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Toxic events in the northwest Pacific coastline of Mexico during 1992–1995: origin and impact

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Abstract

Previously considered as toxin-free, the Baja California Peninsula has witnessed several toxic algal blooms during the past three years. Apparently these 'red-tide' phenomena's outbreaks are not linked to any human related activity. This may just reflect better detection and training. Such events may be periodical and natural rather than induced. The most common types of marine toxins have been detected along the coast of the Peninsula and neighboring waters by mouse bioassay and chromatographic techniques. These are: Tetrodotoxin (TTX), Amnesic Shellfish Poison (ASP), Paralytic Shellfish Poisons (PSP), Diarrhetic Shellfish Poisons (DSP) and even Ciguatera (CFP), which are related to the presence of organisms of *Prorocentrum* sp. and *Alexandrium* sp. groups, and the diatom *Pseudonitzschia* sp. among others. There are also some indications about different kinds of TTX in the puffer fish of the region, and reasons to believe that we are facing a quite different pattern in toxic components, since PSP toxic potency (defined as the number of mouse units per gram (MU/g) of shellfish meat) is very high in spite of low dinoflagellates cell density registered. The ecological and social impact of the above has been considerable, with mass deaths of shellfish, seagulls, dolphins and turtles, and even some human casualties. The locally registered toxicity records: PSP found in one single fanshell reaches to 23 000 MU/100 g of tissue as determined by the mouse bioassay and, on a different event, two persons killed after ingesting puffer fish fillet. The largest reservoir of commercial marine organisms in Mexico is precisely the Northwest coast of the country and important plans for building large harbors and develop aquaculture areas are in progress. Therefore, a monitoring program is essential for an adequate management of such resources. Considering the large extension of the Peninsula (about 1600 km) and, at this time, the lack of efficient communication means and scarce population, the implementation of such monitoring programs presents a big challenge.

Introduction

Outbreaks of mass shellfish deaths on commercial fishing grounds during 1991 in Bahía Concepción (BACO) and 1992 in Bahía Magdalena (BAMA), in the state of Baja California Sur, México, as well as a mass mortality of fish, birds and sea mammals along the coast of *B. Magdalena* in 1992, highlighted the need for the implementation of a program for monitoring 'red tide' occurrences and their impact. To obtain a picture of the prevalence and distribution of marine biotoxins, and to delimit the areas at risk, two sampling programs were carried out at Bahía Concepción, and Bahía Magdalena, where massive mortalities of Catarina scallop, *Argopecten ventricosum* (Sowerby, 1842) had occurred. The nature and amount of toxins in marine bivalves, and the identification and quantification of phytoplankton species present in the area, were determined. In addition, in this report we describe other algal blooms, of different nature and magnitude, that occurred in different areas along the coast of the Peninsula during the past three years. All this demonstrates the need for a widespread monitoring program along the Peninsula.

Description of sites studied

The Northwest Pacific coast of Mexico extends from Latitude 23° to 33° N, and from Longitude 106° to 117° W, and includes the Peninsula of California, the second largest in the world (about 1600 km length), numerous islands and the Eastern coast of the Gulf of California, making a total coast line well above 8000 km.

The sampling program so far implemented was concentrated into two areas along the Peninsula: On the Pacific, Bahía Magdalena (BAMA), from Lat. 24° 15′ to 25° 15′ N and from Long. 111° 30′ to 112° 15′ W, which is an area of about 1390 km^2 constituted by a series of coastal channels of low depth. And, on the Gulf of California, Bahía Concepción (BACO), from Lat. 26° 30′ to 26° 55′ N and from Long. 111° 40′ to 112° 00′ W, with an area of about 400 km2, is a shallow basin with the maximum depth at 30 m in the widest portion. Other sites where important 'red tides' phenomena have been recently observed include Ojo de Liebre at Lat. 27° 45′ N and Long. 114° 14′ W, Vizcaino at Lat. 27° 45′ N and Long. 113° 41′ W, San Hipolito at Lat. 27° 00′ N, and Long. 114° 00′ W, Alijos Rocks at Lat. 24° 57′ N, and Long. 115° 45′ W, Cabo San Lucas at Lat. 22° 30′ N, and Long. 110° 30′ W, La Paz Bay, located at Lat. 24° 15′ N and Long. 110° 15′ W, Loreto at Lat. 25° 45′ N, and Long. 111° 25′ W, and San Felipe at Lat. 31° 15′ N, and Long. 114° 45′ W (Figure 1).

Material and methods

Frequency of sampling

The frequency of sampling at BACO and BAMA was variable due to the high cost of sampling activities. During the first part of 1992, samples were collected each two weeks, then monthly for the rest of the year. During 1993, samples were taken each three months, during the peak of each season (winter, spring, summer and autumn). In 1994 samples were collected monthly for the first 6 months, and then every 4 months in 1995. The rest of the samples were obtained when a blooming event or its sequel was present.

Biological data

Phytoplankton species and density were estimated using Uthermöl's method (1958).

Toxicological data

The toxins were deterrnined by mouse bioassay according to their nature employing several different procedures: PSP and TTX by the AOAC method (1984); DSP by the Yasumoto method (1978); ASP by using a modification of the AOAC method proposed by Iverson (1989); Ciguatoxin (CTX) by an adaptation of the method of Lewis (1992); and cyanobacterial toxins (Hepatotoxins) by the method described by Carmichael (1986). Animals were handled according to UFAW guidelines (1976). Toxin analysis was carried out by means of High Pressure Liquid Chromatography (HPLC) techniques described for each group of toxins: PSP by Thielerth (1991) and Lawrence (1991) methods, TTX by Yasumoto (1985), DSP by Shen (1991), ASP by Quilliam (1995), and CTX by Legrand (1992).

Meteorological data

Meteorological and oceanographic data were obtained from satellite images provided by the Climate Diagnostics Bulletin/NOM, National Weather Service Forecast Office. USA.

Chemicals

Domoic acid (DA) and okadaic acid (OA) were from Sigma Chemicals Co., St. Louis, Mo, USA. Dinophysistoxin-1 (DTX-1), saxitoxin (SAX), dc-saxitoxin (dc-SAX) and neo-saxitoxin (neo-SAX) were donated by the Measurements and Testing Programme, Commission of the European Communities. As qualitative standards, cultures of the cyanobacteria *Aphanizomenon flos-aquae* (Hearey & Jaworsky, 1977) for SAX and neo-saxitoxin and, the dinoflagellate *Alexandrium tamarense* (Balech, 1985) for gonyautoxin-2 (GTX-2) and gonyautoxin-3 (GTX-3) were used.

Results

Sampling at Bahía Concepción (BACO) and Bahía Magdalena (BAMA)

The sampling program for marine biotoxins on the Northwest region of Mexico, confirmed that BACO presents annual cycles of toxicity of the PSP type, mainly during spring but some times a second increase in toxicity is evident during autumn. Previous data

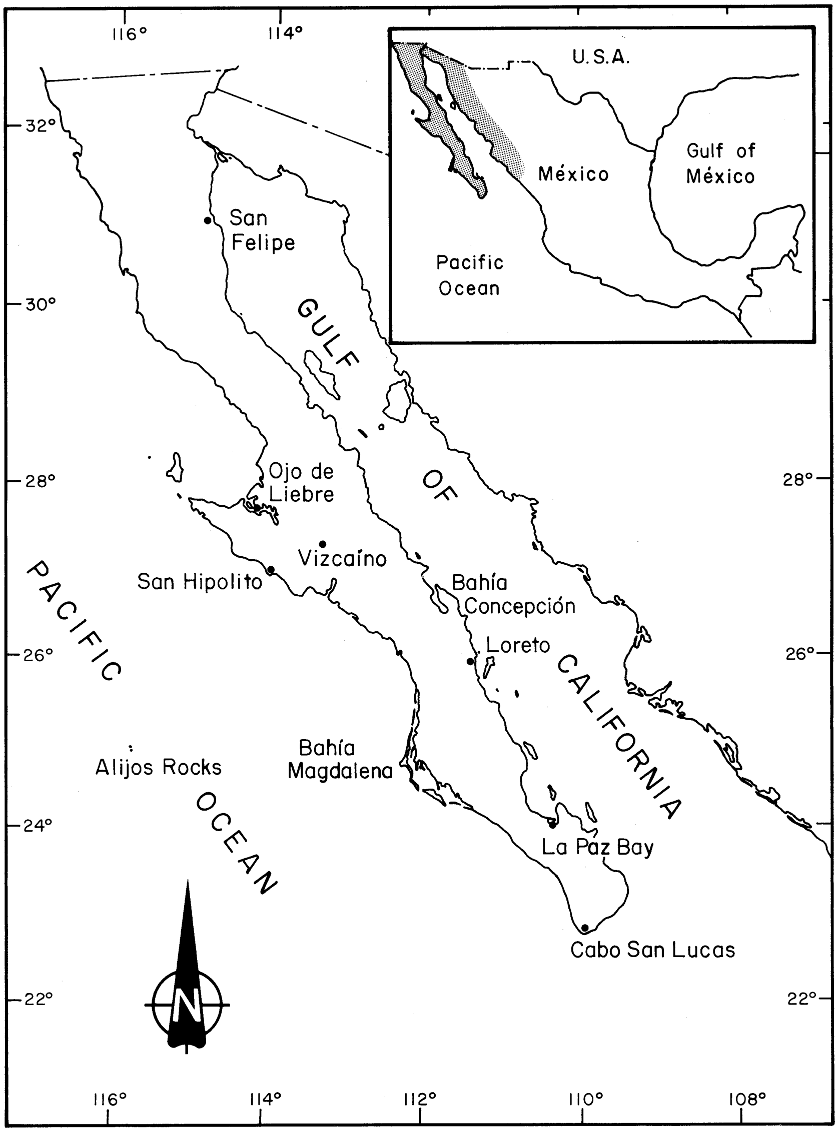

Figure 1. Northwest Pacific coast of Mexico, including the Gulf of California.

obtained in 1992 drew our attention to the fact that high toxicity it is often evident at BACO (caused mainly by PSP carbamates rather than by PSP type B and C), while there is not an evident increase of the phytoplanktonic communities (algal blooms or 'red-tide') (Sierra-Beltrán et al., 1996). During May 1992, an extremely high PSP toxicity value was recorded for a single fanshell, *Pinna rugosa* (Sowerby, 1835) which showed as much as 23 000 MU/100 g. Also, although not quantified, the presence of DSP toxins, okadaic acid (OA) and dynophysistoxin-1 (DTX-1), has been detected in 1992, 1994 and 1995 in shellfish at BACO, with apparently higher values, according to the mouse bioassay, occurring together with the spring peak of PSP toxicity (Figure 2).

At BAMA, on the other hand, only low PSP toxicity was observed in shellfish during spring, barely reaching the detection level of the mouse bioassay, while no DSP has been detected. The ASP-mouse bioassay however, suggested the presence of domoic acid (DA) in shellfish of BAMA during winter in 1994 and 1995.

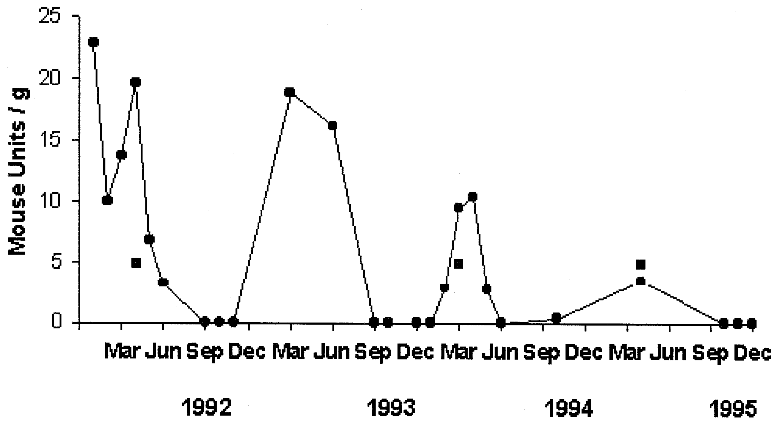

Figure 2. Cycles of shellfish toxicity at BACO as detected by mouse bioassay. Circles: quantified levels of PSP. Squares: time where DSP activity was detected.

Other toxic events

The presence of cyanobacterial toxins in this region has been confirmed with an outbreak bloom of *Oscillatoria erythraea (= Trichodesmium erythraeum*) (Ehrenberg, 1830) in La Paz Bay on April 1993. In this case, the mouse bioassay allowed us to observe the hepatotoxicity of water samples containing the cyanobacteria. Interestingly, one month later, a similar but non-toxic event occurred at BACO and later, in 1995, we were again able to isolate toxic strains of such cyanobacteria, without blooming, from the water body of BACO. This finding suggests that toxicity is not an intrinsic property of the microorganism and its conversion from a non-toxic strain into a toxic one remains a mystery, this could be an issue of life cycle as well as strain.

In a different episode, on May 1993, the crew of a fishing boat became ill after eating grouper fish (*Serranidae* sp. and *Labridae* sp.) caught close to Alijos Rocks, 480 km offshore from Bahía Magdalena in Baja Califomia Sur. The symptoms indicated ciguatera poisoning. Extraction from the fish flesh remains with organic solvents yielded a toxic extract which induced liver enlargement without bleeding and intestine swelling due to liquid accumulation, as well as shrinking of the spleen, in inoculated animals. All the mice suffered severe diarrhea leading to considerable weight loss (Lechuga-Devéze & Sierra-Beltrán, 1995). HPLC analysis of hexane washed extracts showed a peak with a mobility resembling that of ciguatoxin (Legrand, *loc. cit*), notwithstanding that no internal standard toxin was available and therefore the identification remains uncertain. Additional fish poisoning events resembling ciguatera during the last three years at different locations in the Peninsula let us to propose the presence of this toxin in the region. In all cases, poisoning has been associated with consumption of livers from big groupers and snappers (*Serranidae* and *Lutjanidae*), while the livers of young or small ones appear innocuous. Extracts obtained from such large specimens were highly toxic to mice, producing diarrhea, dizziness, breathing difficulties and sometimes death by respiratory arrest.

Globally a more common fish poisoning is known to occur after consumption of the puffer fish. Four of the five species found in the Baja California Peninsula (Bullseye puffer *Sphaeroides annulatus* (Jenyns, 1843); lobeskin puffer *Sphaeroides lobatus* (Steindachner, 1870); Guineafowl puffer *Arothron meleagris* (Bloch & Schneider, 1801) black and golden phases; sponed sharpnose puffer *Canthigaster punctatissima* (Günther, 1870) and *Sphaeroides nsp.*) show high levels of toxicity at least in one organ (liver, skin, flesh, mucus, gonads or guts). In *A. meleagris* (golden phase), for example, a decreasing gradient of toxicity was observed from mucus>flesh>guts>gonads>liver, while in *Sphaeroides* nsp. (a new and unclassified organism in the region) the pattern was liver>gonads/gut>mucus>flesh. In general, the toxins present are TTX, 4-epiTTX and 4,9-anhydroTTX, TTX being the dominant toxin, followed by 4,9-anhydroTTX and 4-epiTTX scantily represented. The exception is the mucus of *A. meleagris*, in which 4,9-anhydroTTX is the dominant toxin, followed by TTX and 4-epiTTX.

Table 1. Events associated with marine toxins in the Northwest of Mexico during 1991–1996.

Time	Place	Organism	Species affected	Toxin determined
1991/Nov	Bahia Concepcion	?	Several tons of shellfish loss	Not done
1992/Jan & Apr (2 times)	Ojo de Liebre	?	Several tons of shellfish loss	Not done
1992/Oct	Bahia Magdalena	Dinoflagellate	Dolphins, sea lions, sea birds, fish & turtles loss	Not done
1992/Apr	La Paz	*Oscillatoria erythraea*	None	Hepatotoxins
1993/May	Bahia Concepcion	*Oscillatoria erythraea*	None	No toxic
1993/May	Alijos Rocks	Serranidae & Labridae fish	7 Humans ill, no casualties	Ciguatoxins *
1994/Apr & Jun (2 times)	La Paz (Lohmann, 1908)	*Mesodinum rubrum*	None	No toxic
1994/Jun	San Hipolito	*Gymnodinium sanguineum* (Hirasaka, 1922)	Fish & sea birds loss	No PSP
1995/Jan	San Felipe	?	Dolphins, whales, sea birds loss	Not done
1995/Jun	Vizcaino	*Sphaeroides* sp.	2 Humans dead	Not done
1995/Oct	La Paz	?	Fish loss (Tetrodontiforme)	Highly potent liposoluble toxin in sampled shellfish
1996/Jan	Atil, Sonora	*Microcystis*/LPPB	Fish loss (*Oreochromis* sp.)	Mucus & scum
1996/Jan	Cabo San Lucas	*Pseudonitzchia* sp.	>150 Brown pelicans loss	Domoic acid **
1996/Feb	Loreto	*Noctiluca scintillans* (Ehrenberg, 1834) & *Pseudonitzchia* sp.	None	No toxic/Ammonia production
1996/Feb	Sta. Ma. del Oro, Nayarit	Cyanobacteria LPPB	Fish loss (*Oreochromis* sp.)	Oxygen depletion
1996/Mar	Cabo San Lucas	Cyanobacteria LPPB & *Chatonella* sp.?	Bentonic fish & fan corals loss	? Probably a secondary infection

* Lechuga-Devéze & Sierra-Beltran, (1995).
** Sierra-Beltran et al. (1997).

A summary of 'red-tide' events, and/or mass mortalities of fish, sea-birds, and other marine animals is shown in Table 1. It may be concluded that this phenomenon is a common and natural one in the area and, therefore, fishing practices and aquaculture activities should take into consideration the risk involved in consuming contaminated organisms: a permanent sampling program needs to be established.

Discussion

We have been able to demonstrate that at Bahía Concepción (BACO), in the Peninsula of Baja Califomia (one of the selected places for the development of aquacultural sites for shellfish), the periodic appearance of PSP toxicity imposes a risk factor that calls for a permanent monitoring program in this area. It is noteworthy that in spite of the high level of toxicity in some shellfish samples, no cases of human poisoning have been reported. This could be explained by the local custom of eating only the callus organ (abductor muscle) and not the viscera of the organisms, where most of the toxin usually concentrates. On the other hand, it is difficult to assess how many of the 300 000 diarrhea cases registered annually in the Southern State of Baja Califomia were due to DSP, since we lack the resources for a correct diagnosis. The knowledge of the exposure rate to these toxins should be highlighted, since the number of cancer patients in the region is well above the national average index and is well known that DSP toxins possess tumor inducing properties (Fujiki et al., 1990).

The results obtained from the sampling at Bahía Magdalena (BAMA) are quite different and of less concern than those of Bahía Concepción (BACO). Bahía Magdalena has been already considered an ideal site for aquaculture exploitation and huge projects are underway. Since PSP seems only a sporadic event, and no DSP toxicity has been detected so far, the site appears suitable for aquaculture practice. Yet, it should be borne in mind that the presence of domoic acid has been detected recently during winter months, and although toxicity values are well below the risk limit; a continuous monitoring of such phenomena is recommended (Sierra-Beltrán et al., 1997).

We have also concluded that ‘red tides’ are not an isolated phenomenon in the Baja California Peninsula. The events appear to present some periodicity and are specially frequent in cold months, in which temperature, marine currents, and nutrients favor the blooms. There is no evidence that such blooms are due to agriculture or man-related activities: they are most likely of natural occurrence and should be considered difficult to prevent or avoid.

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