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AN OVERVIEW OF THE MARINE FOOD POISONING IN MEXICO

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A. P. Sierra-Beltrán, A. Cruz, E. Núñez, L. M. Del Villar, J. Cerecero and J. L. Ochoa. An overview of the marine food poisoning in Mexico. *Toxicon* **36,** 1493–1502, 1998.—In the course of the last decade, huge events related to harmful algal blooms (HAB) have severely affected the environment in Mexico, even causing several human casualties. The tally of the toxins known up to date in Mexican waters includes: neurotoxin shellfish poisoning (NSP), paralytic shellfish poisoning (PSP), amnesic shellfish poisoning (ASP), tetrodotoxin (TTX) or puffer fish poisoning, ciguatera fish poisoning (CFP) and diarrhetic shellfish poisoning (DSP). Actual epidemiological figures profoundly modified the trends manifested on previous decades. Notwithstanding that the red tides are a long time known phenomena in Mexican coasts, no regular observation of the marine environment has been set up. Although there are monitoring activities for PSP toxins on the shellfish culturing facilities that are exploited for export to the U.S.A., these are only effectively applied on specific spots of the Mexican coasts, implying that the biggest part of the country coastal zones are not formerly surveyed. The misleads caused by the medical conception that food poisoning events are mainly due to microbial contamination, is among the factors why the marine food poisoning events are a neglected disease. In spite of the fact that no official statistics consider HAB related events as a subject of research or further monitoring by the health authorities, sporadic scientific documents related to poisoning events were produced in Mexico. An interesting picture is presented for most of the marine toxins mentioned. Trend and prognosis estimates made with such scarce information, provide a minimum measurement of the reality and urge the need for a permanent monitoring program on the Mexican coasts, a place with one of the greatest marine toxin diversity worldwide.

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INTRODUCTION

The oceans are essential to us as a direct food supply, as a biologic pump (carbon dioxide ⇔ oxygen), to determine climate, as a transportation means and as a recreative environment. All these uses can be spoiled by the damage caused to the oceans by overfishing and pollution as well as the global warming and climatic changes, since all these events profoundly affect the energy balance (Pianka, 1974). One of the events related to such damage are the increase of the harmful algal blooms (HAB). The so-called increase in blooming, announced in 1974 on a global basis albeit the lack of previous data on many countries, caused doubt by some researchers (Anderson, 1989). The collection of data compiled during the following years undoubtedly established a global increase not only in the number of events but also in the variety of species and toxins involved (Hallegraeff, 1993), proving that the effects on the aquatic environment produced by HAB events also include the economical and social spheres (Bagnis *et al*., 1992; Damasco and Corrales, 1994; Wessells, 1995; Flores-Hernández, 1997). Recent HAB related events in Mexico produced severe damage to the environment as well as to human health and the economy, making environment authorities prone to supporting monitoring activities. The exploitation of the coastal areas for aquaculture and tourism needs a better knowledge of the relationships established between nature and mankind, in search for a sustainable development of the marine environment.

MATERIAL AND METHODS

Mouse bioassays were made following the method of AOAC (1984) for PSP. Toxins were further analyzed by HPLC according to Lawrence *et al*. (1996). Pure saxitoxin (SAX) and dc-saxitoxin (dc-SAX) were used as standards. Extracts from cultures of *Aphanizomenon flos-aquae* and *Alexandrium tamarensis* were also used as reference for SAX, neo-saxitoxin (neo-SAX), gonyautoxin-2 (GTX-2) and gonyautoxin-3 (GTX-3) (Sierra-Beltrán *et al.,* 1996). Shellfish extracts characterized against those standards were employed as internal standards. Tetrodotoxin was determined following the AOAC (1984) mouse bioassay for PSP, using pure TTX (Sigma) as a standard. The DSP bioassay was carried out according to Yasumoto *et al*. (1978). The method of Shen *et al*. (1991) was used for HPLC. The ASP bioassay was performed following Tverson *et al*. (1989) and, a modification of the Quilliam *et al*. (1995) procedure was used for HPLC (Sierra-Beltrán *et al*., 1997a). Okadaic (OA) and domoic (DA) acids were from Sigma. Ciguatoxin (CTX) was determined by an adaptation of the bioassay method of Lewis *et al*. (1991) and the HPLC method of Legrand *et al*. (1992). Data from the environmental emergencies in Mexico during 1995–1997, were provided by PROFEPA, the Environment Protection Agency. Statistics from 1984 to 1997 were provided by the Environmental Health Office of the Health Ministry.

RESULTS

Regardless that the HABs are a well-known event in Mexican coasts, there was no consistent assessment and recording of such anomalies. Up to 1980, HAB related events in Mexican coasts were reported to be mild and sporadic. Indeed, the first documented event of human poisoning occurred in 1979, on the Pacific coast (De La Garza-Aguilar, 1983; Mee *et al*., 1986). During the present decade, the frequency of such events seems to have increased, as well as the magnitude of the impacts. Also the variety of toxins and the number of species of microalgae involved have incrcascd, causing many human poisoning cases and even deaths (Ochoa *et al.*, 1997a,b). Toxins known and chemically confirmed to date in Mexican waters include: ncurotoxin shellfish poisoning (NSP), paralytic shellfish poisoning (PSP), amnesic shellfish poisoning (ASP), tetrodotoxin (TTX) or puffer fish poisoning, ciguatern fish poisoning (CFP) and diurrhetic shcllfish poisoning (DSP) (Fig. 1). In spite of the fact that no official statistics consider HAB related events as a subject of research or further monitoring by the health authorities, sporadic scientific documents reporting poisoning cvents wcrc produced in Mexico (Table 1). Taking them into consideration, an intcrcsting picture is presented for most of the marine toxins mcntioncd. Actual figures profoundly modificd the previously manifested trends of epidemiological variablcs likc prcvalcnce, incidence and prognosis.

Neurotoxic *shellfish* poisoning (NSP)

In the Gulf of Mexico, the dinoilagcllatc *Gymnodinium breve* (*Ptychodiscus brevis*), producer of the potent liposolublc toxin brevetoxin (BTX), is the dominating species. developing huge blooms almost every year during Autumn, causing fish kills along the coasts of Veracruz and Tamaulipas states and sometimcs affecting other states within the Gulf of Mexico (PROFEPA, 1996, 1997). Sincc 1994, the cvents increased in permanence (reaching more than 100 days during Autumn 1997), as well as in the consequences on the environment and the human hcalth, with huge fish kills and many individuals affected by exposure to sea sprays or immersion in the sea water (Table 1) [Fig. 2(a) and Fig. 3(a)].

Paralytic shellfish poisoning (PSP)

On the contrary, the events on the Pacific coasts wcrc diverse and caused by several species and toxins, covering the full length of the Mcxican coasts (Fig. 1). PSP events are

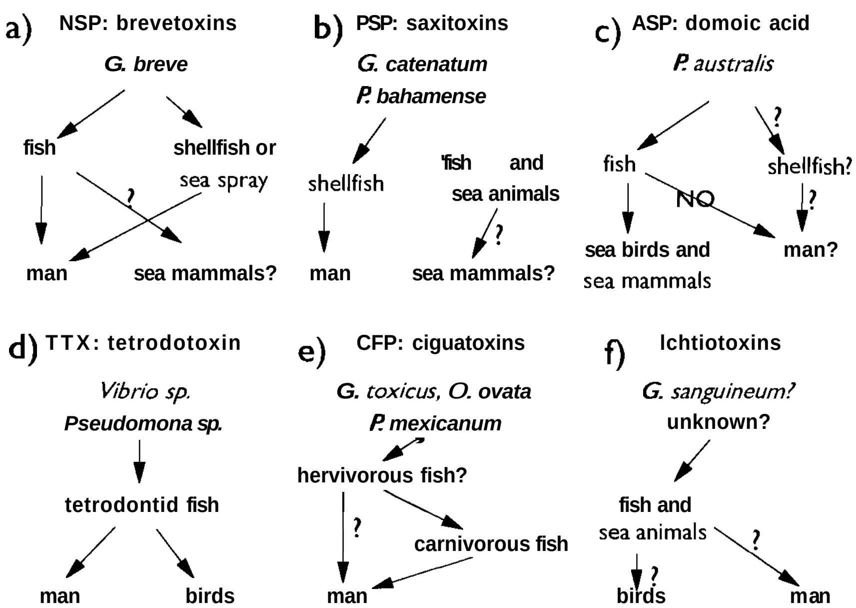

Fig. 2. Source and route of marinc toxins known in Mexico, depicting affected organisms.

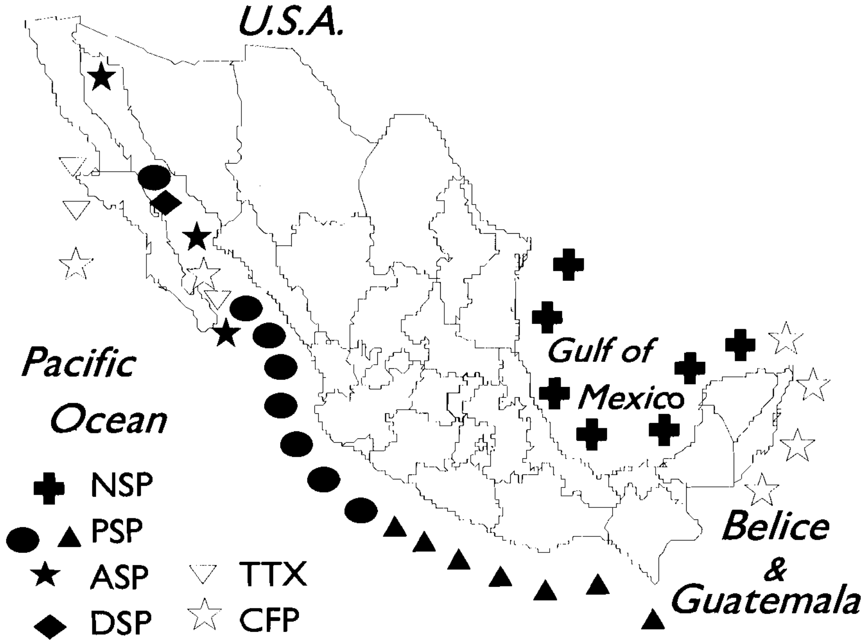

Fig. 1. Marine toxins whose presence was scientifically documented on Mexican coasts. Filled circles represent PSP toxins mainly produced by *G. catenatum*. Filled triangles depict PSP toxins mainly produced by *P. bahamense* var. *compressum*.

Table 1. Documented events of marine food poisoning in Mexico. Entries shows the year the event occurred or the time span. Bottom row depicts the region affected

Decade	NSP	PSP	ASP*	TTX	CtP
70's		76' 79‡		70'	
80's		85† 87† 89 (2)†			84‡
90's	94/95† 96§ 97§	92† 94† 95/96†‡ 97'"'	95§ 96‡§ 97‡§	93' 95† 96†	93‡ 93–96‡ 96¶† 97¶
	Gulf of Mexico	Pacific	Pacific	Pacific	Pacific and Caribbean

*No human poisoning cases occurred yet
†Health Ministry report.
‡Scientific report.
§Environmental Agency report.
¶Press report as only source.

Amnesic shellfish poisoning (ASP)

The most recently reported syndrome in Mexican Pacific coasts, fortunately not yet related to human poisoning, is amnesic shellfish poisoning. Massive poisoning events strike on a yearly basis since 1995 in the Gulf of California area, killing sea birds as well as sea mammals (Table 1) [Fig. 2(c) and Fig. 3(c)]. In the first place, we have shown that domoic acid (DA) was the causative agent of the mass killing of brown pelicans (Pelecanus *occidentalis*) at the tip of the Baja California Peninsula (Sierra-Beltran *et al.*, 1997a). During January–February 1997, we witnessed a new event of mass toxicity and mortality of marine organisms: 766 common loons (*Gavia immer*) and 182 sea mammals, belonging to 4 different species, were affected in the Gulf of California. Microscopic analyses showed the presence of a remainder of Pseudonitzchia (frustules) in common dolphins (*Delphinus capensis*) stomachs and sardine (*Sardinops sagax*) found inside some of the dolphin stomachs. High pressure liquid chromatography (HPLC) analyses of mammal tissue extracts confirmed the presence of DA and some of its isomers. Domoic acid and its isomers were also present in diatom samples collected within sardine stomachs. Scanning electron microscopy of sardine stomach contents allowed the identification of *Pseudonitzchia australis*, a species whose presence was not reported before in the Gulf of California. Histopathological observations of marine mammal tissues showed lesions resembling an acute toxic syndrome in the brain, heart, liver and lungs of some specimens (Sierra-Beltran *et* al., 1997c).

Puffer fish *poisoning, tetrodotoxin* (TTX)

Poisoning related to the consumption of tetrodontic fish is a medical problem with, maybe, the lowest prevalence in Mexico. Recently the incidence increased in the Baja California Peninsula, with an average of one case per year (Table 1) [Fig. 2(d) and Fig. 3(d)]. It is noteworthy that this poisoning has a mortality rate close to 100%, being the highest of all the known marine food poisoning events. A study of the distribution of toxins within puffer fish species present in the Gulf of California and the Pacific coasts of the Baja California Peninsula, showed at least two species that accumulate high amounts of toxins in their flesh (Nuñez et *al.*, in preparation).

Ciguatera fish poisoning (CFP)

Ciguatera is the only type of marine food poisoning that is present at both sides of the coasts of Mexico. There are poisoning cases every Spring–Summer season, both on the Pacific as well as on the Caribbean coasts, but frequently mistaken by different gastric ailments, treated with antibiotics and not further studied (Table 1) [Fig. 2(e) and Fig. 3(e)]. The cases of the Caribbean region are mainly related to the consumption of barracuda (*Sphyraena sp.*) meat, particularly from big fish (Health Ministry). In the area, the presence of the bentic dinoflagellate *Gambierdiscus toxicus*, producer of precursors of ciguatoxins, is amply documented and the Provasoli-Guillard Center have a well known cloned culture.

On the Pacific side of Mexico, Health Authorities reported a mass poisoning event in La Paz, Baja California Sur during 1984. At that time, 200 people were poisoned by the flesh of snapper fish (*Lutjanus sp.*), whose remains were analyzed by means of mouse bioassay (Parrilla-Cerrillo et al., 1993). After that event, two endemic areas were recognized up to now: the Alijos rocks, west of the Baja California Peninsula, and, El Pardito, a small island complex within the Gulf of California. The event on the Pacific was caused by the consumption of flesh from *Serranidae* and *Labridae* fish of small to medium size (less than

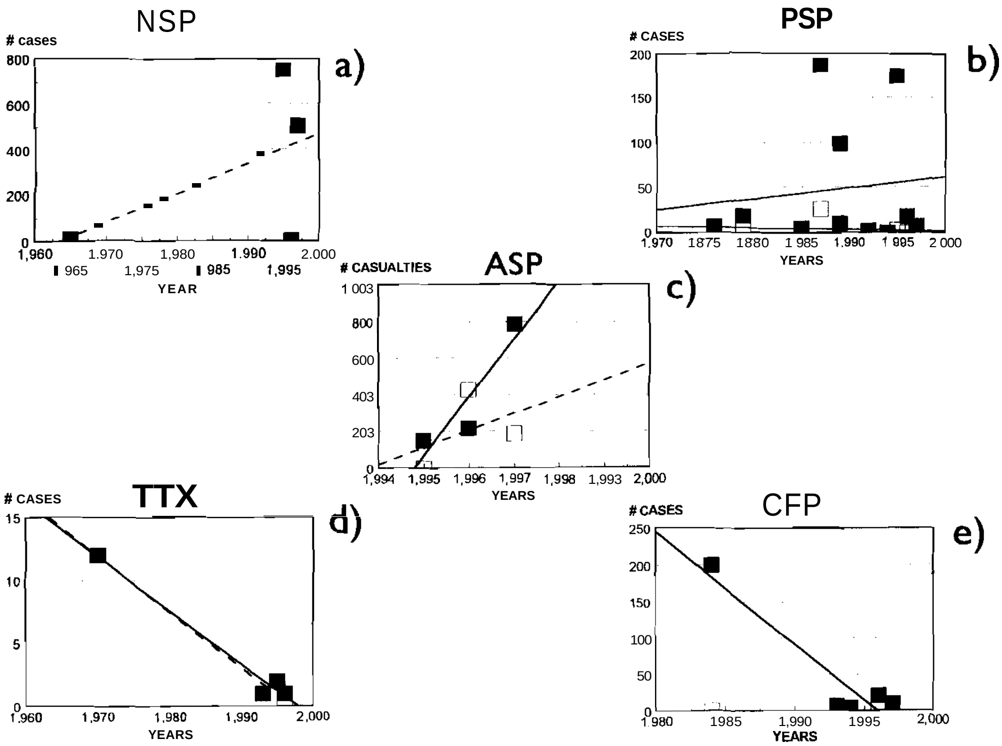

Fig. 3. Trend and prognosis of marine toxins poisoning events which occurred in Mexico. DSP cases have not been recorded until now in spite of the fact that OA and DTX-I have been demonstrated in shellfish since 1992. Filled squares represent poisoning cases and open squares represent casualties. For ASP only, filled squares represent birds and open squares represent sea mammals.

the most known toxic syndrome and, until now, the most dangerous, causing 72% of the events which occurred during the last decade, while three of them represent 87% of the poisoning cases (460 individuals poisoned with 32 deaths) (SSA, PROFEPA). These figures include the event manifested in 1987 on the Guatemalan coast, a few kilometers South from the border with Mexico (Rosales-Loessner *et al.*, 1989). During the PSP events reported in Mexico, great numbers of marine animals like fish and turtles were killed (Table 1) [Fig. 2(b) and Fig. 3(b)]. At first, only saxitoxin (SAX), produced by *Gymnodinium catenatum*, was reported as the toxin responsible for the events (De La Garza-Aguilar, 1983; Mee *et ul.*, 1986). More recently, since 1987 on the Guatemalan coasts, the species *Pyrodinium bahamense* var. *compresum* has been dominating the toxic red tides on the Southeast Pacific coasts (Rosales-Loessner *et al.*, 1989; Sotomayor-Navarro and Dominguez Cuellar, 1993), with a toxin profile composed of dcSAX and SAX as the principal components and low amounts of GTX's (Sierra-Beltrán *et al.*, 1997b). A different toxin profile was observed in the Baja California Peninsula suggesting that the responsible organism is from a different species, *Alexandriurn catenella* or the recently observed *Alexundrium tamiyavanichi* being the most probable sources of the toxins (Sierra-Beltran *et al.*, 1997b).

phenomena are increasing and may, in the future, impound on local sea mammal populations (PROFEPA).

PSP

The events on the Pacific coast have been dominated by red tides of PSP producers, but the composition of such mass bloomings varied in a very particular way (Fig. 1). Before 1987 the toxic red tides were formed mainly by G. *catenatum* and, after the appearance of *P. bahamense* var. *compressum* in the Guatemalan waters in that year, the species started to dominate on the Southern Pacific coasts of Mexico. This change of toxin producer was manifested in a very disgraceful way since the *Pyrodinium* red tides produce a higher net toxicity on shellfish greatly increasing the effects on human and sea animal populations affected.

ASP

Domoic acid (DA) affected to different extents birds, sea mammals and fish, showing that birds are extremely sensitive to DA, with a quick death response. In general, mammals are almost resistant to low amounts, but the peculiarity of the marine environment and the particular physiology of diving mammals acts synergistically to increase the risk and effect on them lowering the lethal doses [Fig. 3(c)]. The same behaviour was observed during a killing of Atlantic humpback whales by PSP toxins (Geraci *et al.*, 1989). Diatoms of the species *Pseudonitzchia australis* accumulated in the gastric tract of fish consumed by the poisoned animals and were identified as the source of the toxins. During both events studied in the Gulf of California no effect was apparent in the fish and it was also observed that the accumulation of DA in the fish flesh is minimum. These results suggest that the toxin is poorly absorbed by the fish gastro-intestinal tract and only accumulates mechanically within. This is very important taking into consideration that sardine and mackerel fish support a heavy fish industry in the Gulf of California and thus, the risk of passing DA into the human food chain is absent.

TTX

Sporadic events of puffer fish mass killings have produced the poisoning of sea birds, mainly juvenile unexperienced animals (Nishikawa *et al.*, 1982). Until now, the origin of such mass mortalities remains unexplained, but could be related to the 'El Niño' periodical global warming effect. Regarding the human poisoning cases which recently occurred, it is important to stress that all the cases could be traced back to individuals recently arrived to coastal areas and thus, inexperienced in the edibility of fish. This observation suggests that the displacement of human populations to coastal areas for economical reasons raises the risk factor of marine food poisoning on such communities.

CTX

Ciguatera is in Mexico a popular known problem in affected areas and, notwithstanding that, there is no official program to prevent it. The last reported outbreak in the country caused two deaths, a response not very common to this food poisoning. Since the coasts of the country are frequently struck by hurricanes, it is possible that these conditions favor the spreading of the producers of the toxin precursor observed in Mexican waters like G. *toxicus*, O. *ovata* or *Prorocentrum mexicanum*.

I kg/fish), which accumulated great amounts of toxins in the flesh (Lechuga-Deveze and Sierra-Beltran, 1995). The HPLC chromatographic profile of the obtained extracts suggest that ciguatoxin-1 (CTX-I) was the principal component (unpublished results). In the period 1993–1996, in El Pardito, human poisoning cases with gastrointestinal, neurological and cardiovascular disorders followed the ingestion of viscera (liver, raw or stewed) of *Serranidae* and *Lutjanidae* fish. Fish belonging to the same families (*Mycteroperca pvionuvu* and *Lutjunus colorado*) were collected during the Summer of 1996 and 1997 in the same area. Liposoluble extracts were prepared from the liver and tested by mouse bioassay, mice developed clinical signs compatible with ciguatera. The M. *pvionuvu* extract reached *3.42* μg of ciguatoxin equivalents per kg of tissue. The extracts were analyzed by HPLC and samples from toxic fish showed chromatography peaks absent in negative controls. Furthermore, their HPLC profile corresponds to fractions described as CTX-1. Recently, we have identified in the area the presence of the benthic dinoflagellates *Gambierdiscus toxicus* and *Ostreopsis ovutu,* well known producers of ciguatera precursors (data not shown).

Diarrhetic shellfish poisoning (DSP)

Mouse bioassays performed with shellfish extracts showed positivity Tor DSP toxins on samples collected in Bahia Concepción, in the Gulf of California, during the Spring seasons of 1992, 1993 and 1994 (Ochoa *et al.,* 1997a). Samples from April 1994 were analyzed by HPLC, showing the presence of okadaic acid (OA) as well as dinophysistoxin-1 (DTX-I). In spite of this results, no confirmed case of DSP has been reported in Mexico until now. Dinoflagellate organisms, well known producers of DSP toxins, are often found in water samples taken from the area.

DISCUSSION

Among physicians, it is common to judge that food poisoning is: "... a very general term formerly applied to diarrhoea caused by almost anything, but most usefully applied to intestinal disorders caused by bacteria contamination of food...". Thus, this has lead to the misconception and mistreatment of the problem on a global basis. The lack of experience on the subject within the general practitioners produces a bias on the official health statistics and an obligated oblivion of the problem of marine biotoxin poisoning. In the absence of epidemiological data that validates the expense of research and monitoring efforts related to marine biotoxin poisoning, the lack of such activities is logical in light of widely recognized health priorities such as cholera or AIDS. We have been dedicating efforts during the last years to recover information related to marine food poisoning cases, whose analysis produce a completely different image of what was currently known.

NSP

The red tides of G. *breve* which have occurred during the last years in the Northern Gulf of Mexico, have been increasing in span of time and impact [Table 1 and Fig. 3(a)]. Even when no human casualties have occurred, the economy of the local fishermen suffer a severe drawback after 60 days of fishing closures on average yearly, also affecting tourism business (PROFEPA). It is important to note that, until now, in Mexico there have been no reports on the occurrence of marine mammal killings as has happened on the Florida coasts (Landsberg and Steidinger, 1997), but it seems that the areas affected by such

DTX

Until now, no case of diarrethic shellfish poisoning has been reported in Mexico. In the Baja California Peninsula, the diarrhea cases reported every year in the health statistics are well above the national mean and many of them are categorized as food poisoning with unknown etiology. It is very important to note that the area where DSP toxins were detected superimpose the area with the highest rate of gastric cancer in the state.

Related toxic events. In the La Paz Bay area a mass killing of *Ballistidae* and *Tetraodontidae* fish occurred during Autumn 1995. During the event, red chocolata shellfish (*Megapitaria auriantiaca*) collected in the area tested positive when assayed for DSP toxins by the mouse bioassay, with a peculiar quick death response resembling PSP toxins, while the PSP extracts of the same shellfish ranked negative. The samples were amply cleaned with dichloromethane and re-assayed with similar results, suggesting the presence of a yessotoxin-like compound (data not shown).

On the Pacific coast of the Baja California Peninsula, mass events of sea animal killings were evident during the last decade (Ochoa *et al.*, 1997b). Sea birds, fish, turtles and sea mammals were found dead along the coasts of Baja California Sur stranded on the beach or floating in the sea. The common characteristic of the above mentioned events are the presence of red tides of the dinoflagellate *Gymnodinium sanguineum*, but until now it was not possible to identify the presence of any toxin or relate both events with scientific basis.

In the long run, changes in the composition of toxic red tides seem to be associated with global climatic changes ('El Niño' effect) since the PSP poisoning outbreaks follow similar patterns (Sierra-Beltran *et al.*, 1997b). The recent findings of species like *A. tamiyavanichy*, G. *toxicus*, *Ostreopsis ovatu* and *Prorocentrum lima* in Mexican Pacific waters suggest a tropicalization of the coasts that allowed the establishment of such species following global warming cycles (unpublished observations). A similar explanation has been suggested for the North Sea (Nehring, 1997).

On the contrary, Winter surface temperature data in the Northern region of the Gulf of California, shows a cooling trend from 1992 to 1997 (Sierra-Beltran *et al.*, 1997b). This may have allowed cold water species such as *P. australis* to travel along the coast reaching inside the Gulf of California in the winter currents. Also, this could be a more plausible explanation for a similar event of sea mammal mass mortality observed during the winter of 1995 (PROFEPA).

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