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ENSO phenomenon and toxic red tides in Mexico

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RESUMEN

El análisis de la influencia de "El Niño" en la dinámica y características de las "Mareas Rojas" tóxicas en México proporciona una explicación parcial del espectro de toxinas marinas que hemos logrado detectar en el litoral Mexicano. Los casos de envenenamiento en humanos (más de 500 con 20 muertes en los últimos 25 años), y el impacto en la vida silvestre (numerosos casos de mortandades masivas de peces, aves marinas, mamíferos marinos, tortugas marinas, etc.) derivados de la exposición a toxinas producidas por el fitoplancton marino, se encuentran ampliamente documentados. Aun así, resulta imposible generalizar respecto al efecto directo del fenómeno de El Niño sobre la incidencia, frecuencia y magnitud de las proliferaciones microalgales nocivas en nuestro país. Por la posición geográfica y las condiciones socioeconómicas que imperan, el impacto de las proliferaciones microalgales nocivas es severo. Este documento plantea le necesidad de investigar a fondo las proliferaciones microalgales nocivas en México para evaluar y mitigar su impacto.

PALABRAS CLAVE: "Mareas Rojas", proliferaciones microalgales nocivas, biotoxinas marinas, fitoplancton tóxico, El Niño.

ABSTRACT

El Niño provides a partial explanation of the spectrum of marine biotoxins (red tides) on the coast of Mexico. Over 500 human poisoning cases with 20 fatalities in the last 25 years, and mass mortalities of fish, sea birds, marine mammals, and marine turtles have been documented. However, the eventual effect of El Niño on the incidence, frequency and severity of harmful microalgal blooms is uncertain. Because of geographical position and socioeconomical conditions, the impact of harmful microalgal blooms in Mexico will be severe, and a study of red tides is justified.

KEY WORDS: "Red tides", harmful algal blooms, HABs, marine biotoxins, toxic phytoplankton, El Niño.

INTRODUCTION

Explosive population growth, demand for fishery resources, pollution, and degradation of lagoons and estuaries, have led to a serious impact on socioeconomical conditions and environmental resources. In Mexico, numerous diseases in humans or animals are seafood-related (Gómez-Aguirre and Licea, 1998; Núñez-Vázquez *et al*., 2000; Parrilla-Cerillo *et al*., 1993; Saldate-Castañeda *et al*., 1991; Sierra-Beltrán *et al*., 1998). Hospitalizations from poisoning (Saldate-Castañenda *et al*., 1991), and massive strandings and mortality of fish, sea birds (Sierra-Beltrán *et al*., 1997, 1999) and sea mammals (Delgado-Estrella *et al*., 1994, Sierra-Beltrán *et al*., 1999), tend to increase year by year (Cortés-Altamirano *et al*., 1995a,b, 1996; Gárate-Lizárraga, 1996; Gómez-Aguirre and Licea, 1998; Herrera-Silveira, 1999; Licea *et al*., 1996; Molina *et al*., 1996; Morquecho Escamilla *et al*., 1997; Ochoa *et al*., 1997; Ochoa and Sierra-Beltrán, 1999; Ramírez-Camarena *et al*., 1996; Sotomayor-Navarro and Domínguez-Cuellar, 1993). A major cause is related to blooming of toxic microalgae. The condition is known as red tide, or harmful algal bloom.

Harmful algal blooms (HABs), are recognized as a common threat to health and the environment (see: http://www.redtide.whoi.edu/hab/). An increase in the number and impact degree of HABs has been observed worldwide. Explanations include (a) displacement of mangrove, salt marshes and wetlands by aquaculture ponds; (b) introduction of new phytoplankton species from ship ballast, or seeding of foreign mollusks and their processing; (c) modification of the coastline water system by acid rain, deforestation or pollution; and (d) "El Niño", an oceanographic condition characterized by above normal surface seawater temperatures that affect the atmosphere, the ocean, and the wildlife (Trenberth, 1997).

Social, environment, and economic impact of harmful algal blooms

A formal evaluation of HABs impact in Mexico is unavailable, although the increase in the number, periodicity, and impact of HABs off its shores are widely recognized. National newspapers have reported that cities like La Paz, Mazatlán, Manzanillo, Acapulco, and Huatulco are frequently stricken by HABs (Figueroa-Torres and Zepeda, 2000; Gómez-Aguirre and Licea, 1998; Herrera-Silveira, 1999; Morales-Blake *et al*., 2000; Ochoa *et al*., 1998; Parrilla-Cerillo *et al*., 1993; Saldate-Castañeda *et al*., 1991; Sierra-Beltrán *et al*., 1998). No socioeconomical cost is mentioned.

Because of the lack of an appropriate and systematic monitoring system, scientific records of HABs in Mexico are scarce (Gómez-Aguirre, 1998).

Only two certified laboratories are authorized by the Health Ministry to detect toxins in mollusk samples. With a coastline of about 11 600 km (Delgadillo-Macías, 1998), this is obviously insufficient to provide warning and assistance in HAB events off the Mexican coast. Official records of the last 22 years report at least 500 cases of hospitalization and 20 casualties, but this may be the tip of the iceberg of HAB's health impact in Mexico (De la Garza-Aguilar, 1983; Mee *et al*., 1986, Rosales Loessner *et al*., 1989; Ochoa *et al*., 1998; Parrilla-Cerrillo *et al*., 1993).

For HABs of different nature and origin in recent years, see Table 1. The Federal Agency of Environment Protection, SEMARNAP-PROFEPA, reported a high incidence of HABs for 1996 and 1997 considered "environmental emergencies". Major mortalities of marine organisms have been reported in Mexico (Dungan and Thomson, 1984) without explicit causes. If man-related activities are a factor (Alonso-Rodríguez *et al*., 1999), this might combine with specific climate and oceanographic conditions to promote HAB events. Some of the reported locations of read tides include popular beach resorts of Mexico such as Los Cabos, Mazatlán, Manzanillo, Vallarta, Acapulco-Zihuatanejo, Huatulco and Cancún.

"El Niño" and HABs in Mexico

El Niño affects the marine biota (Yin *et al*., 1999) playing also a complex role in fisheries and phytoplankton biomass variation along the Peninsula of California (Gárate-Lizárraga and Siqueiros-Beltrones, 1998), the Gulf of California (González-López, 1994; Mee *et al*., 1985), the northeast Pacific coast in general (Smith, 1999), the Mexican Caribbean and the Gulf of Mexico. For example, the best catch indexes of *Lutjanus peru* in Michoacán appear associated to winter periods and to La Niña, rather than to El Niño (Vera and Sánchez, 1997), while tuna *Katsuwonus pelamis*, which represents about 70% of the world is catch, is better linked to "El Niño" (Lehodey *et al*., 1997). Success in sport fisheries off Baja California, appears to depend also on El Niño conditions, which increase the landings of northern anchovy and Pacific mackerel, while those of yellowtail and swordfish are reduced (Hamman *et al*., 1992). As a result of El Niño in 1998, the total cost on fisheries losses in the Pacific coast of Mexico due to reduced landings were calculated as 500 million pesos (Delgadillo-Macías, 1998), supporting the idea that by increasing our prediction capability the identification of areas with major abundance for a specific species in particular fisheries during El Niño years is plausible.

El Niño seems to cause a decline in upwelling-based primary productivity along the west coast of the peninsula of Baja California, thus affecting the population distribution of many cetaceans and sea birds (Tershy *et al*., 1991). López-Cortés *et al*., (1991, 1992) have confirmed these observations studying the distribution of organic matter in the central part of the Gulf of California and report that, favored by current and upwelling movements, such region is especially important in primary productivity (Lara-Lara *et al*., 1986). In the mouth of the Gulf, in contrast, above-normal temperatures (29-30°C) that could be attributed to the presence of El Niño, favor the replacement of nutrient-rich waters by oligotrophic waters, causing a very low productivity (González-López and Siqueiros-Beltrones, 1990). Hence, in the Gulf of California primary productivity depends to a large extent on the strong tidal mixing and upwelling events that often tend to mask the effects of El Niño (Santamaría-Del Angel *et al*., 1994).

Upwelling regions, such as those in the Gulf of California and off the Pacific coastline of Mexico (Blasco, 1977), considered among the most fertile and complex habitats of the sea, show episodic die-offs of fish and invertebrate communities provoked by "Red Tides" (Smayda, 2000). The combination of nutrient-mixing-advection and relaxation events characteristic of upwelling habitats, can also promote the blooming of toxic dinoflagellates and diatoms that are well adapted to such conditions. Within this context, one remarkable strategy is the chain-forming capacity of some dinoflagellates. This ability increases their swimming speeds and allows them to survive the strong physical forcing and the biophysical consequences of entrainment within advective currents, frontal zones and turbulence and thus, to bloom (Smayda, 2000). It is interesting that *Gymnodinium catenatum* and *Pyrodynium bahamense* var. compressum, which are the two most predominant toxic species involved in wild life mass mortalities and human poisoning episodes in the Pacific coast of Mexico (Ochoa and Sierra-Beltrán, 1999), show this capacity.

Considering that dinoflagellates are very sensitive to environmental changes, and in particular to temperature variations, an attempt to identify some dinoflagellate as "markers" of El Niño phenomena off Mexico has been carried out (González-López, 1994). The analysis of 14 events with different intensity and persistence between 1921 and 1992, within the Gulf of California, made it possible to propose that a number of dinoflagellate species, mainly of the genus *Cerratium* and *Protoperidinium*, are indicators of El Niño in this region (Table 3). Also, Gárate-Lizárraga and Siqueiros-Beltrones (1998) have described the variation of phytoplankton abundance in Magdalena Bay, Baja California Sur, after El Niño of 1982-1983, which affected not only the volume, but the species of the sardine (*Sardinops*

Table 1

Phytoplankton associated with HAB's in Mexico.

Organism	Toxity in or against	Toxin	Location	Reference
Alexandrium catenella	Bivalves	STX	Baja California Sur (Concepción Bay).	Gárate-Lizárraga, 1996; Herrera-Silveira, 1999; Morquecho-Escamilla *et al*.., 1997; Lechuga-Devéze *et al*., 2000.
Alexandrium monilatum (=Gonyaulax monilata)	Bivalves	STX	Sinaloa (Mazatlán Bay).	Cortés-Altamirano and Nuñez-Pastén 1992.
Alexandrium sp. = *Gonyaulax* sp.			Sonora (Bacochibampo Bay), Sinaloa (mazatlán) and Nayarit.	Cortés-Altamirano *et al*., 1995a,b; Herrera-Silveira, 1999.
Alexandrium catenella = Gonyaulax catenella	Bivalve	STX	Oaxaca (Salina-Cruz-Huatulco).	Saldate-Castañeda *et al*, 1991.
Alexandrium digitale = Gonyaulax digitale			Baja California	Blasco, 1977.
Alexandrium polyedra = Gonyaulax polyedra			Baja California (San Hipólito), Baja California Sur (Concepción Bay).	Blasco, 1977; Orellana-Cepeda *et al*., 1993; Cortés-Altamirano *et al*., 1996; Gárate-Lizárraga, 1996; Morquecho-Escamilla *et al*., 2000.
Alexandrium polygrama = Gonyaulax polygramma	Fish	Oxygen depletion	Baja California (Los Angeles Bay) and Gulf of California	Cortés-Altamirano *et al*., 1996; Herrera-Silveira, 1999; Millán-Nuñez, 1988.
Alexandrium triacanta = Gonyaulax triacantha			Sinaloa (Mazatlán Bay).	Cortés-Altamirano *et al*., 1995a,b; Herrera-Silveira, 1999.
Alexandrium verior = Gonyaulax verior			Baja California Sur (Concepción Bay).	Morquecho-Escamilla *et al*, 1997.
Chatonella sp.	Corals		Baja California Sur (Cabo San Lucas).	Herrera-Silveira, 1999.
Cochlodinium catenatum	Fish		Baja California (Ensenada Bay), Jalisco-Nayarit (Banderas Bay)	Orellana-Cepeda *et al*., 1993; Cortés-Lara *et al*., 2001.
Cochlodinium polykrikoides	Fish		Baja California Sur (La Paz Bay)	Gárate-Lizárraga *et al*., 2001.
Dinophysis acuminata			Baja California (Ensenada Bay), Sinaloa (Guasave).	Orellana-Cepeda *et al*., 1993; Martínez-López, *et al*., 2001.
Dinophysis caudata		DSP	Baja California Sur (Concepción Bay), Veracruz (Tamiahua Lagoon).	Morquecho-Escamilla *et al*., 1997; Figueroa-Torres and Weiss-Martínez, 1999; Lechuga-Devéze *et al*., 2000.
Gambierdiscus toxicus	Fish	CTX	Baja California Sur (Rocas Alijos (?), El Pardito) Gulf of California (?), Quintana Roo (Isla Mujeres, Cozumel), Quintana-Roo (Laguna de Bojorquez, Cancún)	Cortés-Altamirano *et al*., 1996; Herrera-Silveira, 1999; Lechuga-Devéze and Sierra-Beltrán, 1995; Popowski-Casañ *et al*., 2000; Heredia-Tapia *et al*., 2002.
Gymnodinium brevis= Karenia brevis	Fish, aerosols	NSP	Veracruz (Tamiahua Lagoon), Tamaulipas-Veracruz, Gulf of México, Yucatán.	Cortés-Altamirano *et al*. 1996; Figueroa-Torres and Weiss-Martínez, 1999.
Gymnodinium catenatum	Bivalve, Crustacea, Fish	STX	Sonora (Bacochibampo Bay, Guaymas), Sinaloa (Mazatlán Bay), Baja California Sur (Concepción Bay), Gulf of California, Oaxaca (Salina-Cruz-Huatulco), Colima (Manzanillo and Santiago Bays), Guerrero (Acapulco).	Cabrera-Mancilla *et al*., 2000; Cortés-Altamirano *et al*., 1995, 1996; Gárate-Lizárraga, 1996; Manrique and Molina, 1997; Morales-Blake, *et al*., 2000; Morquecho-Escamilla *et al*., 2000; Saldate-Castañeda *et al*, 1991;

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Gymnodinium peridinium			Guerrero (Acapulco Bay, Puerto Marquéz).	Cortés-Altamirano *et al*., 1996.
Gymnodinium sanguineum			Baja California (San Hipólito), Baja California Sur (Tortugas Bay, Magdalena Bay, Concepción Bay).	Orellana-Cepeda *et al*., 1993; Cortés-Altamirano *et al*., 1996; Gárate-Lizárraga, 1996.
Gymnodinium splendens			Sinaloa (Maztlán Bay), Jalisco (Chametla Bay).	Cortés-Altamirano *et al*., 1996; Herrera-Silveira, 1999.
Gymnodinium tripos var. ponctic.			Sinaloa (Mazatlán Bay).	Cortés-Altamirano *et al*., 1996.
Gyrodinium spirale			Veracruz (Tamiahua Lagoon)	Figueroa-Torres and Weiss-Martínez, 1999.
Mesodinium rubrum			Sinaloa (Mazatlán Bay), North Gulf of California, Baja California Sur (La Paz Bay), Oaxaca (Barra de San Francisco, Zicatella Bay, Puerto Escondido, Tonalá).	Alonso-Rodríguez *et al*, 1999; Cortés-Altamirano *et al*., 1995a,b, 1996; Gárate-Lizárraga, 1996; Hernández-Becerril, 1987; Herrera-Silveira, 1999.
Nitzschia spp		ASP	Guerrero (Zihuatanejo Bay).	Cortés-Altamirano *et al*., 1996.
Nitzschia pungens			Baja California (Ensenada Bay).	Orellana-Cepeda *et al*., 1993.
Noctiluca scintillans	Fish	Ammonia	Baja California (Ensenada Bay), Sonora (Bacochibampo Bay), Baja California Sur (Mulegé Bay, Loreto, Concepción Bay), Jalisco (Banderas Bay), Oaxaca (Salina Cruz). Veracruz (Tamiahua Lagoon).	Gárate-Lizárraga, 1991; Orellana-Cepeda *et al*., 1993; Cortés-Altamirano *et al*., 1995a,b, 1996; Gárate-Lizárraga, 1996; Morquecho-Escamilla *et al*, 1997. Herrera-Silveira, 1999; Figueroa-Torres and Weiss-Martínez, 1999.
Oscillatoria erythraea			Baja California Sur (La Paz, Concepción Bay), Sinaloa Mazatlán Bay).	Cortés-Altamirano *et al*., 1995a,b; Gárate-Lizárraga, 1996; Morquecho-Escamilla *et al*, 1997.
Oxyphysis oxitoxoides			Veracruz (Tamiahua Lagoon).	Figueroa-Torres and Weiss-Martínez, 1999.
Proboscia alata			Baja California Sur (Magdalena Bay).	Gárate-Lizárraga and Siqueiros-Beltrones, 1998.
Prorocentrum spp.			Sonora (Bacochibampo Bay), Baja California Sur, Jalisco (Chametla Bay), Oaxaca (Laguna Superior).	Cortés-Altamirano *et al*., 1995ab, 1996; Gárate-Lizárraga, 1996.
Prorocentrum compressum			Baja California Sur (Concepción Bay).	Lechuga-Devéze *et al*, 2000.
Prorocentrum dentatum			Sonora (Bacochibampo Bay), Sinaloa (Mazatlán).	Cortés-Altamirano *et al*., 1995; Cortés-Altamirano and Núñez-Pastén, 2000.
Prorocentrum lima	Fish	Okadaic Acid and DTX-1	Baja California Sur, Isla El Pardito.	Heredia-Tapia *et al*., 2002.
Prorocentrum mexicanum			Baja California Sur (Concepción Bay), Sinaloa (Mazatlán)	Gárate-Lizárraga and Martínez-López, 1997; Cortés-Altamirano and Nuñez-Pastén, 2000; Morquecho-Escamilla *et al*, 1997; Lechuga-Devéze *et al*, 2000.
Prorocentrum micans	Bivalves		Baja California (San Hipólito), and Baja California Sur (Concepción Bay), Sinaloa (Mazatlán), Veracruz (Tamiahua Lagoon).	Blasco, 1977; Orellana-Cepeda *et al*., 1993; Figueroa-Torres and Weiss-Martínez, 1999; Lechuga-Devéze *et al*, 2000; Cortés-Altamirano and Nuñez-Pastén, 2000.
Prorocentrum minimum		Non-toxic	Sinaloa (Guasave, Mazatlán Bay).	Cortés-Altamirano *et al*., 1996; Lechuga-Devéze *et al*, 2000; Martínez-López, *et al*., 2001.
Prorocentrum triestinum			Sinaloa (Mazatlán)	Cortés-Altamirano *et al*., 2000.

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Protoperidinium conicum			Veracruz (Tamiahua Lagoon)	Figueroa-Torres and Weiss-Martínez, 1999.
Pseudonitzschia australis	Sea-birds, Fish, Marine mammals	ASP	Gulf of California, Sinaloa (Guasave), Nayarit.	Sierra-Beltrán *et al. 1997,* Martínez-López, *et al*., 2001; Meave-Del Castillo et al. 2000.
Pseudonitzschia cf multiseries			Sinaloa (Guasave)	Martínez-López, *et al*., 2001.
Pseudonitzschia spp.	Sea-birds Fish	ASP	Baja California Sur (Cabo San Lucas, Loreto).	Sierra-Beltrán *et al*, 1997.
Pyrodinium bahamense var. bahamense		Non-toxic	Veracruz (Tamiahua Lagoon), Gulf of México and Mexican Caribbean.	Cortés-Altamirano *et al*., 1996; Gómez-Aguirre and Licea, 1998; Herrera-Silveira, 1999.
Pyrodinium bahamense var. compressum	Bivalves (Clams, mussels, and oysters), fishes and turtles	STX	Guerrero (Acapulco), Oaxaca (Salina Cruz-Huatulco), Chiapas (Puerto Madero).	Cortés-Altamirano *et al*., 1996; Orellana *et al*., 1998; Sotomayor-Navarro and Domínguez-Cuellar, 1993; Ramírez-Camarena *et al*., 1996.
Scripsiella trochoidea			Baja California (Ensenada Bay), Sinaloa (Mazatlán Bay), Veracruz (Tamiahua, lagoon).	Orellana-Cepeda *et al*., 1993; Alonso-Rodríguez *et al*, 1999; Figueroa-Torres and Weiss-Martínez, 1999; Cortés-Altamirano *et al*., 1995a,b.
Skeletonema costatum		Non-toxic	Sinaloa (Mazatlán Bay), Colima (Manzanillo).	Figueroa-Torres and Zepeda, 2000.
Stephanopyxis palmeriana			Sonora (Kino Bay), Gulf of California.	Molina *et al*, 1996.

caerulae vs *Opisthonema libertate*) wild catch in the region. These authors identified the diatom *Proboscia alata* as the most conspicuous and abundant species in all algal blooms in Magdalena Bay. As may be inferred, a relationship between El Niño and HABs incidence off Mexico's coastline is unclear. For example, Cortés-Altamirano (1988) reports that El Niño favors the development of harmful blooms in Mazatlán Bay, but not in the Gulf of California (Cortés-Altamirano *et al*., 1995a,b). Also Manrique and Molina (1997) have found an inverse relationship between El Niño and HAB occurrences in the Gulf of California. Our group has detected the diatom *Pseudonistzchia australis* and the toxin domoic acid in the bodies of stranded animals in 1997, after an undetected bloom that occurred, apparently under conditions corresponding to a strong El Niño year (Sierra-Beltrán *et al*. 1997; PROFEPA, 1997).

Monitoring "Red Tides"

As pointed out, the impact of HABs on either the environment and health of population is a serious threat (Table 2). Timely detection can make the difference between important savings in treatment or depuration costs when commercial organisms have been affected. There is, therefore, a great pressure for developing and introducing new tools that could be effective to detect and characterize such events. Our experience also emphasizes the importance of prolonged, or long term, monitoring programs which can indicate the degree or trend of HABs phenomena and how they associate with El Niño. Opportune detection would also help to protect areas dedicated to aquaculture and may serve as a signal to justify other investigations aimed at characterizing together the distribution and physiological stage of the phytoplankton in an oceanographic context.

The fact that most organisms implicated in HAB events are photosynthetic suggests that such phytoplankton is capable of absorbing and emitting light in the ocean. Hence, we could expect that some optical methods can be applied in the analysis and study of these natural phenomena. Passive optical systems can measure the color of the ocean and the penetration of sunlight in the water surface, and both parameters are related to the medium constituents, especially the phytoplankton. Some sensors exist that can measure radiometric radiations and thus, calibration and comparison between determinations from different sites and for long periods is plausible. The radiometric buoys are useful to characterize the biological variation of the surface water on scales from minutes to months, so HABs can be observed easily. Some sophisticated equipments use artificial light to determine absorption coefficients and dispersion, giving opportunity to estimate and provide information concerning the characteristics of the phytoplankton community; i.e. its density, distribution, and in some cases composition (Cullen *et*

Table 2

Main vectors of marine biotoxins affecting human's health

Location	Common Name	Scientific Name	Toxin	Reference
Baja California Sur (Concepción Bay)		*Argopecten circularis*	PSP	Lechuga-Devéze and Morquecho-Escamilla, 1998.
Baja California Sur (Concepción Bay; San Carlos, Magdalena Bay)	Catarina Clam	*Argopecten ventricosus*	PSP	Sierra-Beltrán *et al*., 1996.
Chiapas, Oaxaca, Guerrero, (Tehuantepec Gulf	Mejillón	*Choromytilus palliopuncyayus*	PSP	Saldate-Castañeda *et al*., 1992; Sotomayor-Navarro and Domínguez-Cuellar, 1993.
Baja California Sur (Concepción Bay)	Ostión	*Crasostrea palmula*	PSP	Sierra-Beltrán *et al*., 1996.
Tamaulipas, Veracruz, Tabasco, Campeche Yucatán, Quintana Roo, Chiapas, Oaxaca, Guerrero	Ostión	*Crasostrea virginica*	PSP?	Saldate-Castañeda, *et al*., 1991; Gómez-Aguírre and Licea , 1998.
Baja California Sur (Concepción Bay)	White clam	*Diosinia ponderosa*	PSP	Sierra-Beltrán *et al*., 1996.
Baja California Sur	Pargo, snappers and groupers fish	*Labridae sp*. .	CTX? Okadaic acid and DTX-1	Parrilla-Cerrillo *et al*., 1993; Heredia-Tapia *et al*., 2002.
Baja California Sur	Pargo, snappers and groupers fish	*Lutjanus colorado*.	CTX? Okadaic acid and DTX-1	Parrilla-Cerrillo *et al*., 1993; Heredia-Tapia *et al*., 2002.
Baja California Sur	Pargo, snappers and groupers fish	*Lutjaneus sp*.	CTX? Okadaic acid and DTX-1	Parrilla-Cerrillo *et al*., 1993; Heredia-Tapia *et al*., 2002.
Baja California Sur (La Paz)	Almeja Chocolata	*Megapitaria aurantiaca*	PSP	Sierra-Beltrán *et al.,* 1998.
Baja California Sur (Concepción Bay)	Choros	*Modiolus capax*	PSP	Sierra-Beltrán *et al*., 1996.
Chiapas, Oaxaca, Guerrero, (Tehuantepec Gulf	Mejillón	*Mytilus sp*	PSP	Saldate-Castañeda *et al*., 1992; Sotomayor-Navarro and Domínguez-Cuellar, 1993.
Guerrero (Acapulco), Michoacán, Gulf of Tehuantepec	Ostión	*Ostrea iridiscens*	PSP	Orellana-Cepeda, *et al*., 1998; Ramírez-Camarena *et al*., 1996; Sotomayor-Navarro and Domínguez-Cuellar, 1993.
Baja California Sur (Concepción Bay)	Almeja voladora	*Pecten vogdesi*	PSP	Sierra-Beltrán *et al*., 1996.
Baja California Sur (Concepción Bay, Santa Rosalía)	Callo de hacha	*Pinna rugosa*	PSP	Sierra-Beltrán *et al*., 1996.
Tehuantepec Guf	Goose barnacle	*Pollicipes polinerus*	PSP	Sotomayor-Navarro and Domínguez-Cuellar, 1993.
Gulf of California	Sardine	*Sardinops sagax*	ASP	Ochoa *et al*., 1998; SEMARNAP-PROFEPA, 1997.
Baja California Sur	Mackerel	*Scomber japonicus*	ASP	Sierra-Beltrán *et al*., 1997.
Baja California Sur	Pargo, snappers and groupers fish	*Serranidae sp*.	CTX? Okadaic acid and DTX-1	Parrilla-Cerrillo *et al*., 1993; Heredia-Tapia *et al*., 2002.
Quintana Roo	Barracuda fish	*Sphyraena sp*.	CTX	Cortés-Altamirano *et al*., 1996; Sierra-Beltrán *et al*., 1998.

Table 3

Exogenous Dinoflagellates Present in the Gulf of California during El Niño events*

Genus:	Species:
Ceratium	*biceps*
	boehmii
	contrarium
	falcatiforme
	geniculatum
	humile
	incisum
	inflatum
	pavillardii
	praelongum
Ceratocorysi	*magna*
Dissodinium	*gerbaultii*
Gonyaulaux	*brunii*
	fragilis
Ornithocercus	*thumii*
Protoperidium	*elegans*
	subpyriforme
Phyrophacus	*vancampoe*

* From González-López, 1994.

al., 1997). On the other hand, pigments which are specific components of certain toxic phytoplankton species can be used as signatures of their presence, distribution, and abundance. For instance, in the case of Gymnodinium breve, the carotene giroxantine diester is a suitable marker for estimating its biomass. Cellular concentrations correspond to the amount of cells (number) and to the chlorophyll a concentration during a bloom. In contrast to other pigments, this ester does not change during the physiological cycle, or age of the organism, and the relationship of pigment to chlorophyll a exhibits a low variation during development and senescence of the bloom. The absorption spectra of other chlorophylls and carotenoids, as for example fucoxantin, can be distinguished from the *Peridinium* spectrum of diatoms and other haptophyte and prasinophyte organisms, although it is difficult to distinguish between the species when the cells appear "packed" or very closely associated. Thus, an absorption spectrum cannot always be recommended for organism identification in such cases (Millie *et al*. 1997).

Sea surface temperature determination, as done now for El Niño follow up, is also a useful approach to follow the evolution of a HAB outbreak once it is triggered. Using a sophisticated radiometer of a very high resolution and satellite-borne sensors, Aguirre-Gómez *et al*. (1999) have recorded the evolution of a HAB episode in the Mazatlán Bay, Sin. Mexico, successfully. This strategy appears to provide useful information about short-term oceanic processes responsible for the development and behavior of HABs.

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