub> and 24.34µM SiO<sub>2</sub>) were related with upwelling waters that promoted the algal bloom that began after registering the year lowest sea-surface temperature, favoring the rapid growth of *G. catenatum* (up to 1.02 x10<sup>7</sup>cells/L). Phytoplankton counting was carried out using sedimentation chambers and cells enumerated on appropriated area. The bloom persisted in the bays for approximately two weeks and was associated with toxicity (determined with HPLC) in local oysters (1525.8µg STXeq/100g), and in phytoplankton (10.9pg STXeq/cells) samples. Strong variations in cell toxicity (1.4 to 10.9pg STXeq/cells), most likely reflected the availability of inorganic nutrients. The toxin profile of the phytoplankton samples consisted of 11 toxins and resembled those recorded for several strains of *G. catenatum* isolated from other coastal areas of Mexico. Rev. Biol. Trop. 60 (1): 173-186. Epub 2012 March 01.

**Key words:** *Gymnodinium catenatum*, algal bloom, toxicity, upwelling.

Algal blooms occur in coastal waters worldwide and have been mainly ascribed to upwelling systems, oceans fronts, and anthropogenic discharges, among other factors (Hallegraeff 1993, Kudela *et al.* 2008, Trainer *et al.* 2009). Bloom events are a source of concern, since under certain circumstances bloom-forming algae produce toxins, with adverse consequences to marine ecosystems, human health, and the economy (Kudela *et al.* 2008, Shipe *et al.* 2008).

In coastal areas of the North Pacific, harmful algal blooms (HABs) have become more frequent, most likely associated with biological, physical, and chemical processes related to the California current (Kudela *et al.* 2010, Trainer *et al.* 2010). In events dominated by the naked dinoflagellate *Gymnodinium catenatum* Graham, increases in nitrogen compounds during winter-spring transitions in the water column and periods of upwelling in North Pacific coastal waters, stimulate the production of

toxins, including those causing paralytic shellfish poisoning (PSP) toxin (Kudela *et al.* 2010).

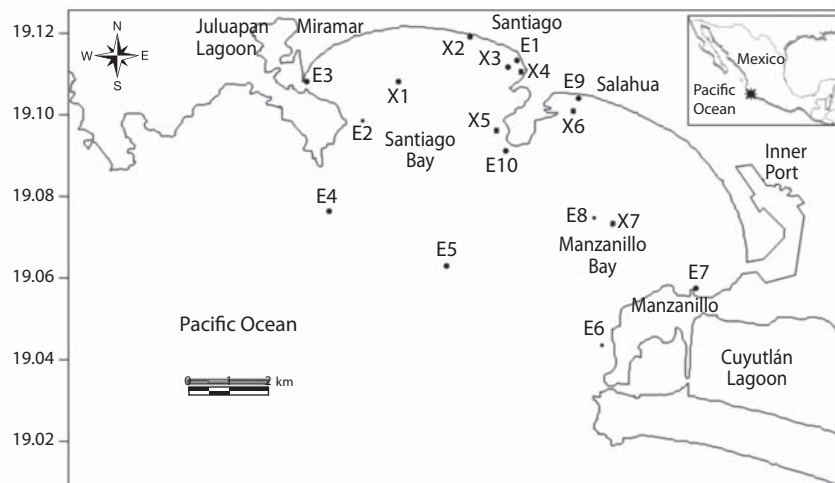
The first record of *G. catenatum* in Mexican waters was in 1939, in the Gulf of California (Graham 1943). An historical review of the presence of blooms and toxins of *G. catenatum* in the Mexican Pacific has been done by Band-Schmidt *et al.* (2010). These authors reported many scarcely recognized relevant studies. Along the central Mexican Pacific coastline, *G. catenatum* has been found in a 700km area stretching from Bahía Banderas (21°N) to the port of Lázaro Cárdenas (~18°N). Despite that, abundances of this dinoflagellate have been as high as  $2.1 \times 10^5$  cells/L, there is only one report relating these species with toxicity in bivalves in Bahía Manzanillo, with a high toxicity value of 235.28 µg saxitoxin/100g wet weight, in the oyster *Crassostrea iridescens* during that bloom (González-Chan *et al.* 2008). Species of dinoflagellates, diatoms and ciliates have been identified as the main phytoplankton components of bloom events. In this case, the species responsible for high-abundance proliferations were: *Ceratium divaricatum* ( $4.5 \times 10^8$  cells/L), *Myrionecta rubra* ( $3 \times 10^6$  cells/L), *Dictyocha fibula* ( $2.8 \times 10^5$  cells/L). The presence of *G. catenatum* in Bahía Manzanillo was reported lately in August 1989 and April 2002 (Ortiz-Lira & Jiménez-Quiroz 2006). Furthermore,

Figuerroa-Torres & Zepeda-Esquivel (2001) have described *G. catenatum* blooms at the Internal Port of Manzanillo on April and December 1999 and in March 2000.

The characteristics and toxicity of HABs and the environmental and hydrodynamic conditions that favor these events are largely unknown, due to the lack of a systematic monitoring program in the affected areas. A better understanding of the hydrodynamic conditions present at the time of the bloom will improve our ability to predict these events, and thereby potentially limit their negative consequences. Therefore, the aim of this study was to evaluate the 2010 bloom of *G. catenatum* in the Bahía Manzanillo and Bahía Santiago.

## MATERIAL AND METHODS

**Sampling:** The study area included Bahía Manzanillo and Bahía Santiago, in the central zone of the Mexican tropical Pacific (19°05' N - 104°23' W) (Fig. 1). Both bays are semi-circular in shape and open to the ocean, with a distance of 15km between Punta Carrizal to the North and Punta Ventanas to the South. The bays, from the mouth to the shore, are about 6.5km long and have an area of 120km<sup>2</sup>. The bathymetry of Bahía Santiago indicates an average depth of about 6m; it is connected with



**Fig. 1.** Location of the sampling stations (E1-E10) in the Bahía de Manzanillo and Santiago. Additional stations were sampled on May 7th (X1-X3) and X4-X7 on May 12th (X4-X7). The buoy is located at station E2.

the Juluapan lagoon. The Bahía Manzanillo has an average depth of 43m, with a maximum of 86m and, near the coastline, a minimum depth of 10m (Secretaría de Marina 1973, Galicia-Pérez 1987, Galicia-Pérez & Gaviño-Rodríguez 1996).

The monitoring program area included a routine monthly sampling carried out since 2009, which consisted in ten coastal and off-shore stations; a phytoplankton bloom was detected between May 3<sup>rd</sup> to 20<sup>th</sup> of 2010 (Fig. 1). During this event, samples were taken at seven additional stations X1-X3 on May 7<sup>th</sup> and X4-X7 on May 12<sup>th</sup>.

**Temperature and salinity:** Both parameters were measured *in situ* with an YSI (model 85) probe. Additionally, data was recorded every 10min at a hydrographic buoy anchored at station two. The buoy contained a CTD with temperature and conductivity sensors, and an antenna for real-time data transmission via the Argos satellite system. Therefore, this data reflected daily changes in the variables of interest and verified the equipment optimum functioning.

**Nutrients:** Seawater samples for nutrient analysis (DIN [NO<sub>3</sub><sup>-</sup>, NO<sub>2</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup>], PO<sub>4</sub><sup>3-</sup> and SiO<sub>2</sub>) were collected with a Niskin bottle and analyzed in a Skalar San Plus autoanalyzer as described in Grasshoff *et al.* (1983).

**Phytoplankton counting:** In the course of this routine monitoring program a bloom of *G. catenatum* was detected, lasting from May 7<sup>th</sup> - May 17<sup>th</sup>, 2010. During this period, sampling was increased, with samples collected every fifth day at 11 stations, and visual examination of sea-surface color changes were performed every hour between 8:00 and 14:30h. Water samples were collected using a 3m long silicone hosepipe (Stations E3 and E7) or 10m (the remaining Stations), depending on the depth. The contents of the hosepipe were mixed in a bucket, with two 500mL subsamples transferred to plastic bottles and preserved with Lugol's solutions. Phytoplankton taxonomic

identification subsamples of the integrated water samples were examined using sedimentation chambers, and an area with a representative number of cells enumerated (20mL settled and more than 300cells enumerated) under an inverted bright-field light microscope (Motic AE31), at 200-400× magnification (Thronsdén 1995). The abundance distribution data was transformed using the natural logarithm, and graphs were written. The total phytoplankton population was counted on 28 samples.

**Toxin sampling and analysis:** Water for toxin analysis was sampled at stations E7, X1, and X3 on May 7<sup>th</sup> 2010 and at stations X4, X5, X6, and X7 on May 12<sup>th</sup>. Samples were kept in plastic bottles on ice until filtration in the laboratory. Approximately 400mL of water was filtered, or until the filters (GF/F type) were saturated; these were kept at -20°C until analyzed. The extraction process begun with the addition of 2mL of acetic acid, followed by five min of sonication in an ice bath, and by centrifugation (3 000rpm for five min). The supernatant was filtered through a single-use syringe filter (0.45µm) and an aliquot (150µL) hydrolyzed with 1M HCl. A total of 10µL of each extract (hydrolyzed and non-hydrolyzed) was injected into a HPLC system (model HP 1100) equipped with a fluorescence detector (HP 1200) and previously described methods were followed (Hummert *et al.* 1997, Yu *et al.* 1998). Paralytic toxins contained in the extracts were separated on an ion-pair buffer gradient consisting of a solution made up of octansulfonic acid, ammonia phosphate (pH 6.9) and acetonitrile. After post-column oxidation with alkaline periodic acid, the resulting products were identified with a fluorescence detector (HP 1116) set to a wavelength of 330nm for excitation and 395nm for emission. Paralytic toxins were identified by comparing chromatograms obtained from sample extracts with those resulting from an injection of standard solutions (National Research Council Canada). Toxin content was quantified by comparing the peak areas in the chromatograms of sample extracts with those of the corresponding response factor.

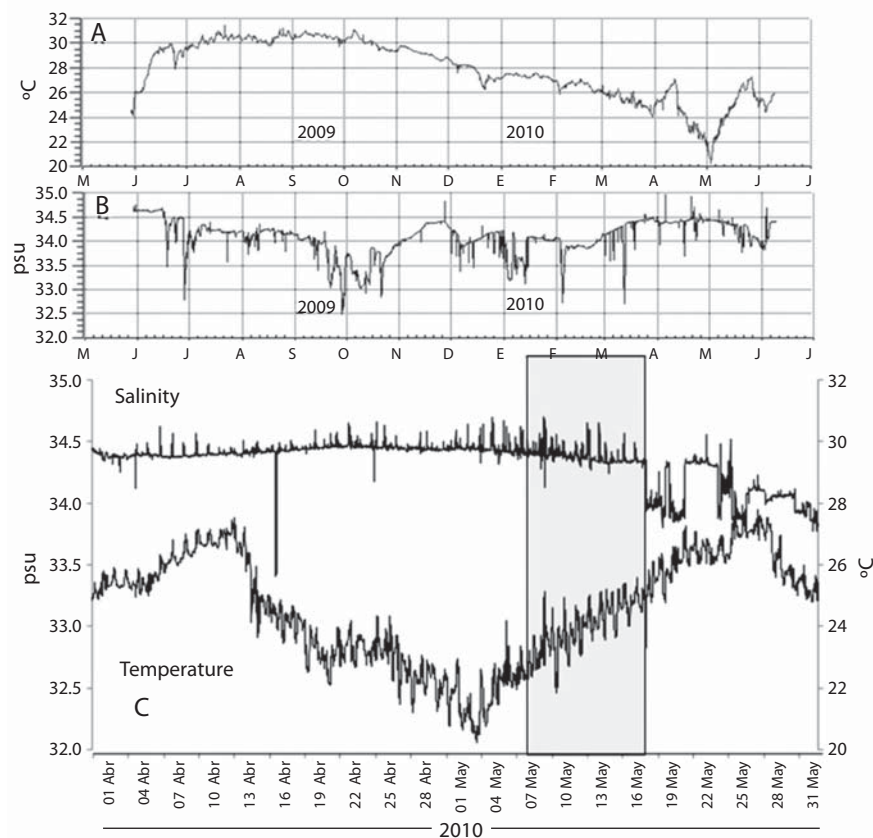
Additionally, a sample of a local oyster, *Chama echinata* Broderip, known as red oyster, was collected on May 12<sup>th</sup> 2010 at station X5. Approximately 100g of fresh tissue were homogenized with a tissue grinder, from which 2.0g were subsequently treated with 4mL of acetic acid (1M) for toxin extraction. The sample was homogenized and then centrifuged (3000rpm for five min), with the resulting supernatant treated as the phytoplankton filter for extraction and HPLC analysis.

## RESULTS

**Temperature and salinity:** The buoy sea-surface registered temperatures from June 2009-June 2010. Results showed a rapid increase

in June 2009, from to 24°C-30°C, this latter value persisted for the following few months. In November 2009, temperatures began to decrease gradually, reaching a minimum of 21°C in the beginning of May 2010, when the annual cycle started again. The corresponding salinity records showed variations between 32.5 and 34.6, with an association between the low values and the area's rainy season [average of 963.8mm (INEGI 2010)] (Fig. 2).

During the studied bloom event, salinity remained almost constant (34.4psu), but temperatures varied widely (from 20.5 to 27.5°C). Five days after a minimal temperature, a water discoloration was observed (May 7<sup>th</sup> at 22.5°C), and when the temperature reached 25.5°C on May 17<sup>th</sup>, the event was not perceived (Fig. 2).



**Fig. 2.** (A) Sea-surface water temperature from June 2009 to June 2010; (B) salinity psu from 2009 to June 2010; (C) temperature and salinity during 1<sup>st</sup> April-1<sup>st</sup> June of 2010. The blooming period is shown in grey.

**Nutrients:** In general, phosphate and DIN varied only slightly, both at the surface and at 5m depth. On the contrary, silicates concentrations varied greatly in surface samples (as seen by the standard deviation); and by the end of the bloom, when a clear increase was observed at 5m depth (Table 1).

DIN values were initially low and uniform at the surface (3.1 to 7.4 $\mu$ M), while at 5m depth high values were consistently recorded; these values increased from the ocean towards the coast, with the maximum at E10 (12.2 $\mu$ M). On May 12th, DIN values were low at Bahía Santiago, with a slight increase towards Bahía Manzanillo; whereas at 5m depth, high concentrations persisted along the coast, with maximum values at E9 and E6 (about 14.4 $\mu$ M). By the end of the bloom, the concentration at 5m decreased (average of 8 $\mu$ M) between E2 and E10.

During the first two sampling days of the bloom, phosphate concentrations ranged between 0.2 and 0.8 $\mu$ M uniformly in both bays, but on May 17<sup>th</sup> a peak was detected toward the coast of Bahía Santiago (1.9 $\mu$ M), while at 5m, the low concentrations observed were similar to those recorded at the beginning of the event (0.8 $\mu$ M).

Silicates initially showed only a small variability, with low concentrations in both bays (about 6 $\mu$ M), but on May 12<sup>th</sup> both at the surface and, most notably, at 5m depth, the concentrations increased (E9 and E6), reaching a maximum of 26.1 $\mu$ M. At the end of the bloom, concentrations of values around 21 $\mu$ M were determined at surface stations located in the middle of the two bays (E10 and E5), while at 5m depth, the highest concentrations occurred at Bahía Manzanillo (16 $\mu$ M, E8).

Nutrient concentrations at E10 did not vary significantly for DIN (8.68 $\mu$ M on average), while phosphate reached a minimum on May 12<sup>th</sup> (0.37 $\mu$ M), that coincide with the maximum phytoplankton abundance. Silicates increased steadily in a notorious trend until May 17<sup>th</sup>, when the maximum was reached (24.31 $\mu$ M) (Table 1).

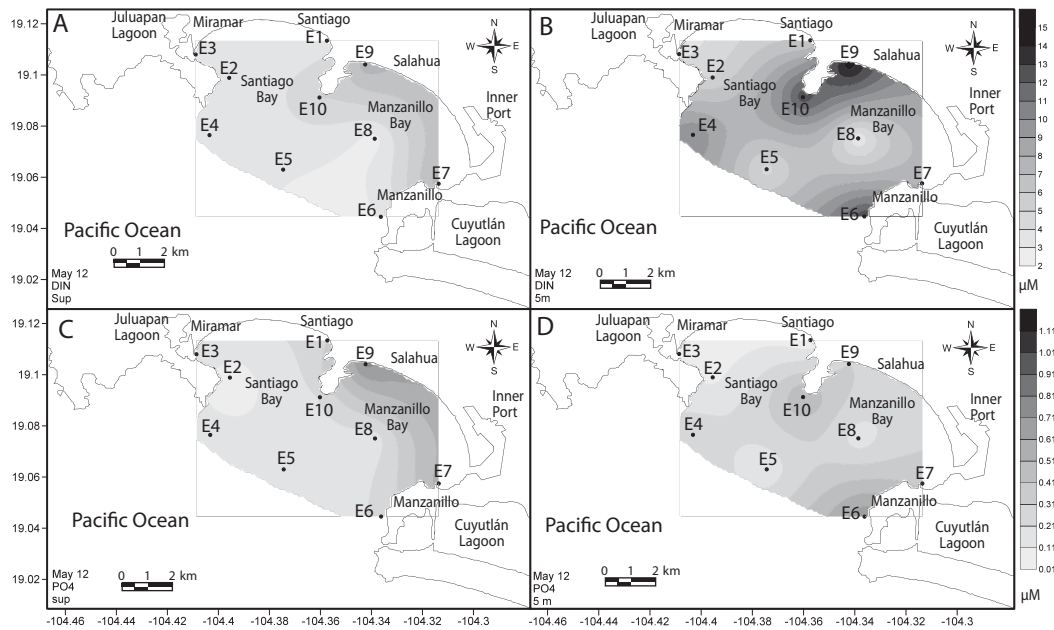
The spatial distribution of nutrients during the peak of phytoplankton abundance (May 12<sup>th</sup>) reflected the increased concentrations of DIN and silicates, both at the surface and at 5m, increasing from the ocean to the coast. Maximum values of both nutrients at E10 and E9 were maintained along the near shore, in the direction of the port, as determined based on the bay's dynamic pattern. The distribution of phosphate showed the same distribution: with higher concentrations in surface waters towards the coast of Bahía Manzanillo (Fig. 3). It is important to note that the nutrient availability during May coincided with an upwelling period in the Central Mexican Pacific area, and was clearly the most intense event when compared to the preceding five years (Fig. 4).

**Phytoplankton counting:** The event was also monitored with qualitative daily observations of near shore waters. No water color changes were observed during the morning (from sunrise to midday); nevertheless, after 13 hours, water color changed throughout the afternoon, indicating high cell abundances >10<sup>5</sup>cells/L.

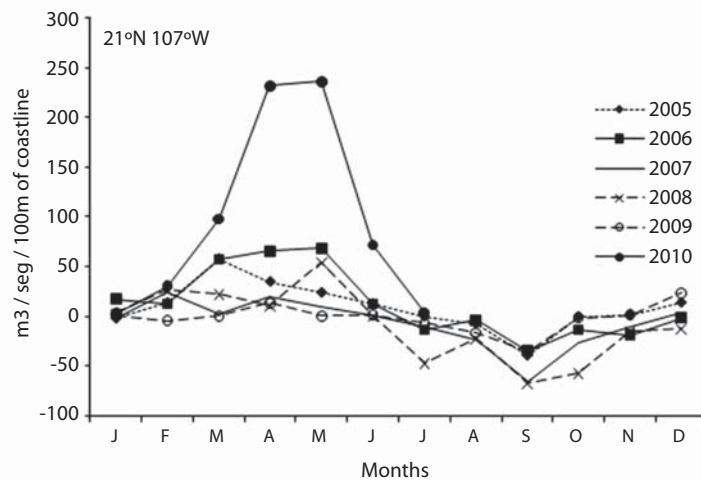
High abundances of phytoplankton at the surface were observed on May 7<sup>th</sup> in both bays, Bahía de Santiago and Bahía Manzanillo, with a maximum of 1.67×10<sup>6</sup>cells/L at station X2. *G. catenatum* was present only in Bahía

TABLE 1  
Mean nutrient concentrations at station E10 during the May 2010 bloom event of the toxic dinoflagellate *Gymnodinium catenatum*

Date	DIN $\mu$ M	Mean	SD	PO <sub>4</sub> $\mu$ M	Mean	SD	SiO <sub>2</sub> $\mu$ M	Mean	SD
May-07	8.86	6.45	2.61	0.78	0.51	0.19	8.46	7.49	2.68
May-12	8.88	6.16	3.72	0.37	0.27	0.21	9.31	8.48	7.27
May-17	8.3	6.44	2.59	0.68	0.28	0.32	24.31	21.07	9.34



**Fig. 3.** Spatial distribution of nutrient (May 12): (A) DIN surface, (B) DIN 5m, (C) phosphate surface and (D) phosphate 5m depth.



**Fig. 4.** Average monthly upwelling index ( $\text{m}^3/\text{s}/100\text{m}$  of coastline) for the location  $21^\circ \text{N}$  and  $107^\circ \text{W}$ . The data were obtained from the web site of the Pacific Fisheries Environmental Laboratory-NOAA (<http://www.pfeg.noaa.gov/>).



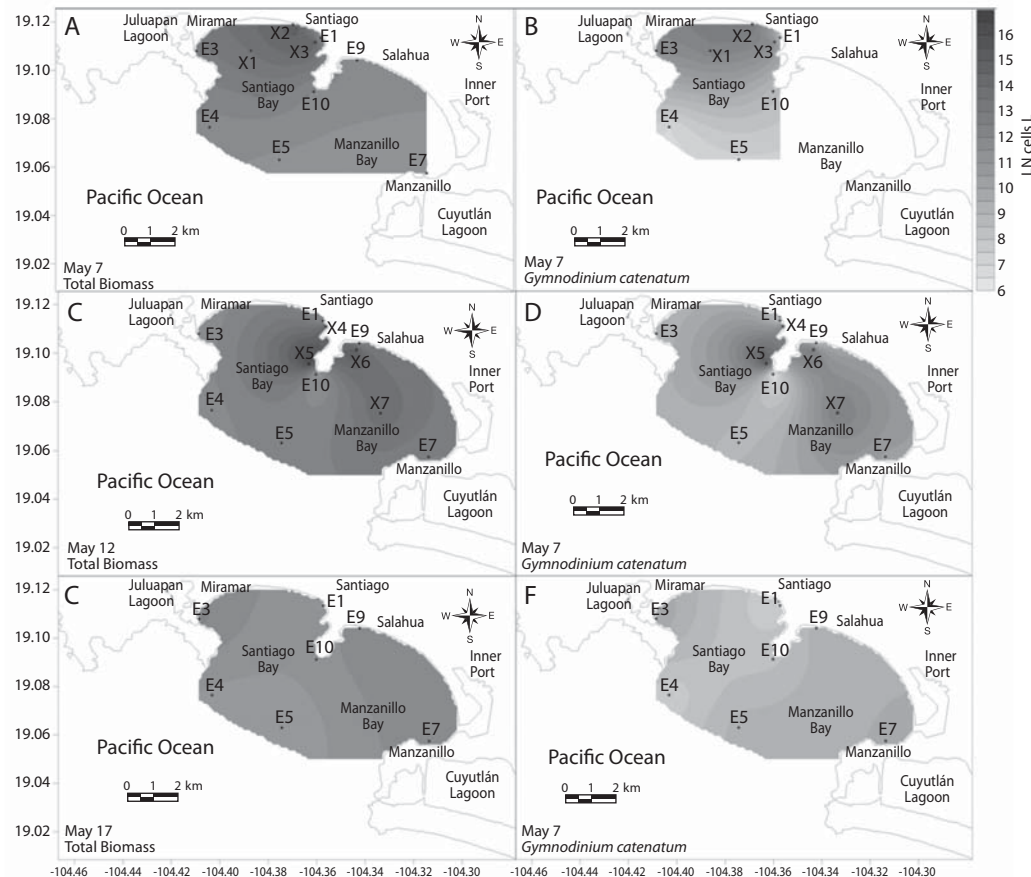
Santiago, where it reached a maximum abundance of  $3.49 \times 10^5$  cells/L for the same station (Fig. 5).

Five days later, on May 12th, high abundance of phytoplankton was observed in both bays, with a maximum of  $1.02 \times 10^7$  cells/L at X5, which coincided with a maximum of *G. catenatum* ( $3.65 \times 10^6$  cells/L). Due to these high abundances, the water at Bahía Santiago became discolored. However, on May 17th, the bloom was not visible due to low *G. catenatum* densities of  $1.04 \times 10^4$  cells/L at E5, and the maximum observed of  $2.25 \times 10^4$  cells/L at E3 (Fig. 5).

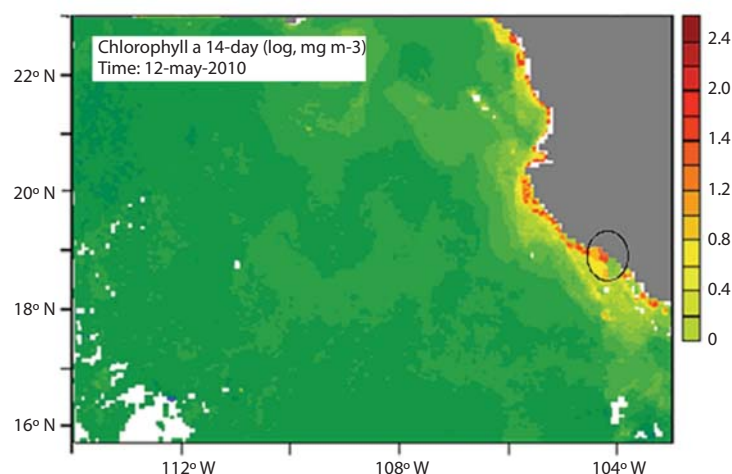
Satellite images (NOAA 2010), for the bloom period (mean composition from May 5th-17th), showed high chlorophyll *a*

concentrations ( $1.2\text{--}2.0\text{mg/m}^3$ ) extending from Bahía Banderas (Jalisco, Mexico) to the Colima coast, indicating a high biomass concentration along the coastal area, including the study zone during that period (Fig. 6).

**Toxin content and toxicity:** Table 2 shows the toxin content and toxicity per sample station determined in a single red oyster sample. Toxin content in phytoplankton samples oscillated between 5.3 and 40.3pg/cell, with an average of 17.5pg/cell. Toxicity was also variable, ranging from 1.4 to 10.9pg STXeq/cell, with an average of 4.2pg STXeq/cell. The high variability of both measurements is noteworthy (as evidenced by the standard deviation of 13.38 and 3.5 for toxin content and toxicity,



**Fig. 5.** Spatial distribution of the total phytoplankton abundance (cell/L) (A) 7 May, (B) 12 May and (C) 17 May 2010 and *Gymnodinium catenatum*, (D) 7 May, (E) 12 May and (F) 17 May 2010.



**Fig. 6.** The 14-day mean values of chlorophyll *a* as determined from a satellite image. The ellipse indicates the study area. <http://coastwatch.pfeg.noaa.gov/erddap/griddap/erdMBchla14day.graph>

TABLE 2

Toxin content (in pg/cell and fmol PSP/cell) and toxicity of *Gymnodinium catenatum* (pg STXeq/cell) from phytoplankton samples and the oyster *Chama echinata* in Bahía Manzanillo

Station	pg/cell	pg STXeq/cell	fmol PSP/cell
X1	5.3	1.6	12.6
X2	6	1.4	13.8
X3	22.7	5.7	52
X4	27.5	5.9	62.5
X5	7.3	1.6	16.4
X6	10.9	2.4	24.5
X7	40.3	10.9	93
Mean (SD)	17.5 (13.3)	4.2 (3.5)	39.3 (30.8)
	$\mu\text{g}/100\text{g}$	$\mu\text{g STXeq}/100\text{g}$	
Oyster	3648.4	1525.8	

Stations were sampled the 7 May 2010 (X1, X2 and X3) and 12 May 2010 (X4 to X 7 and oyster). Standard deviation (SD) are shown in parentheses.

respectively). Oyster analysis revealed a high toxin content and toxicity (3648 $\mu\text{g}/100\text{g}$  and 1525.8 $\mu\text{g STXeq}/100\text{g}$ , respectively); these values were above the saxitoxin concentration allowed for human consumption.

**Toxin profile:** Phytoplankton samples contained a group of 11 toxins (Table 3), predominantly the sulfocarbamoyl C2 (55.48%)

and C1 (17.55%), followed by the more potent ones from the carbamoyl group, saxitoxin (16.2%) and neosaxitoxin (3.3%). Toxins of the decarbamoyl group (dc GTX2-3 and dcSTX) were less represented (<5%). An interesting general aspect was the small variability exhibited among the samples with respect to entire toxins % (i.e., the standard deviation). The most abundant paralytic toxins in oyster



TABLE 3  
Toxin profile (% mol) of *Gymnodinium catenatum* and the oyster *Chama echinata* in Bahía Manzanillo

Sample/ toxin	STX	Neo	GTX2	GTX3	dcSTX	dcGTX2	dcGTX3	B 1	B 2	C 1	C 2
X1	1.84	24.3	0.22	0.2	1.23	1.5	5.01	1.69	0	18.2	45.9
X2	4.59	13.91	0.13	0.14	1.3	1.59	3.57	0.79	2.3	22.8	48.8
X3	3.01	17.51	0.18	0.06	0.53	0.64	1.71	0.86	2.73	15.7	57.2
X4	2.51	13.67	0.12	0.14	0.8	0.99	2.47	2.65	2.43	19	55.2
X5	2.88	13.31	0.12	0.1	0.75	0.92	3.06	1.5	0.33	15.2	61.8
X6	3.29	13.31	0.07	0.12	0.61	0.74	2.18	0.66	0.19	17.2	61.6
X7	5.41	17.72	0.08	0.11	0.6	0.73	2.56	0.09	0	14.8	57.9
Mean	3.36	16.25	0.13	0.12	0.83	1.02	2.94	1.18	1.14	17.6	55.5
SD	1.23	4.04	0.05	0.04	0.31	0.38	1.09	0.84	1.27	2.79	6.09
Oyster	12.14	26.29	0.5	0.02	8.86	10.86	4.7	0.14	1.93	24.5	10.1

Stations were sampled on 7 May 2010 (X1, X2 and X3) and 12 May 2010 (X4 to X7 and oyster). STX, saxitoxin; Neo, neosaxitoxin; GTX2-3, Gonyautoxin 2 and 3; DcGTX2-3, decarbamoyl gonyautoxin 2 and 3, B1-2 and C1-2, N-sulfocarbamoyl toxins. (SD) standard deviation.

samples were those of the carbamoyl group (neosaxitoxin and saxitoxin), which represented 38% of the total toxins, followed by toxins of the sulfocarbamoyl group, with 34%.

## DISCUSSION

For this study, the lowest water temperatures occurred between March and May, which coincides with an annual pattern reported for Bahía Manzanillo, and algal blooms have been detected after these events (Morales-Blake *et al.* 2000, Figueroa-Torres & Zepeda-Esquivel 2001, González-Chan *et al.* 2008). In May, these conditions were present and allowed the proliferation of *G. catenatum* as reported by Band-Schmidt *et al.* (2004) who described that for Mexican waters, this species are able to grow in a broad array of habitats, with temperatures ranging from 15 to 29°C and salinities from 26 to 30ups.

The origin of these algal blooms is unclear, but they could arise from offshore sources or from resting cysts present in the sediments (in shallow and low-dynamic areas). The latter possibility is, however, unlikely because near coast bay dynamics do not favor the bottom accumulation of either sandy, fine-grained

sediments or, likewise, cysts (Lancin & Carranza 1976, Galicia-Pérez & Gaviño-Rodríguez 1996). According to the upwelling index from a nearby zone (at North of Bahía Banderas 21° N and 110° W), the *G. catenatum* bloom evaluated in this study, coincided with an upwelling period and compared to the preceding five years was clearly the most intense HAB during this interval (NOAA 2010). Torres-Orozco *et al.* (2005) and López-Sandoval *et al.* (2009) described similar conditions in the area between Cabo Corrientes and the Islas Marías. They found that the prevailing wind favored the development of coastal upwellings that generated frontal zones caused by the interaction between cold deep water and the surrounding surface water. In the present study, strong winds and cold water were likewise present, with a high content of inorganic nutrients (silicates) generated during the relaxation of a frontal zone. Therefore, the conclusions drawn by Torres-Orozco *et al.* (2005) may also be valid for the *G. catenatum* bloom of this study, but remains to be confirmed with further studies on bloom.

Daily changes in the degree of water discoloration variations could reflect the conjunction of two patterns: *i*) the wind influence, which in

the morning, characteristically, flows from the coast to the ocean, carrying the bloom offshore, and in the early afternoon, that flows in the opposite direction, resulting in the near-shore bloom accumulation (Galicia-Pérez & Gaviño-Rodríguez 2001); and *ii*) the ability of *G. catenatum* to migrate (migration rate of 1.5m/h, as determined by Hallegraeff & Fraga (1998) to sub-superficial waters during the night or early morning, with subsequent cell emergence in superficial waters in the afternoon (Hallegraeff & Fraga 1998). According to Smayda (2002) and Smayda & Reynolds (2001), during upwelling relaxation events (species type V) dinoflagellates such as *G. catenatum* are adapted for survival within upwelling habitats and bloom during upwelling relaxations.

Our results suggest that *G. catenatum* is always present in the oceanic water column in low abundance. In favorable circumstances, such as upwelling relaxation, the dinoflagellate grows exponentially, forming blooms that can be transported to coastal areas. In Bahía Manzanillo, the accumulation of cells in different areas account for the typical pattern of water discoloration.

Diverse data on toxin content and toxicity for the many strains of *G. catenatum* found in Mexican waters have been published (Band-Schmidt *et al.* 2005, Gárate-Lizárraga *et al.* 2005, Band-Schmidt *et al.* 2006); however, most were obtained in studies performed under culture controlled conditions. To our knowledge, only one study has determined toxin profiles and toxicity under natural conditions in Mexico, reporting a record 1.01pg STXeq/cell in Bahía Mazatlan during a bloom in 2001 (Gárate-Lizárraga *et al.* 2004a). We found even higher cell toxicity, oscillating between 1.4 and 10.9 STXeq/cell (Table 2), albeit this broad variation was most likely an abnormality, perhaps the result of physiological alterations of the cell growth phase. Factors that induce such alterations may be related to biomass production, which is influenced by the availability of inorganic nutrients. In this study, the concentrations and ratios of N and P were not limiting at the beginning of the bloom, and there was

an increased availability of DIN. In addition, the oceanographic conditions, with low temperatures related to the presence of the frontal zone of an upwelling system, and the particular features of the studied geographic region, may also have influenced cell growth and thus the toxin content variability (Reguera & Oshima 1990, Flynn *et al.* 1996, Lippenmeier *et al.* 2003, Hernández-Sandoval 2010).

Cultured strains isolated from diverse sites on the Mexican coast differ in their toxicity (Band-Schmidt *et al.* 2006, Gárate-Lizárraga *et al.* 2006). In a previous paper, Band-Schmidt *et al.* (2010) pointed out that the toxicity of cultured strains of *G. catenatum*, isolated from Mexican waters, were higher than those determined in field samples of the same strains. Our data supports this observation, as we found toxicity to be low under natural conditions and most likely a feature of the “Mexican” *G. catenatum* population, as reported by Gárate-Lizárraga *et al.* (2004a). As part of our study, we have isolated a strain from Bahía Manzanillo during the bloom, and we are currently measuring its toxicity under culture conditions.

The toxin profile of our phytoplankton samples consisted of 11 toxins corresponding to the profile recorded for several strains isolated from Mexican coasts (Band-Schmidt *et al.* 2005, Gárate-Lizárraga *et al.* 2005, Band-Schmidt *et al.* 2006). Our results confirm the dominance of toxins C1 and C2, followed by the more toxic carbamoyl group toxins. These profiles provide strong evidence for the existence of autochthonous *G. catenatum* strains in this region of the tropical Pacific Ocean.

The toxins decarbamoyl (dcGTK2 and dcGTK3) and *N*-sulfocarbamoyl (C1 and C2) usually has a high molar contribution to the toxicity of *G. catenatum* (Gárate-Lizárraga *et al.* 2004a, Hernández-Sandoval *et al.* 2009). In this work, a relatively high percentage of NeoSTX was noted, accounting for an average of 16.25% of the total toxins. (Bustillos-Guzmán *et al.* pers. comm.), in a strain of *G. catenatum* isolated from Bahía Concepción (Gulf of California), found that the molar percentage of each toxin changes with the growth phase of the culture.

Toxins of the sulfocarbamoyl group, mainly C1 and C2, predominate during adaptation and maximal growth, and thereafter toxins of the carbamoyl group dominate. Therefore it is plausible to infer that in the sampled bloom, *G. catenatum* population was in decay. This possibility is supported by the absence or low densities of dinoflagellates observed a week afterwards. It is important to note that natural toxicity and toxin composition is the result of the cell response to specific physical and chemical conditions from the sampled area (Cembella 1998, Montoya *et al.* 2010). Therefore in a direct comparison with other studies it is only valuable to look for a general pattern of local or regional populations, if any. Studies made in natural conditions of Mexican waters of *G. catenatum* present important variations in the toxin profile with no clear patterns (Gárate-Lizárraga *et al.* 2004a, 2004b, 2006, Hernández-Sandoval *et al.* 2009) indicating a clear necessity for further field investigation for this species.

Finally, despite concentrations found in oyster exceeded the Mexican regulation for saxitoxin (NOM-129-SSA-1995) of 80 µg STXeq/100g allowed for human consumption there was no human poisoning during this event. Also, the presence of Neo should be considered with caution because the post-column oxidation used by Yu *et al.* (1998) is not very efficient in separating dcNeo from Neo (data not shown). Recently, a Mexican strain from the Gulf of California was negative for the presence of Neo (Bustillos *et al.*, 2011).

To our knowledge, this is the first report of a *G. catenatum* bloom in Mexican waters where detailed physical and chemical data were obtained. Toxin analysis showed the typical toxin profile and low toxicity of natural populations, as described by Gárate-Lizárraga *et al.* (2004a). This low toxicity contrasts with the relatively high level recorded for cultured strains (average 23pg/cell). Oyster analysis revealed a toxin content and toxicity above the saxitoxin concentration for human consumption, with no human poisoning during this event.

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## RESUMEN

La proliferación de *Gymnodinium* son motivo de preocupación, debido a que en algunas circunstancias producen toxinas, que tienen consecuencias desfavorables para los ecosistemas marinos, la salud humana y la economía. Este trabajo describe las condiciones fisicoquímicas presentes durante una proliferación algal detectado en mayo de 2010 en la Bahía de Santiago y Bahía Manzanillo (Colima, México). La proliferación algal inició poco tiempo después de registrarse las temperaturas oceánicas superficiales más bajas del año, las cuales permitieron un aumento de las concentraciones de nutrientes (8.88 µM DIN, 0.78 µM PO<sub>4</sub> and 24.34 µM SiO<sub>2</sub>) que favorecieron el desarrollo de *G. catenatum* (hasta 1.02 x 10<sup>7</sup> cel/L). Esta proliferación se detectó en las bahías durante dos semanas y fue relacionada con toxicidad en ostiones de la localidad (1525.8 µg STXeq/100g) y en muestras de fitoplancton (10.9pg STXeq/cel). Fuertes variaciones en la toxicidad de *G. catenatum* (1.4 a 10.9pg STXeq/cel) pudieron reflejar la disponibilidad de nutrientes inorgánicos. El perfil de toxinas de las muestras del fitoplancton consistieron en 11 toxinas semejantes a las de varias cepas de *G. catenatum* aisladas de otras áreas de las costas de México.

**Palabras clave:** *Gymnodinium catenatum*, proliferaciones algales, toxicidad, surgencias.

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